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Complexity is the new normality

SEFI 47th Annual Conference

Proceedings

SEFI Annual Conference
16 – 20 September 2019
BUDAPEST I HUNGARY
COMPLEXITY IS THE NEW NORMALITY

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Managing editor:
Linda Citterio

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György Ádám Horváth

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SEFI – EUROPEAN SOCIETY FOR ENGINEERING EDUCATION

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SEFI is an international forum composed of higher engineering education institutions, academic staff and teachers, students, related associations and companies present in 48 countries. Through its membership and network, SEFI reaches approximately 160.000 academics and 1.000.000 students. SEFI represents more than four decades of passion, dedication and high expertise in engineering education through actions undertaken according to its values: engagement and responsibility, respect of diversity and different cultures, institutional inclusiveness, multidisciplinary and openness, transparency, sustainability, creativity and professionalism. SEFI formulates ideas and positions on engineering education issues, influences engineering education in Europe, acts as a link between its members and European and worldwide bodies, contributes to the recruitment of good students whilst always promoting an international dimension in engineering curricula.

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Varietas delectat...
Complexity is the new normality
Industry 4.0 and Diversity in Engineering Education

Creation is not finished! Roles and expectations for universities keep on changing in the 21st century whilst the mission of science, engineering and higher education remains substantial. Stakeholders expect academia to better promote innovation, reform the knowledge economy, and manage vastly altered student populations.

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The themes for the 47th annual conference of SEFI are (but are not limited to) the followings:

- Diversity in Engineering Education?
- Fundaments of Engineering Education: Mathematics and Physics
- Gender, Inclusion and Ethics
- How to detect and attract talents with new generations of learning technologies and networks?
- Impacts of demographics in tertiary education
- Integrated learning environments for the digital native learners
- Lifelong learning
- Network Capital
- New Complexity quest in engineering sciences
- New notions of interdisciplinarity in engineering education
- Open and online teaching and learning
- Strong demand for democratic involvement in educational processes
- Sustainability reflecting the complexity of modern society
- Talent management
- 4th Industrial Revolution

WELCOME TO THE 47TH ANNUAL CONFERENCE IN BUDAPEST 16 - 20 SEPTEMBER 2019

BALÁZS VINCE NAGY

SEFI 2019 Conference Chair

Vice-Rector for International Affairs
Budapest University of Technology and Economics

At the Budapest University of Technology and Economics, we believe that engineering is the science of the 21st Century. Our University's 237 years of age is a proof that our science lasts long and with strong roots of classical knowledge, strengths in natural sciences and experience from application we may develop it constantly. The proximity to industry and to innovation, along with the ever changing demands of the ecosystem around us requires us to continuously research and discover new educational methodology that follows the needs of the new influx of students.

That is one of the numerous reasons why we are so excited to have the large number of top engineering educators from all the world with us at the 47th SEFI Annual Conference. We intend to receive a greater insight on the new trends of engineering education and cutting edge solutions, to learn from each other and to contribute to and debate on the latest achievements in this unique field of knowledge.

I'm delighted to welcome the participants of the 47th SEFI Annual Conference from Europe and from all around the world. We intend to show you Budapest, Hungary and the great traditions of the BME flavoured with modernity.

KEYNOTE
SPEAKERS

KEYNOTE SPEAKERS

TIBOR NAVRACSICS

European Commissioner for Education and Sport

Tibor Navracsics is Hungarian. He holds a degree in law and a Doctoral Degree in Political Science (1999) from Eötvös Loránd University (ELTE), where he was Associate Professor at the Faculty of Law and Political Sciences. He has covered a number of political duties in Hungary, such as Member of Parliament and Deputy Prime Minister. In 2014 he was appointed European Commissioner for Education, Culture, Youth and Sport.

VALÉRIA CSÉPE

President of the Hungarian Higher Education Accreditation Committee

Valéria Csépe is research professor at the Research Centre of Natural Sciences (RCNS) of the Hungarian Academy of Sciences (HAS), professor of cognitive psychology and neuroscience (Technical University of Budapest, University of Pannonia), and member of the Hungarian Academy of Sciences and the Academia Europaea. Her research focuses on the behavioral and brain correlates of typical and atypical cognitive development from infancy to adulthood. The research group of Neurocognitive Development founded by her at the Brain Imaging Centre of RCNS HAS, investigates brain correlates related to the development of spoken and sign language, reading acquisition and disorders, spatial navigation, music as well as executive functions and probabilistic learning with various brain and behavior methods.
She served as deputy secretary General of the Hungarian Academy of Sciences, elected for two terms (2008 - 2014), being the first female in such a high position there. Between 2012 and 2018 she worked for the strategic committee of the International Council of Science (ICSU) as elected member

and took part in the preparatory works of the International Science Council (merger of ICSU and ISSC). She is president, appointed in 2016 and 2018, of the Hungarian High Education Accreditation Committee. As of 2017 she is principal investigator of the national curriculum redesign and implementation EU project in Hungary, member of the Education 2030 focus group as well as invited expert of the Research Precariat Scoping Group of the OECD.
She has more than 350 publications, including several highly cited papers, journal articles, monographs, edited books, book chapters and conference papers in English and Hungarian.

Abstract

Humans under evolutionary pressure in time of the fourth industrial revolution

The general argument of evolutionary biologists is that humans have evolved in much the same way as all other life on Earth. Mutations in genes from one generation to the next gave rise to new adaptations. The human brain had gone through a remarkable evolution in a short amount of time, e.g. within a few tens of millions of years and resulted in getting bigger and more complex. Several researchers assume that the increasingly social nature of the humans' environment might require greater cognitive abilities. However, tools of increasing complexity, technical and cultural inventions should have also had a great impact on the human brains' development.

Although it is an evergreen question how our cognitive abilities change with crucial and widely distributed inventions, one of the most challenging one of the recent years is how the fourth industrial revolution may affect our abilities, skills, coping potential, and especially our brain. Therefore, the presentation will highlight and elaborate on four related topics:

- Models of cognitive and neural adaptation (print, math and the brain networks)
- Humans under digital pressure (facts, myths, possibilities and limitations)
- Engineers' impact on the environment and human evolution
- Engineers' mind (knowledge, creativity, brain networks)

How do we overcome the unfinished evolution in the time of fast and large-scale changes requiring unprecedented skills? How the human brain's adaptation capacity should or may change? How our education should evolve? The presentation aims at answering these and several other questions or provoke further ones.

JIAN LIN

Deputy Director of the Center for Engineering Education, Tsinghua University, Beijing, China

Professor Jian Lin is Deputy Director of the Center for Engineering Education (CEE), Tsinghua University. The mission of the CEE is serving Tsinghua and State, including participating in policy-making, the design and implementation of reform programs, and providing the suggestion and advice in engineering education, etc.

He is a Vice- Head of Expert Group for the China "national Plan for Educating and Training Outstanding Engineers (PETOE)", a key member of Expert Group of the Ministry of Education of China for "Research and Practice for New Engineering Disciplines", and an Expert of the Ministry of Education of China for Colleges and University Auditing and Assessment

Professor Lin received his bachelor degree in civil engineering in 1982, master degree in system engineering and management in 1988, and PhD in management science in 1993 from Lancaster University, UK. He has been a professor since 1997 and had been the Executive Dean of Management School of Beihang University (1996-1998) and the President of Wuyi University (1998-2007).

As a nationally recognized leading expert in engineering education, Professor Lin has published over 60 academic papers in engineering education. His papers recently published have been cited over 4,000 times and then made him become the most cited author in this field in the past 10 years in China. He has also been rated by a related authority as the most innovative and influential author in higher education in China. In addition, Professor Lin had published independently four influential academic monographs in Chinese.

Abstract

Facing the Future: New Engineering Disciplines Construction in China

China has the largest engineering education scale in the world. Engineering education reform and development is not only a main engine driving China's higher education towards a great power in its quality, but also a important support to Chinese national strategies. After a brief summary the current situation of engineering education in China and an overview of PETOE (a China's national Plan for Educating and Training Outstanding Engineers), the keynote will focus on the new engineering disciplines (NEDs) construction, the 2.0 version of PEOTOE, which plays a demonstrating and leading role in the reform and development of China's higher education and is implemented nationwide and guided by Chinese government, including NEDs' connotation and its construction goal, the government policies and measures to promote NEDs construction, the emphases of NEDs construction for different types of colleges and universities, and the current situation of NEDs construction, etc.

XAVIER KESTELYN

Vice-President for Academic and Student Affairs, School of Engineering, Arts et Métiers ParisTech, France

Xavier Kestelyn was born in Dunkirk, France, in 1971. He received the Ph.D. degree in electrical engineering from the University of Lille, Lille, France, in 2003. After ten years as a teacher of electrical engineering in high school, he was an Associate Professor for ten years and is currently a Full Professor of electrical engineering in the Laboratory of Electrical Engineering and Power Electronics, Arts et Metiers ParisTech, Lille, France. His research interests include the modeling and control of multiphase drives and new power grids with a high penetration of power electronic converters.
He is currently the Vice-President for Academic and Student Affairs, School of Engineering, Arts et Métiers ParisTech, composed of 8 campuses with 6000 students and a 400 people teaching staff.

Abstract

Responding the challenges of the Industry of the Future in a unique ecosystem?

Created to respond to the challenges of the first industrial revolution, Arts et Métiers has been able to support the evolution of needs brought about by the electrification of systems and the automation of the production lines. True Institute of Technology offering educational programmes from bachelor to doctorate, Arts and Métiers is today a talent booster for the industry of the future.
In full capacity to respond to the new needs of the territories through its 12 sites in France and strategic alliances on different continents, Arts et Métiers develops a pedagogy around the paradigm Human / Real Industrial / Digital:
- The human, at the center of the educational system, is trained in the acquisition of skills grouped into four blocks: disciplinary, personal and professional, interpersonal as well as trades of the executive or middle manager of the industry of the future. With 14 research laboratories, we put first the training through research.
- The real, materialized by 14 technological platforms on an industrial scale, is the construction space of the privileged competence where inductive and deductive pedagogies are alternately deployed. An Arts et Métiers student spends more than half of his time in contact with the industrial real, materializing all the operations of the life cycle of a manufactured product or a production system.
- The digital is systematically associated with the real to innovate (IA, VAR / VR) and with the human to increase its performance. Key partnerships with Dassault Systèmes and ESI enable the deployment of advanced digital tools.
Beyond the training of executives and middle managers able to transform the company, Arts et Métiers allows learners to access Intra / Entrepreneurship by Technological Innovation.
The purpose of this presentation is to show how Arts et Métiers is developing its training capabilities in order to respond to the challenges of the Industry of the Future in a unique ecosystem.

CONCEPT

ORDERED ALPHABETICALLY BY LEADING AUTHOR

Interdisciplinary Education:
a case study at the University of Twente

D. Kuiphuis-Aagten[1]
Educational Advisor
University of Twente, Netherlands
E-mail: d.aagten@utwente.nl

K.M.J. Slotman
Educational Advisor
University of Twente, Enschede
E-mail: k.m.j.slotman@utwente.nl

M.A.J. MacLeod
Assistant Professor
University of Twente, Enschede
E-mail: m.a.j.macleod@utwente.nl

Conference Key Areas: New notions of interdisciplinarity in engineering education

Keywords: interdisciplinary learning, interdisciplinary education design, interdisciplinary skills

ABSTRACT

The ability to cross boundaries is considered fundamental to the ability of scientists, engineers and others to solve modern real-world problems. As with other educational fields engineering higher education needs to find suitable interdisciplinary approaches to meet these requirements. While there is much current study of interdisciplinary learning it remains a challenge to formulate general strategies for implementing interdisciplinary education in a way that students become skilled collaborative problem-solvers. At the University of Twente there are currently opportunities to explore different responses educators have to this challenge, through the study of the *High Tech Human Touch* minors: a programme which offers minor courses to meet interdisciplinary learning objectives. This case study performs a comparison between the 10 *HTHT* minor courses relying on the education model ADDIE, to elicit similarity and diversity, and related challenges, with respect to how instructors in each course have responded to their interdisciplinary task. To make this comparison the student-perspective has been taken into account through interviews and evaluations, in addition to desk-research and semi-structured interviews with teachers. In current literature there is little information about how students perceive interdisciplinary education, yet such information can help understand the complexity needed for an interdisciplinary 'pedagogy'. Comparing the 10 *HTHT* minors, a range of different interdisciplinary educational designs can be identified, with distinct challenges to each, beyond the canonical model of collaboration-based designs. Especially noteworthy is the fact that students consciously opt for these *HTHT* minors to learn from other disciplines, but that this is not often the learning outcome, signalling a frequent gap between student expectations and educational outcomes.

[1] D. Kuiphuis-Aagten, d.aagten@utwente.nl

1 INTRODUCTION

Modern engineers are expected to possess professional skills, but also the ability to operate across disciplinary boundaries in order to overcome contemporary and future challenges which cross those boundaries [1]. As such universities across the world are putting more emphasis on interdisciplinary programmes to educate students in the hope that they acquire those skills. Literature reveals that there are different strategies with respect to how interdisciplinary education can be organized. For example, an educational programme may include study material from other disciplines in its own discipline [2], or an educational programme can be set up in a way that the population of students in the course consists of students from multiple disciplines [3]. Nevertheless, there is at present a lack of concrete differentiation and categorization of the different interdisciplinary learning course structures applied in educational programmes. Mostly interdisciplinarity is conceptualized these days in terms of collaborative skills or the ability to integrate disciplines through the agency of collaboration [4].[2] Additionally, there is not much reported on interdisciplinary programmes in which there is a combination of engineering disciplines and social sciences [5]. This is important, given the goals governing interdisciplinary learning for engineers often demand engineers to have the ability to address complex problems requiring the integration of environmental, medical, social and economic aspects into their work [4,6]. Overall according to the ABET criteria, solving problems subjected to multiple non-engineering constraints and non-engineering success criteria is a necessary skill engineering students need to master, to be able to function in their field [7]. This means that we need to teach students to reflect critically on their own discipline in relation to others, and recognize limitations and advantages of different perspectives [8]. Although research has been done examining these kinds of interdisciplinary skills [9], there is not much known about the student experience in interdisciplinary programmes [10]. Nevertheless, the student-perspective is of great help understanding and evaluating novel educational approaches [11].

As an answer to these challenges the University of Twente changed their bachelor education in 2013 from a subject-based approach to a more holistic approach of project-oriented education, employing what is known as the Twente Education Model (TOM). TOM aims to educate students to become entrepreneurial T-shaped professionals; students who are not afraid and capable to venture off the beaten path, apply their disciplinary knowledge in broader contexts, in collaboration with other disciplines and society [12].

The aim of this case study is to analyse the experiences of the High Tech Human Touch (HTHT) minor courses. This HTHT programme was developed in line with TOM to create space in the curriculum for interdisciplinary topics which might give monodisciplinary students skills to cross boundaries particularly into political and social realms. Instructors were given tasks to design material to fit those ends. More concrete, the goal of this study is to understand and evaluate how instructors addressed this task set by the HTHT programme, through their conceptualization of interdisciplinary visions and goals, and how well students themselves perceived and

[2] In this review study two-thirds of the reviewed interdisciplinary engineering education papers reported on a collaborative project or problem-based learning course or programme structure.

conceptualized these goals and felt their expectations were met. As a result we extend knowledge on the potential educational designs of interdisciplinary programmes including in cases where biological, engineering and social scientific knowledge is involved. To extract elements of design and assess their performance, we have relied specifically on the ADDIE model, in conjunction with instructor interviews, student interviews and student evaluations.

2 BACKGROUND INFORMATION

2.1 Twente Education Model

All 19 bachelor programmes at the University of Twente implemented the Twente Education Model (TOM) in 2013; a major curriculum innovation with the aim to better prepare students for the future labour market. One of the three pillars of TOM is project-led work; an overarching didactical approach that fits the university's vision in which students are facilitated and encouraged to develop an entrepreneurial attitude using non-academic problem-solving and co-creation skills [13].

TOM consists of a pre-defined curriculum structure, with courses of 10 weeks each 15 European Credits. Moreover, in a bachelor programme at the University of Twente there are 4 courses a year, resulting in 12 courses in total. As shown in *Figure 1*, in the third year of the TOM bachelor programme students have the freedom to choose a minor course, which is a compulsory six-months of education amounting to 30 European Credits.

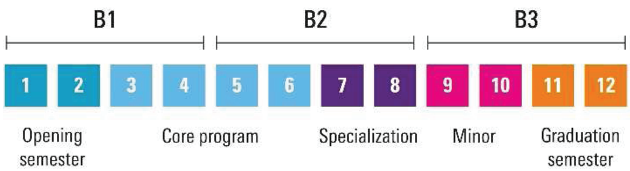

Figure 1. The TOM bachelor programme

The university offers diverse options among which are the *High Tech Human Touch* (HTHT) minor courses. The *HTHT* courses are required to be open to students from any background and focuses on problems in society, with the aim of giving students knowledge and skills to address political, social, environmental and medical problems outside their usual disciplinary sphere of activity and to develop sustainable HTHT solutions. Naturally there is an opportunity, if not necessity, to conceptualize some of the skills required as interdisciplinary ones. The choice however of how to do that has remained with the instructors.

There are 6 minor packages of 30 EC and 4 minor courses of 15 EC. An example is the minor course 'Aeronautical Engineering and Management'. In this minor course, students get acquainted with the development and operation of an aircraft. The aerospace industry is a fine example of the interrelationships between technology, economics, social and human sciences. Students explore how the needs of organizations, such as airlines, define the aircraft that aerospace manufacturers Boeing and Airbus develop, how technology is used to turn the aircraft from ideas into reality, and what is required of humans to operate them safely.

In all minor courses the project is central. A problem is outlined as the starting point of the student's learning process. In other words, these courses are designed using a project-based learning approach. Because of the interesting combination of social sciences, medical and engineering education, there is large variation in the degree programme of students undertaking minor courses and in the project-based learning strategy applied. The HTHT minor courses provide an excellent opportunity to examine the questions: 'how do instructors address the task of building courses on subjects outside the domain of participating students, who come from multiple backgrounds, and how well do students themselves perceive and conceptualize these goals and feel their expectations are met?'

2.2 ADDIE model

The ADDIE model provides a systematic instructional approach to course design, which in turn offers a framework for delimiting essential instructional features and comparing how the interdisciplinary courses we review have been designed to meet the HTHT interdisciplinary and societal programme goals. The ADDIE model stands for the five steps *Analysis, Design, Development, Implementation* and *Evaluation*. It is a guiding framework with an iterative process often used in designing educational programmes [14]. See *Figure 2*.

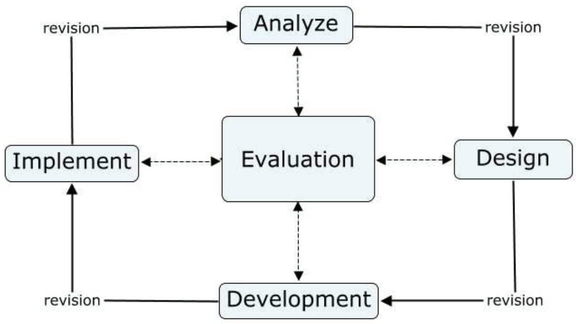

Figure 2: ADDIE model

The first step, *Analysis*, relates to the vision and overall aim of the course, programme or other educational unit; what do you want students to learn- and how are the learning objectives related to this. According to Borrego & Cutler this is essential to determine in order to be able to evaluate and enhance the learning process of students [15]. The *Design* phase addresses realization - how is the vision of the course put into practice through the structural design of the course including learning goals, -activities and assessment? In the next step, the *Development* phase, learning content and tools are developed in alignment with the design and vision. This phase answers questions: How will students be facilitated to reach the learning goals and what will the contribution of the teachers be? In the *Implementation* tools or instructional strategies are tested during a run of the course with actual students. *Evaluation* runs the length of the course, in which the quality of the design is assessed. Target questions include 'How do students experience the course?' and 'What are successful elements?' [16].

At first sight, the components within the different phases of ADDIE seem comprehensive, but no mention of constructive alignment is made explicitly. According to Biggs 'constructive alignment' is an essential factor of educational quality, measuring how well educational aims link to educational designs [17]. However constructive alignment is arguably at the heart of the ADDIE system, the extent to which each phase is assumed to align the components it develops with previous ones up the chain. As such to investigate the interdisciplinary HTHT courses in this case study the ADDIE model and constructive alignment are applied together as an evaluative framework for the educational designs.

3 METHODS

3.1 Research Design

This case study used a qualitative descriptive research design to examine how interdisciplinary education is designed in practice, specifically in the HTHT minor courses of the University of Twente. Qualitative research following the ADDIE model gives the opportunity to gain in-depth understanding with respect to the differences in design and motivation these minor courses apply to interdisciplinarity. The data was collected in the 2018 iteration of the programme during and at the end of the minor courses, to receive the most current and reliable information. The questions formulated for the interviews are in accordance with the framework of Interdisciplinary Learning in Engineering Education, which is based on a literature review of 110 articles in engineering education on interdisciplinary learning [4, 18] (*Figure 3*).

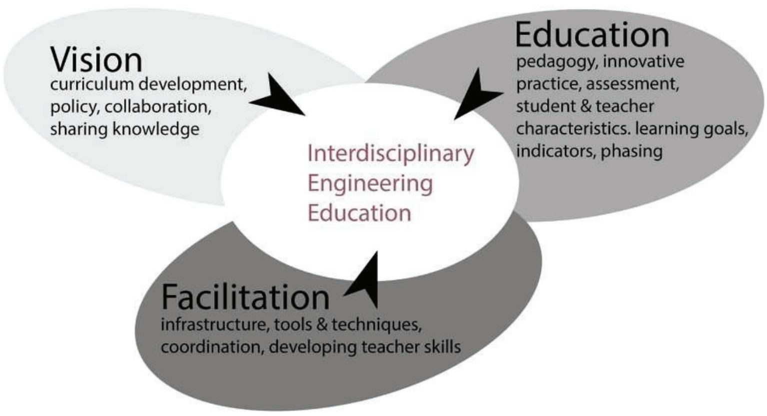

Figure 3. 3TU – Centre for engineering education – framework (Beemt and Ven [18], Beemt et al. [4]).

In *table 1* an overview of the instruments used for data gathering are presented.

What	Instrument
minor course coordinators perspective on educational design of interdisciplinary minor	Semi-structured interviews using the ADDIE model [14], in accordance with the framework on interdisciplinary learning developed by a consortium of the 3TU Centre of Engineering Education, with an emphasis on ‘education’ (See figure 3).
Student perspective on educational design of interdisciplinary minor	Semi-structured interviews using the ADDIE model, in accordance with the framework on interdisciplinary learning developed by a consortium of the 3TU centre of Engineering Education, but rephrased from a student perspective. The interview sessions were organized with groups of students, functioning as a panel. We chose groups of students rather than individuals as students can reinforce each other’s views and experiences, and help formulate answers to unfamiliar questions, since they are all in the same position’; i.e., they are all students, have none to little experience in interdisciplinary education, and have similar levels of knowledge and experience. For these interviews the interviewer kept in mind that every student in the panel had input and should be invited directly to participate.

SEQ (Student Experience Questionnaire) on educational design of interdisciplinary minor	The Student Experience Questionnaire (SEQ) is a standard evaluation of the TOM courses in the bachelor. For the minor courses the SEQ is extended specifically on the interdisciplinary learning aspect. These specific questions are taken into account in this case study to elicit the student-perspective. An example of a question is 'it was an advantage that the students in my minor were from different disciplines' that can be answered on a scale from 1 to 5.
Analysis of documentation (e.g. minor course/minor manual) on similar aspects as semi-structured interviews	All minors have a minor course manual for students. In this manual the structure of the programme, learning objectives, learning activities and assessments are presented. Also in the University's Learn Management System (Osiris) some basic information of the minor is shown. Of three courses, we obtained access to their CANVAS page, where all documents related to the minor course were available. This documentation clarified and supported our understanding of the educational design of the HTHT minors.

4 RESULTS

The results of this case study of the 10 HTHT minor courses are analysed using ADDIE and constructive alignment in accordance with our research goal: to understand and evaluate how instructors address the task of building courses on subjects outside the domain of participating students, who come from multiple backgrounds, and how well students themselves perceive and conceptualize these goals and feel their expectations are being met'. Below a short explanation is given of how different phases of ADDIE were used to structure the interviews. The results of the ADDIE analysis are shown in Appendix I, *table* 2. Based on these outcomes, three representative minor courses each with a different interdisciplinary approach were chosen for in-depth interviews with students. The summary of qualitative information from those interviews can be found in 4.2 below.

4.1 Application of ADDIE to HTHT courses

With respect to *Analysis*, all instructors face the challenge of constructing a course which can encompass a societal dimension, technical knowledge and a diversity of students of different backgrounds. This is the specific context in which notions of interdisciplinarity and strategies for training could be freely developed by HTHT instructors. For the *Design* phase we focused here on learning objectives, learning activities, assessment, and constructive alignment. For the *Development* phase we considered the learning content, tools and contributions of the teachers which facilitate students obtaining, in this case, interdisciplinary learning goals. In *Implementation* we examined if teachers are trained and if instructional strategies are tested to foster interdisciplinary learning and thinking. Finally, in *Evaluation* we assessed the quality of the design through the use of the SEQ results which track student perceptions.

4.2 In depth-interviews with students

In this section we give a summary of three specific courses and present some of the student reactions and comments. These courses are illustrative of the diversity of approaches instructors are taking with respect to the HTHT task. Based on the interviews with module coordinators, review of course descriptions and handouts we distinguish 3 different interdisciplinary design structures amongst the minors courses: 1) training largely mono-disciplinary students in an interdisciplinary domain, 2) training new knowledge and skills for a mixed discipline group, and 3) training interdisciplinary collaboration and integration as necessary skill. Each of the 10 courses matches broadly in design with one of these.

4.2.1 Biorobotics

In this minor course a large mono-disciplinary group of students is trained in an interdisciplinary domain. Biorobotics applies high-tech systems & control knowledge of robotic design to the biomedical interaction with the human body, and thereby combines a vast number of disciplines. Much of the interdisciplinary materials and skills required in this minor course is the same for all students. Although this minor course is open to all students, only a very small amount of students from engineering programmes outside biomedical engineering or advanced technology follow it. The principal challenge for instructors is providing a course design which helps students create links between their background knowledge in biomedical engineering or advanced technology and the new interdisciplinary knowledge of robotics.

In the interview session students (4 in total) stated that their goal in following this minor course was to learn in more depth about different subjects from another field of study, in this case ‘robotics’. Interdisciplinary collaboration was not a stated learning goal of the course. Students reinforced this stating that guidance or learning activities related to interdisciplinary integration and collaboration were not necessary to complete the project. They agreed upon the fact that they were all on the same level, because each was undertaking a degree in biomedical engineering. Nonetheless one student stated to us: “The integration of the human aspect could have had more attention, also how you could effectively integrate this in your solution, and for sure I think an interdisciplinary project team helps to learn to understand another discipline better.” The comment suggested that the lack of interdisciplinarity somewhat limited their ability to fully appreciate and integrate the new material they were learning.

4.2.2 Smart ways to get smart cities smarter

In this minor course a mixed student group is trained new knowledge and skills. The goal for students is to acquire understanding of how the construction of Smart Cities affects the physical urban built environment, and how such Smart City solutions can be implemented in existing city spaces. Besides working together with students from different disciplines, the students in this minor course are working with an entirely new set of methods and concepts that are not based on a specific scientific background. Central is a step by step plan designed for finding smart city solutions. The content is thus novel and actively taught by teachers. In this model of interdisciplinary learning collaboration or peer learning is hoped to facilitate students’ ability to acquire new knowledge and skills in an unfamiliar area. More specifically, instructors do require that students are able to explicate and transfer their specific domain knowledge to fellow students from other fields (peer-learning), but only by means of applying these new methodological skills effectively. As such interdisciplinary collaboration is more of a learning context, than a specific problem-solving requirement.

The interview session included two students from the minor course ‘Smart ways to get smart cities smarter’; one from mechanical engineering and one from University College Atlas. They stated that scaffolding the collaboration process could have helped to get more out of the interdisciplinary collaborative learning process. As one student put it: “It would have been nice if there were process tutors who coach and guide you in the collaboration process by focusing on how we could use each other’s expertise; someone capable of bridging the gap between different disciplines.” According to Borrego a key element for improving the success of interdisciplinary collaboration is providing instructors and tutors capable of bridging perspectives [19].

4.2.3 Science to Society

An example of the third design is the minor course ‘From science to society’, a package of 30 EC. In this course students, who come from a wide range of disciplines, need to design a prototype and a solution to a societal challenge by using multiple scientific approaches. During the first 10 weeks (minor course 1: from Idea to Prototype) the students are introduced to the foundations of different scientific disciplines and skills to ensure that they share a common set of appropriate skills and methods in their project team. Next, they delve into the state-of-the-art of the science behind the theme of their choice, with the goal to look for novel ways of applying their own background expertise in a closely guided yet agile design process. Students walk the path from a general idea to one or more scientifically and practically grounded prototype(s) for the challenge at hand. In the second half of the minor (minor course 2: from prototype to society) student project teams focus on realizing the prototypes developed in the first part, and researching issues surrounding the implementation and use of the product-in-development. Accordingly, the prototype is enriched with a business model addressing the feasibility of the product. In this design the focus is on interdisciplinary collaboration. Interdisciplinary collaboration skills are a central learning goal, in which each student is expected to bring their background expertise to the table. For example one of the learning goals of the minor course ‘From science to Society’ is: ‘students are able to apply a design process while working in a multi-disciplinary team, and ‘student need to be able to reflect on his and the other team members’ role and contribution to the team.’

In the interview session students of the minor course ‘Science to Society’ stated that they perceived the workshops of interdisciplinary team work as useful, but it was in their opinion not enough to support the interdisciplinary collaboration process. One of the students of the minor course ‘Science to Society’ said: “I now understand better that you have to acknowledge and understand the strengths of everyone to find the best solutions, but it was hard to find my own role in the group and find out how my expertise could be used”. However, one student of this minor course said: “Travelling to the industry stakeholder, and other informal team activities, helped in the process of getting to know each other’s expertise.” As stated by Borrego interaction is time one of the key elements to improve the success of interdisciplinary collaboration [19], and identification and integration of individual knowledge and skills in the common knowledge is not always easy, but the creation of a common ground can have a noticeably positive effect on interpersonal relationships [20].

5 DISCUSSION

Although in all the HTHT minor courses learning goals related to interdisciplinarity are formulated, the educational value of interdisciplinarity as specific types of skills or knowledge is conceptualized differently depending on the nature of the knowledge and skills the instructors wish to convey, and the relevance of interdisciplinarity to problem-solving in that area. Notably while collaborative and integrative problem-solving skills are often singled out as relevant learning targets central to interdisciplinary learning in education, only four of the design structures require it as a specific learning goal based on our analysis, even if “collaborative skills” or teamwork skills are otherwise cited as a learning goal. Nevertheless, opening up students to different perspectives outside their basic disciplinary orientation is accounted for in all course designs. Students in the minor courses all absorb the message that it is important to be able to speak ‘another language’ and that the human aspects in technical solutions should have more emphasis in their educational programme. This is one of the main reasons, students report, as to why they choose an HTHT minor course.

In addition, while an ADDIE analysis brings forth relatively clear and distinct interdisciplinary learning goals in each case, these are not always well mapped or constructively aligned to elements of *design*. For instance although all students are expected to develop interdisciplinary teamwork in the course of problem-solving, in the majority of the minor courses there are no explicit learning activities for training these skills or assessment events. Only in some minor courses students are asked to submit a reflection on the project process, for example about their own contribution to the group work and what they learned from other disciplines. However, this part counts for a small percentage of the total grade and the majority of the interviewed students did not feel that sufficient guidance was given regarding the interdisciplinary collaboration process. As such while the various courses develop a variety of interdisciplinary learning goals to suit their educational visions, design elements which reinforce or implement these explicitly are limited.

Regarding the *development* phase, where facilitation by tools or teachers are central, most minor courses show that they make use of tutors. Most of the time an expert in a specific domain, to whom students can ask questions related to that topic. Only in three minor courses are ‘process’ tutors available, to whom students can ask questions related to the process or collaboration process. For example in the minor course ‘Science to Society’ master-student assistants have the role of ‘process’ tutor, but these only have to act upon their role on the initiative of the students. In the minor course ‘Innovations in sustainable chain management’ and ‘Aeronautical engineering and management’ there are tutor meetings on a regular basis to monitor group work.

From interviews with students it became clear that a useful tool for developing their interdisciplinary skills was the step by step plan used in the minor courses ‘Science to Society’, ‘Aeronautical engineering and management’ and ‘Smart ways to get smart cities smarter’. These plans provide a systematic approach to designing a solution, which, according to students, also help to structure the collaboration process and develop a common way of working. However apart from these initiatives most students are left to manage the interdisciplinary learning aspects themselves without explicit resources.

As such the student perspectives we encountered here suggest a strong sensitivity of students to interdisciplinary goals, and demand for assistance meeting them, rather than being left to handle them themselves. Further, students show a preference towards assessment tasks that can help them develop a concrete understanding of what their interdisciplinary learning objectives are. This information reinforces the importance and necessity of constructive alignment, particularly in interdisciplinary contexts.

Further, results from the *implementation* phase, suggest how important it is for teachers themselves to manage how they educate and guide a mixed group of students from different disciplines. Some of the teachers received tutor training, and a smaller proportion received training which did address interdisciplinary groups. However many teachers in the HTHT minor programme do not have this training and guide the students based on their own experience and expertise. In addition tools or instructional strategies are rarely tested in terms of their ability to facilitate interdisciplinary learning and thinking of students. Only in the minor courses ‘Science to Society’ and ‘Aeronautical engineering’ teachers gathered qualitative information by interviewing students about the methods that were used.

6 CONCLUSION

In spite of numerous positive student learning outcomes the design and development of interdisciplinary programmes is not without difficulties. Our results suggest that when instructors are given an ostensibly interdisciplinary task, they will formulate a diversity of responses which conceptualize the educational value and content of interdisciplinarity in different ways. Not all these responses will rely on or promote interdisciplinary collaboration. This means that what counts as effective design and constructive alignment in one case will not be in another. Educational scholars should take account of this diversity when arguing for or evaluating interdisciplinary learning. However while our instructors did demonstrate capacity to shape learning goals and an overall course structure to meet the open-ended interdisciplinary goals of the HTHT programme, the generation of learning elements to support the ability of students to obtain those goals, and elements of constructive alignment, were still lacking. This creates a disjunction between the expectation the students had of a course regarding what they would get out of it, and what they eventually did. Students need to be provided with specific teaching approaches to support the development of interdisciplinary skills. These approaches, and the awareness of what is needed in an interdisciplinary educational setting are essential in the design of interdisciplinary programmes to be able to produce quality interdisciplinary work in future professional lives and to solve complex problems [4, 19].

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8 APPENDIX I

Table 2: results of semi-structured interviews with module coordinators/teachers of HTHT minor courses

Minor Courses / ADDIE phase	Analyse	Design	Development	Implementation	Evaluation
30 EC package					
Aeronautical Engineering and Management	The minor consists of two courses ‘aircraft engineering (1)’ and ‘aerospace management (2)’. The first course focuses more on the technical/engineering part whereas students in the second course learn how these technical aspects are integrated with the social aspects/human factors.* The two courses of the package are self-contained, and though collaborative work is a prerequisite of the design process followed by the interdisciplinary student	Most learning objectives are related to the content of the courses, with the comment that students need to be able to take the technical and human factors into account when making strategic and operational decisions. Some learning objectives are related to design or project skills, with the prerequisite to be able to work and operate in an interdisciplinary project team. Students are prepared through a series of	Students are, during the process of their project, supported by tutors; this can be an expert in a specific domain, to whom students can ask questions related to that topic, but can also be a “process tutor” who helps to improve the collaboration process. Tutor meetings take place on a weekly basis. Besides, students work according to a	Teachers have experience in aeronautical engineering and management; a broad and creative field of research and expertise. Most of the teachers did receive tutor training, but are not trained specifically to educate and guide interdisciplinary group of students. The workshops, and design process are the tools used to foster interdisciplinary	In course 1 students experienced it as an advantage to have students in their project group from different disciplines. Also on average they think they learned much about the other disciplines, and think it is valuable for their future work. In course 2, students didn’t experience the

	teams, the aim of the package is to provide students new knowledge and skills for aeronautical engineering and management.	workshops (3 in total) to become more effective as a team in an interdisciplinary setting. All the other learning activities are content related. The knowledge and skills are tested by 6 content specific tests, assignments and a simulation game, but also twice a report (with a small reflection part) and presentation including an oral exam are part of the assessment.	design process and are prepared by 3 workshops about interdisciplinary effective teamwork.	team work. These tools are qualitatively examined by the teachers by interviewing students [21].	advantage of having an interdisciplinary project group and also stated that they did not learn from students from other disciplines. Looking at the composition of the student groups, this could be a result of the homogenous student groupings in part 2. (Results from SEQ).
Geographic information system and earth observation	Students who take both courses get a comprehensive introduction to acquiring, storing, analysing and visualizing geo-information. They can directly make the relation between how one can sense processes on earth and how that can be translated to information on a global,	All learning objectives are related to the content of the course and are not focused on the collaboration process, or on interdisciplinary skills. As stated by the module coordinator of these minor courses: “These minor courses, as well	Students at the faculty of ITC are educated with the method of decision-supported questions: the perspective of diverse experts needs to be taken into account for a solution which can handle real-life problems.	Teachers are not trained, but only briefed about the expectations of the courses. Also students are not trained on interdisciplinary skills and no specific tools are used to foster	From the SEQ (student experience questionnaire) only information of course 2: earth observation is available. 9 students indicated that the project was valuable, and

	national or even individual level.* The two courses of the package are self-contained, and though collaborative work is a prerequisite of the design process followed by the interdisciplinary student teams, the aim of the package is to provide students new knowledge and skills in Geo-information systems and Earth observation.	as the faculty of Geo-information System and Earth observation, where these courses take place, are interdisciplinary in itself." The learning activities are set-up in a way that students are introduced to new concepts which they can apply in the projects. The assessment consists of multiple assignments, presentations and written exams, all related to the subject of study. An important aspect of study is retrieving geo-information in combination with effective communication to stakeholders.	Practicals are used to support students in linking the data (that has been collected for multiple purposes) and the application. In analysing this connection students need a technical and social view, which can enhance interdisciplinary thinking. There is minimal supervision / tutoring to support students in their collaboration or learning process. The students self-regulation of learning is seen as very important.	interdisciplinary thinking.	they learned the most of the cooperation with other students and liked the integration of subject matters. No answers specifically on the 'interdisciplinary' aspect was given.
Innovation, entrepreneurship & business development	The first course of this package prepares for independent venturing, based on commercialization of a product/service idea into a plan that assesses feasibility of the idea.	Most learning objectives are related to the content of the courses. Only one explicitly states: "students are able to collaborate multi-disciplinarily using	Students are taken by the hand: there are fixed moments for feedback, peer review and intermediate pitches of ideas. In both courses there are methods used for	Teachers in these minor courses are all experts, who started a company or own one. They share their expertise and their experience. They connect theory with	From the SEQ it can be concluded that students think the learning path is extremely fixed. So they cannot decide

	The second takes this knowledge into an inquiry that aims at exploiting an invention by identifying conditions and potential adopters and users of the technology for the decision either or not to appropriate it by the UT for future technology transfer purposes.* The aim of the courses is to develop students' entrepreneurial mind, provide them new knowledge and project management skills, and develop their ability to appreciate and use each other's expertise in real life cases.	project management skills." (course 2). Students are introduced to the different aspects of innovation, entrepreneurship & business development by virtue of an "acceleration game", lectures and tutorials, homework assignments and in the end in both courses a project (where students work on real-life problem situations companies have dealt with). Subparts are assessed separately (individually) but for the project (business plan) students: -report -peer review -reflection report -get feedback product & process of tutors (formative) -presentation.	the process students have to follow to finalize their project. For example in the first part students use the 'Lean start-up' approach. Students from social sciences and technical sciences are combined in one group and guided through the process by a 'coach'; an expert teacher of the module team.	the practical side of the project. The set-up – namely, real-life cases, real-life business methods, regular feedback - should help students improve their interdisciplinary thinking (which is not tested explicitly). However, the involvement of real-life companies and the extreme diverse group of students makes it also complex to implement this module (as stated by the module coordinator).	when, how and what they learn. In course 1 student stated that it is an advantage that students were from different disciplines, but they also stated that they didn't learn a lot about the disciplines of others. Overall however they are satisfied and enjoyed learning and working in an interdisciplinary course. In course 2 students are satisfied about with the 'interdisciplinary' aspects, but doubt about the learning effect, assessment and teaching methods.

Philosophy and Governance of Science and Technology	In this package consisting of two minor courses students develop a basic understanding of how science and technology can influence the human being and society, focusing on human behaviour, knowledge and values, and on evaluating and governing social change. They will do so using insights and perspectives from philosophy (course 1) and from science and technologies studies and governance studies (course 2), and by applying those to projects in which students will work on concrete examples of technologies in collaboration with the UT science and technology institutes (both courses).* The aim of the minor courses is that students develop skills to systematically and critically reflect on science & technology and their social roles.	All learning objectives are related to the content of the courses, but these can be seen as 'interdisciplinary'; "students are able to explain how technological and societal dynamics mutually influence each other drawing on concepts and theories from science, technology and innovation studies". Regarding the assessment all subparts are assessed separately with assignments and an exam. In course 1 projects should integrate all components in the study of an engineering or scientific lab. In course 2 students should integrate components in preparing strategy recommendations for an innovation actor.	The teacher team decides the composition of the groups; to mix students from different disciplines. However, there are many students from psychology, and a few from other studies. No specific tools, workshops or guidance is given regarding the 'interdisciplinary aspect'. Students are made aware of the influence the research fields have on each other; so the content is interdisciplinary in that respect.	The set-up, with real-life cases connected to theory and discussion moments these minor courses hope to achieve that students improve their interdisciplinary thinking (which is not tested). Teachers are all experts, and it is expected from them that they improve their education based on the feedback they get from students; they are not trained to work with interdisciplinary group of students.	The SEQ results showed that students in general appreciated the project, and working in groups. Also, they stated that the minor helped to understand that a technical solution and society are connected to each other. However, students do not report learning much about other disciplines, or collaborating across boundaries.
Science to Society	This package uses real-life problems that need to be solved in multidisciplinary	The learning objectives are very diverse, focusing on the	Students are, during the process of their project, supported by	Most teachers have experience in educating students	SEQ results show that students

	teams with the goal to cultivate increasingly important skills, such as; team player skills, communicative skills, and reflection skills. Real-life problems focus on societal challenges in diverse fields like energy, healthcare, learning and robotics. In part 1 students work on generating novel ideas and design concepts, transforming these into a prototype. In part 2 students evaluate critically how this can be realized using a business model addressing its feasibility.* The overall aim of this minor is that students become aware of their own (possible) impact in the whole design process and the (possible) impact of others, self-regulating the collaboration process and their own learning process.	implementation, use, validation and grounding, theoretical underpinnings, design method, results and teamwork/project management. For example; students need to reflect on their and the other team members' roles and contributions in a multidisciplinary team, but also need to be able to integrate multiple disciplines in the whole design process e.g. in the research question. (In addition, students are also asked to write down their own learning objectives). The idea of these courses is that students start a design using the iterative design cycle of the 'Design lab'. Small workshops about project management, product design, interdisciplinary teamwork, research	tutors; in this courses this can be an expert in a specific domain, to whom students can ask questions related to that topic, but also process tutors who help to improve the collaboration process. However, most of this support is only available on the request of the student.	from different disciplines. Most of the teachers did tutor training, with some receiving guidance in facilitating interdisciplinary group of students. The workshops, the design process, the lectures on research skills and project management are all tools used to foster interdisciplinary team work (qualitatively tested through interviews with students). One unique aspect of this minor is that it is structured solely around a project.	experience this minor as very valuable with a large learning effect regarding the cooperation with students from different disciplines. Also, students enjoyed working in a multidisciplinary group, learned from others, recognized their contribution and value for the project and that of others, see the advantage for their future and see the connection of social and technical sciences. The only things that can be improved according to the SEQ results is

		skills, and subject specific lectures related to the chosen project case are given for this purpose. Assessment is often formative providing students feedback. Peer-review, intermediate and final reports and presentations, are summative assessment tools.			the exchange of expertise between teacher and students and that feedback comes in time.
Innovations in Sustainable Chain Management	The central theme of this minor is the sustainability analysis and management of integral chain of resources, materials and societal processes. The need for knowledge on energy and resource efficiency, on process emissions, logistics, law and governance, chain (network) management , transition management, etc. to analyze and manage such chains from a sustainability perspective	The learning objectives are very diverse, focusing on the analysis, plan, validation and grounding, theoretical underpinnings, design results and individual interdisciplinary skills. For example; students need to be able to elaborate and synthesize different perspectives of individual students, and teachers into a plan for a	As stated by the module coordinator this minor is set-up in a way that students have to work in an interdisciplinary fashion otherwise they cannot fix the problems they face in real-life cases. Students are supported by teachers from the social sciences and technical sciences.	Teachers are all experts in one of the aspects that has to do with supply chain management. They are not specifically trained in guiding interdisciplinary student groups, or integration amongst their different fields. Tools, and the set-up are not tested regarding	There is minimal to no evaluation material available.

	makes this theme very suitable for a High Tech Human Touch module. In the first module (Analysis) students learn to map and analyze the interaction between materials, technology, economy and society in chains from different disciplinary perspectives. In the second module (Design) students practice how to design sustainable solutions for the problems found in the analysis. In both modules students expand knowledge in their own discipline, learn the basics from other disciplines and work in multidisciplinary teams in the analysis and the design in the real life case.* Overall aim of the module is that students learn to use different tools to analyse and design aspects of supply chains, and translate concepts into practice.	group assignment, and to be able to handle and synthesize and pull meaning from partial strategies and designs in a multidisciplinary environment by producing a report in the contexts of society and if relevant the commissioning organization (conclusions and advice/ recommendations). Teaching activities consists of lectures in which literature is reviewed, subject specific methods/approaches are explained, and students work on a real-life assignment. Based on this knowledge and work students write papers, do presentations, peer-review each other and hand in a group report.	They stimulate and facilitate interdisciplinary thinking by using an external client and by asking critical questions during the moments of contact.	interdisciplinary learning and thinking.	
15 EC minor course	**ANALYSE**	**DESIGN**	**DEVELOP**	**IMPLEMENT**	**EVALUATE**

BioRobotics	During the minor course, students need to construct a robot which interacts with the human body to improve the quality of life for an individual with a movement disorder. Worldwide scientific and industrial demand for skilled engineers with advanced systems and control knowledge of robotic systems who can apply this knowledge in biomedical or general high-tech systems is strongly increasing. The minor BioRobotics applies high-tech systems & control knowledge of robotic design and construction to the biomedical interaction with the human body, thereby combining a vast number of disciplines. The overall aim of the course is to educate students in the subject of bio-robotics. This subject is implicitly interdisciplinary.	All learning objectives are related to the content of the course components, but these can be seen as ‘interdisciplinary’; i.e. designing a robot for application to a biomedical problem using multidisciplinary knowledge from mechanical, electrical, control and software engineering domains. Lectures on the diverse aspects are given; control of BioRobotic systems, robot kinematics, biological signal analysis, programming of embedded systems. The assessment consists of two MC exams where all subpart are tested, and for the project a report, project demo, presentation and oral exam.	Students are, during the process of their project, supported by tutors. These tutors are student assistants who help minor students in the process of developing their project (on their own request). Student work systematically through a design trajectory; preferably in a homogenous student group so students cannot distribute tasks. (on the basis that all student learn all aspects of the design) Also, the course tries to involve a patient with a movement disorder to motivate students. In the end students have to reflect on the ethical aspects of their design based on one lecture given on this subject.	The teachers that are involved are experts in the specific field of study; aspects of BioRobotics. No specific workshops, training for tutors or skills education is provided for students to foster interdisciplinary learning.	Almost all students are from the programme of Biomedical Technology or Advanced Technology (which are interdisciplinary in itself). So for them this is an in-depth minor. From the SEQ students stated that they had a valuable contribution to the project and are aware that social and technical sciences are by definition connected to each other. But they did not experience collaboration with other disciplines because of the homogenous groups.

Materials for the design of the future	This minor course is a multidisciplinary profile course on one of the main research topics of the university and deals with the basics of different selected materials. In this module, students study the methodology of materials research and apply this knowledge to solve problems society is facing, or improving daily life of individuals. They learn how unique possibilities arise in the search for materials with interesting properties which enable the design of new functionalities for future applications. The overall aim of the minor course is that students are able to work on a smaller scale, at the molecular level, and on a larger scale, and integrate these levels.	Most 'course' objectives are related to the content of the course. However, in the materials requirements of sustainability, environmental and health hazards, recyclability etc are given as necessary to be considered. Also, the design must be evaluated from a technical and social view, i.e. students need to account for impact to humans and society. The learning objectives of the student are very technical. Learning activities consist mostly of subject specific lectures, lab work, and self-study. There is one lecture about human aspects. The assessment consists of two written exams of the two subparts (both 5 EC), an	Students can get guidance from the specific departments that are involved; MESA, MIRA + and mechanical engineering department. Research and the practical side of this field of study is involved closely. The practical assignment is a real-life question from Apollo (tires); this can motivate students to be creative and collaborate well with his peer-student (groups of two mostly an engineering student with a science and technology student).	The teachers that are involved are experts in the specific field of study; aspects of materials. Chemical teachers are often already at the interface of two disciplines, that makes them experienced in dealing with interdisciplinary aspects (as stated by the module coordinator). No specific workshops, training for tutors or skills education is provided for students to foster interdisciplinary learning.	The SEQ results showed that students in general appreciated the project. Also, they stated that the minor helped to understand that a technical solution and the broader social connection are by definition connected to each other. However, students did not acquire knowledge about other disciplines, or experience collaboration with students from other disciplines.

		assignment, project report and presentation.			
Smart ways to get smart cities smarter	In this minor students study how smart cities confront challenges related to urbanization, energy transitions and more accessible, reliable, safe and secure environments, and how urban life should be improved in smarter cities (e.g. through the use of smart energy grids, ubiquitous computing and location based services). In the first weeks, lectures focus on current developments toward smarter cities and attend lectures covering basic theory in geophysics, systems engineering, traffic data science, and robotics. Next, students are clustered in groups and assigned to projects. In groups they solve a real-life 'non-invasive city engineering' design problem. The overall aim is that students can systematically	Almost all learning objectives are related to the content of the course; aspects related to the container concept of smart cities (interdisciplinary in itself). For example, students are able to define how robotics, geophysics, and smart traffic solutions all can support construction of Smart urban life & mobility improvement. However, there is one learning goal focusing on an interdisciplinary skills: namely students should be able to explicate and transfer their specific domain knowledge to fellow students from other fields. The learning activities consists mostly of subject-specific lectures, tutor meetings, a company visit, and	Students need to know and must be able to work with the System Engineering V-model; a systematic process approach in this design project. Students are supported by tutors; but most of the time these tutor meetings were on by request only. In the second part, students work on a real-life case for companies for motivation. As additional motivation companies are formatively involved in the assessment of the students: they provide feedback. Students are made aware of the influence the research fields have on each other;	The teachers that are involved are experts in the specific field of study; aspects of smart cities. No specific tools, workshops or guidance is given regarding the 'interdisciplinary aspect'.	The SEQ results show that students enjoyed working in groups, with different disciplines, and also perceive that the broader social context and technical solution are by definition connected to each other, and think their contribution to the project was valuable. However, students do not learn much about other disciplines, or learned a lot regarding the cooperation with students from other disciplines.

	design a solution for non-invasive city engineering problems.	project meetings (on own initiative). Regarding the assessment, there is one large written exam covering all subjects, two assignments, two pass/fail products (poster/symposium) and a group report.	so the content is interdisciplinary.		Remarkable in this module is that they stated the module was not intellectual stimulating or challenging.
Cybersecurity & cybercrime	This minor introduces students to the fields of Cybersecurity and Cybercrime. Cybersecurity encompasses measures taken to protect a computer system, a network, or the Internet as a whole, against unauthorized access or attack. As far as the Internet is concerned, however, the spectrum of abuse is large: it ranges from cyber deviance (a behaviour outside or at the edge of the formal norms of society, but not yet illegal) to real cybercrime (an activity that violates a set of legal norms). The overall is that students need to include	All learning objectives are related to the content of the courses, which is in itself ‘interdisciplinary’; students should be able to explain the principles of a situational approach to crime, social engineering and compliance in relation to cybersecurity and cybercrime, and develop ideas for social intervention. The learning activities consist mostly of subject specific lectures, tutorials and project meetings, with the exception of one	Students are supported by tutors; but most of the time these tutor meetings were by request only. Students work on a very open project assignments, and the composition of groups is really mixed. One 2 hour workshop is used, to help students collaborate in an interdisciplinary project team. However, students are made aware by the teachers of all the perspectives that need to be taken into	Teachers are all experts in their own field of study, but they are not trained to educate or guide such interdisciplinary student groups.	Overall (based on the SEQ) students had mixed feelings about the minor course. For technical students it was too easy, for psychological students too difficult. They enjoyed being in an interdisciplinary project group, but overall they stated that the minor was not very challenging and intellectual stimulating. No

	technological, privacy, psychological, economical and ethical aspects into a cybersecurity solution.	workshop about interdisciplinary teamwork. The assessment consists of 2 written tests, more than 4 assignments, a final report and a presentation.	account when thinking of a cybersecurity solution.		results are available about the value of cooperating in an interdisciplinary project group.

**Students are not obliged to do both parts of this package*

Teaching the limits of functions

using the theory of didactical situations and problem-based learning

I Abou-Hayt[1]
Aalborg University
Copenhagen, Denmark

B Dahl
Aalborg University
Aalborg, Denmark

CØ Rump
University of Copenhagen
Copenhagen, Denmark

Conference Key Areas: Fundaments of Engineering Education: Mathematics and Physics, New Notions of Interdisciplinarity in Engineering Education

Keywords: Problem Based Learning, Theory of Didactical Situations, engineering mathematics, limits of functions

ABSTRACT

The concept of limit plays a central role in the foundation of modern mathematical analysis. However, the concept itself plays a minor role in both upper secondary and undergraduate engineering education, leaving the students with many misconceptions about the concept, resulting in poor performance in calculus and calculus-based engineering courses. Most emphasis in teaching has been on how to calculate the limit instead of on understanding its definition. In this paper, we will use the frameworks of Brousseau's theory of didactic situations (TDS) and Problem-Based Learning (PBL) to suggest a method to teach engineering students the concept of limit and explain its formal definition. The purpose is to enable the students to generate a precise definition of limit of a function that captures the intended meaning of the conventional ε-δ definition. Moreover, we will argue that TDS bears many similarities with PBL, as both frameworks require that the students act and engage in non-routine and realistic problems.

1 INTRODUCTION

Although mathematicians have long accepted the concept of limit as the foundation of modern calculus, the concept of limit itself has been marginalized in upper secondary schools and undergraduate engineering programs. Engineering students' understandings

[1] Corresponding Author: I Abou-Hayt, imad@plan.aau.dk

of calculus will greatly influence their ability to study more advanced analysis courses and engineering courses, such as dynamics, since these courses all require calculus as a prerequisite. One obstacle that can contribute to the difficulties of teaching and learning limits is the symbolic representation of the limit itself, $\lim_{x \to x_0} f(x)$. It can give rise to apparently contradictory processes such as: One that potentially never ends, and another of "getting close to". Nevertheless, as we will try to show in this paper, teaching the concept of limit successfully may not be an unattainable task if we use proper strategies and tools.

The focus of this paper will be on how the PBL and TDS frameworks helped us in structuring our approach of teaching the concept of limit at both upper secondary and college level. Moreover, we demonstrate how PBL, *in a mathematics teaching context*, is *compatible* with TDS.

2 WHY LIMITS ARE IMPORTANT?

Teaching and learning the concept of limit has long been a very important subject to mathematics educators. In fact, the concept itself has a long and interesting history [1]. Many mathematical and engineering concepts depend upon the concept of limit and without a proper definition of it, mathematical analysis as we know it today would simply not exist, since basic notions in mathematics and engineering are limits in some sense, e.g.,

- Instantaneous velocity and acceleration are the limits of average velocities and average accelerations, respectively [2].
- The area of a circle is the limit of areas of inscribed polygon as the number of sides increases infinitely.
- The slope of a tangent line to a curve is the limit of the slope of secant lines.

3 ON PROBLEM-BASED LEARNING (PBL)

In PBL, problems drive the learning. A teaching session begins with a problem to be solved, in such a way that students need to gain new knowledge before they can solve the problem. In contrast to a traditional teacher-centered pedagogy, PBL is a learner-centered educational method based on realistic problems encountered in the real world. These problems act as a stimulus for learning, integrating and organizing learned information in ways that will ensure its application to new, future problems [3]. Thus, PBL is not merely preparing problems for the students to solve in the class, but also about *creating opportunities* for the students to *construct* knowledge through effective interactions and collaborative inquiry. In PBL, an important task of the instructor is to initiate class discussions to enhance the students' reasoning skills and encourage them to apply their previous experiences to a novel case, thus enabling them to identify areas of gaps in their knowledge and prepare them to new knowledge acquisition. Through PBL, students are gradually given more and more responsibility for their own learning and become increasingly independent of the teacher in their understanding. The methodology of PBL will be illustrated when we design teaching situations that gradually guide the students to the formal definition of limits.

4 ON THE THEORY OF DIDACTIC SITUATIONS (TDS)

TDS is based on the idea that students construct *new* knowledge when they solve *non-routine* problems while adapting to what is called a didactical milieu [4]. Non-routine problems typically do not have an immediately apparent strategy for solving them. In TDS, the teacher's aim is to *engage* the students by *designing* didactical situations in such a way that the targeted mathematical knowledge would be the best means available for understanding the rules of the game and elaborating the winning strategy [5]. The withdrawal of the teacher and the subsequent transfer of the responsibility of the learning situation to the students is the essence of Brousseau's notion of *devolution*, where the students become the "owners" of a given problem, and thus enter the *adidactic* level, to produce the knowledge needed to solve it. [6] mentions four phases of didactic situations: *Action*, *formulation*, *validation* and *institutionalization*. These phases are exemplified below when we create didactical situations that eventually lead the students to capture the idea of limit.

5 RESARCH QUESTIONS

The main research questions of this article are

- How can we *design* didactical situations that lead to the rigorous ε-δ definition of limits in an introductory calculus course?
- Can the PBL and TDS frameworks be applied to teaching abstract notions in engineering mathematics, such as limits?

We will try to show that even seemingly theoretical notions in engineering mathematics are amenable to the PBL and TDS frameworks. The raison d'etre of this paper came from two similar teaching situations that the first author taught to engineering students at a higher education level in 2018. These students had no experience with any mathematically rigorous processes using the definition or proofs related to limits. The didactical situations described below require that the students participate in well-designed activities that use real-life problems, which presumably would guide the students to the correct conception of limits.

6 A PROBLEM-BASED APPROACH

6.1 Sources of Difficulties in the Teaching of the Concept of Limit

The differences between everyday language and the language of mathematics may contribute to the students' misconceptions, and hence also bring learning obstacles. For example, one may say that "my limit of running continuously is four kilometers". This everyday understanding of limit may suggest that a limit is some value one cannot exceed. The difficulties the students may encounter in understanding the concept of limit are discussed in [7], where three forms of obstacles to students' understanding of limits are mentioned:

- Epistemological obstacles related to the historical development and formalization of the limit concept.
- Cognitive obstacles related to the abstraction process involved in the formalization of the concept of limit.
- Didactical obstacles related to the ways the concept of limit is presented to students.

One consequence of these obstacles is that a formal definition of limits is not included in the Mathematics A curriculum in Denmark (the highest level possible), apparently due to its conceptual difficulty. Thus, upper secondary mathematics textbooks, such as the one by [8], give the following *informal* definition of limit:

If the values of the function $f(x)$ approaches the value L as x approaches x_0, we say that f has the limit L as x approaches x_0 and we write

$$\operatorname*{Lim}_{x\to x_0} f(x) = L$$

The real motive behind introducing the limits of functions in upper secondary school mathematics is its use in defining the derivative of a function at a point:

The derivative of a function f at a point x_0, denoted $f'(x_0)$, is given by

$$f'(x_0) = \lim_{h\to 0} \frac{f(x_0+h) - f(x_0)}{h}$$

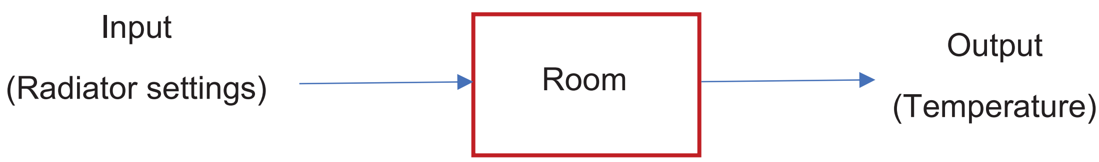
provided this limit exists.

The definition of the derivative is a so-called indeterminate form of type $\left[\frac{0}{0}\right]$ [9]. These forms can usually be evaluated by cancelling common factors, which is the usual method used in upper secondary school mathematics. Thus, it seems that the limit concept is reduced to an *algebra* of limits, suppressing the *topology* of limits, which is crucial in the formal definition: This didactical obstacle may lead to the misconception that the algebra of limits and topology of limits may be completely disconnected. The informal definition of limits therefore has its shortcomings. First, the definition does not precisely convey the mathematical meaning of the concept of limit. Second, the expression "approaches to" may result in the confusion whether limits are dynamic processes, where motion is involved, or static objects.

6.2 Teaching Situations Leading to the Concept of Limit

In response to the above-mentioned difficulties, we will show how we tackled teaching the concept of limit, using a terminology that is close to the one used in the formal definition, without sacrificing the topological aspect in the definition. Moreover, the concepts we use should be familiar to the students from their previous experiences. Specifically, we address the question: *Given a process or system, how can we control the error tolerance in the input, given that the output (or product) should have a given error tolerance*? So, in introducing the topic "*Introduction to Limits of Functions*" to the students, we started the lesson by giving the students five tasks. These tasks represent several teaching situations that may be needed to reach the institutionalized knowledge of limits of functions, i.e. the tasks can be regarded as a *gradual transition* from the students' personal knowledge to *institutionalized* knowledge.

Task 1: *Discussion*. How do you control the temperature of this classroom? Usually, we require that the room temperature to be the *ideal* $20^{\circ}\mathrm{C}$, but can we be sure that it is *precisely* $20^{\circ}\mathrm{C}$? If a temperature of exactly $20^{\circ}\mathrm{C}$ is practically unattainable, how can we keep the temperature of the room *close* to it? The discussion is open for all students. Many students gave the answer "We have to *continuously adjust* the settings of the radiator to guarantee that the temperature is always *near* $20^{\circ}\mathrm{C}$". Other students argued that "opening and closing the windows and the door also affect the temperature". All agreed that the temperature in the classroom is *dependent* on many factors. To make things simple, we *intervened* in the discussion and drew the following figure on the white board and asked the students to elaborate on it:



The purpose of this task is to guide students to reach the (simple) conclusion: To *control* the room temperature, one should *adjust* the settings of the radiator. Using TDS terminology, this task corresponds to the *formulation phase*, where the *milieu* is an open discussion. The students here construct *personal knowledge* about radiators and heat while *interacting* with the problem of maintaining a constant room temperature. Using the figure, the students' personal knowledge is being *validated* and becomes more formalized. Besides, this task encourages students to use relevant *experience-based knowledge* in order to arrive at a plausible conclusion, to use PBL terminology [10].

Task 2: The area of a circular plate is given by $A = \frac{\pi d^2}{4}$, where d is its diameter. A machinist is required to manufacture a circular metallic plate to be used in radio-controlled wall clocks. The area of the circular plate should be $169\pi\ \mathrm{cm}^2$. But since nothing is perfect, the machinist would be satisfied with an area *machined* within an error tolerance.

a) Within an error tolerance of $\pm 1\ \mathrm{cm}^2$ for the area, how *close* to $26\ \mathrm{cm}$ must the machinist control the diameter of the plate to achieve this?

b) Given a positive number ε. Within an error tolerance of $\pm\varepsilon\ \mathrm{cm}^2$ for the area, find a formula for the resulting tolerance δ of the diameter of the plate.

An excerpt of a student solution of Task 2 is shown in Fig. 1. The aim of Task 2 is twofold:

- To support the students' development of personal knowledge regarding the concepts of closeness and distance, which culminate in the result $|d - 26| < 0.024$ (Fig. 1).
- To help the students acquire new knowledge about tolerances, namely the fact that δ depends on ε.

To use TDS terminology, the teacher hands over the milieu to the students by presenting the problem and explaining the rules for solving it in such a way that the students can engage in the intended activities [4]. This corresponds to the *devolution* phase in TDS. This is also a PBL situation where teaching should offer the students the opportunity to engage in activities like those of a researcher. "PBL assumes that students learn best when applying theory and research-based knowledge in their work with an authentic problem" [3].

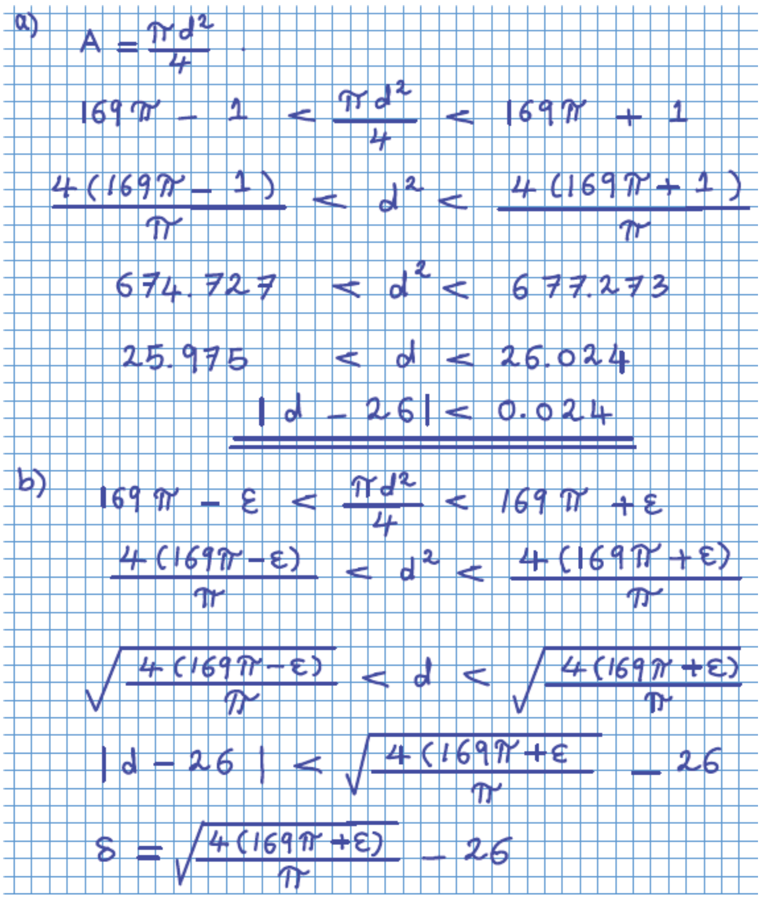


Fig. 1. An example of a student solution to Task 2.

Engaging in the task, the students employ their previously developed experience with inequalities and absolute values in order to solve the problem. In TDS, this corresponds to the *action* phase, where the situation is *adidactical*.

Task 3: This is a *didactical situation* where we explicitly interact with the students, in order to improve their understanding of error tolerances and provide them with some background for the independent acquisition of knowledge about dependent and independent variables. The function of the machine is to take metal sheets as *input* to produce circular plates as the final products, i.e., the *output*.

Input (metal sheets) → Machine → Output or Product (Circular plates)

The machinist must adjust the machine settings to satisfy the specifications of the products. The question now is: What error tolerance for the diameter *d* should be used so that the product (circular plates) requirements are met? Mathematically, Given $\varepsilon > 0$. Find δ such that if $|A - 169\pi| < \varepsilon$ then $|d - 26| < \delta$, where *A* is the area of the circular plate.

Task 4: This task is a partial generalization of the third one. This task is really a "didactical game" consisting of a challenge and a response. The "machine" now is a function f that transforms a number x (input) to another number $f(x)$ (output). Like the machinist's work, we want the output $f(x)$ to be equal to a number L. In practice, we may be satisfied with an output $f(x)$ *somewhere* between $L - \varepsilon$ and $L + \varepsilon$, where ε is the error tolerance of $f(x)$. The question now is how accurate our control setting for x (the input) must be to guarantee this degree of accuracy in the function value $f(x)$. This error tolerance for x is usually denoted by δ. The function given to the students is $f(x) = 5x - 3$, together with the two numbers $L = 2$ and $x_0 = 1$. The challenge is to make $|f(x) - L|$ less than a given number $\varepsilon > 0$ by finding a number $\delta > 0$ such that $|x - x_0| < \delta$. The number ε itself is given in the following table:

Table 1. The challenge and the response

The challenge, ε	The response, δ
$\frac{1}{10}$	
$\frac{1}{100}$	
$\frac{1}{1000}$	
$\frac{1}{10000}$	

In the language of TDS, this task is the starting point directing the student's acquisition of the institutional knowledge of limits. Within the framework of PBL, it helps students acquire the skills required to tackle new problems involving limits. The students were required to work in groups of two to find the "response" δ of the challenge ε, by completing the table. A two-student group consisted of a *skeptic* and a *scholar*: The skeptic presented ε-challenges to show that there is room for doubt. The scholar should answer every challenge with a δ-interval around x_0 that keeps the function values within ε of L. The *culmination* of this task consisted of giving the students a new challenge: Find a formula for δ in terms of ε.

The series of the tasks mentioned above constitutes a TDS teaching process to arrive at the sought definition of a limit. This process also conforms to the essence of a PBL framework [11]. The *institutionalization* of all these tasks, where the students' personal knowledge finally reaches the state of institutional knowledge, is attained by confronting the students with the formal, rigorous definition of a limit of functions, as given in most engineering mathematics books, e.g. [9]:

We say that $f(x)$ approaches the **limit** L as x **approaches** x_0 if for every number $\varepsilon > 0$ there exists a corresponding number $\delta > 0$, such that for all x, if $|x - x_0| < \delta$ then $|f(x) - L| < \varepsilon$. And we write

$$\lim_{x \to x_0} f(x) = L$$

As a part of the *institutional* knowledge, we mentioned two remarks to this definition to the students:

- The definition does not ask for a "best" positive δ, just one that will work.
- Note that there is no need to evaluate $f(x_0)$. In fact, $f(x_0)$ may or may not equal L or may not exist at all! The limit L of the function $f(x)$ as $x \to x_0$ depends only on nearby values!

Task 5: This final task consists of some exercises, the purpose of which is to test if the students grasp the concept of limit: Use the formal definition of limit to prove the indicated limits. Due to page limits, we only discuss one of these:

1) Use a CAS tool to plot the graph of the function $f(x) = \frac{x^2-9}{x-3}$. Show, graphically, that $\lim_{x \to 3} \frac{x^2-9}{x-3} = 6$.

This task is a *validation* situation, i.e. students convey their ideas and the teacher plays a role of bridging their knowledge to achieve the intended knowledge [4]. Regarding this exercise, the students used *GeoGebra* and *Maple*. Both these CAS tools produced *wrong* plots of the function. The students, who are used to use CAS to solve mathematical problems, including trivial operations on numbers, were surprised that the CAS tools failed to draw the right graph. They were not aware of the limitations of these CAS tools. Here is the misleading graph which all students got (Fig. 2, left):

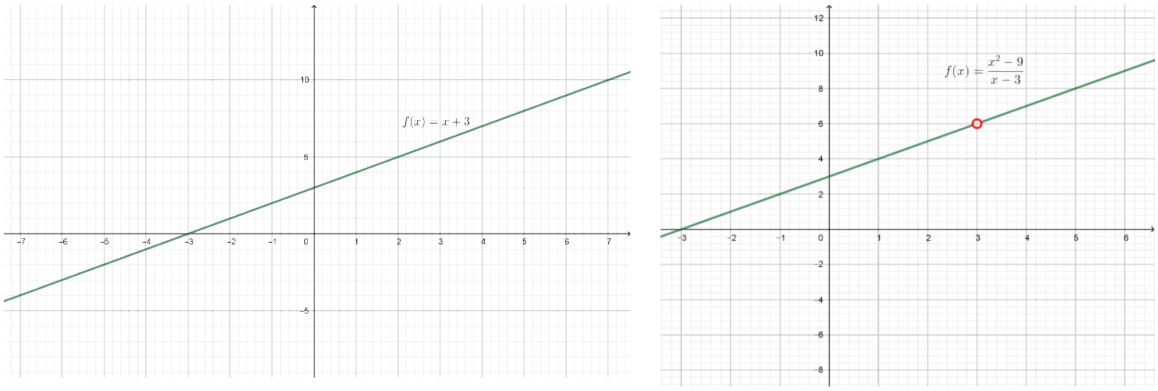


Fig. 2. Left: The “wrong” graph of the function $f(x) = \frac{x^2-9}{x-3}$. Right: The right graph.

The catch is that CAS tools automatically try to reduce an expression without showing the condition under which the reduction is valid. In our exercise, the function $f(x) = \frac{x^2-9}{x-3}$ is reduced to $f(x) = x + 3$, without further notice: The result is a straight line, where *x* can be any number! It is too easy to declare that one should have a critical attitude regarding the outputs of CAS tools, as this requires deeper insight and knowledge in the internal workings of these tools, something most students do not possess. The impact of CAS tools on mathematics teaching and learning is still subject to intensive research [12] and it is beyond the scope of this paper to account for the possible contribution of CAS tools in improving the students understanding of mathematical topics. It is crucial to present the true graph of the function $f(x) = \frac{x^2-9}{x-3}$ to the students (Fig. 2 right) and elaborate on the analogy with the previous tasks: A straight line with a “hole” at $x = 3$ means of course that $x \neq 3$. However, this does not prevent us from investigating the values of the function for values of x that are close to 3, like what we did in the previous tasks:

- In Task 1, it was beyond our reach to require a room temperature of *exactly* $20^{\circ}\mathrm{C}$, but we can get closer and closer to it.
- In Tasks 2 and 3, it was impossible to produce circular plates having a diameter of *exactly* $26\ \mathrm{cm}$ but we can get closer and closer to that.

Similarly, in the exercise in Task 5, we cannot give x the value 3, and hence the function cannot have the value 6. However, as the graph shows, the function *can* get closer and closer to 6 whenever x is sufficiently close to 3.

7 CONCLUDING REMARKS AND DISCUSSION

According to the PBL framework, “the problem is the starting point directing the student’s learning process. A problem can be both theoretical and practical. It must also be authentic and scientifically based” [3]. The main requirement of the PBL framework is that the students seek new knowledge, through realistic problems. Thus, both PBL and TDS share the idea that a teacher provides students with the initial problem, so that the students act and formulate concepts related to the problem-solving activity.

At Aalborg University, both students and researchers are supposed to engage in problem-based, project-oriented approach in their academic work [13]. This paper itself can be regarded as a problem-based approach to applying TDS in introducing the theory of limits to engineering and upper secondary school students. In our own classes, many students were in fact able to prove that a given number is the limit of a given elementary function, using the formal definition. In fact, the problem that some students encounter was not in applying the definition, but rather in the algebra of inequalities involving absolute values. The ultimate purpose of the tasks mentioned is to make students capture the similarities between the following situations:

- We cannot guarantee a room temperature of exactly $20^{\circ}\mathrm{C}$, but we can get close to it.
- We cannot produce circular plates having an area of *exactly* $169\pi\ \mathrm{cm}^2$, but we can make their areas closer and closer to that.
- We cannot divide by zero, but it is possible to investigate the properties of a rational function[2] for values close to the zeros of its denominator.

We therefore do not believe that the ε-δ definition of limits is too advanced for the mathematics curriculum at the upper secondary school and undergraduate engineering programs. Since, by using carefully designed teaching situations and pedagogical approaches, it can be possible to equip the students with a proper understanding of the concept of limit, and we hypothesize that it will pay off in other mathematics and engineering science courses the students may encounter in their study.

8 FUTURE RESEARCH PERSPECTIVES

The methodology of this concept paper has been used in an introductory calculus course for engineering students at Aalborg University in Copenhagen, Denmark. However, no pre-tests or post-tests were conducted in the course. The first author has only tested the students understanding of the concept of limit through Task 5. The informal assessment of the course seemed to be promising. However, more research in teaching the concept of limits at upper secondary schools is still needed to get a nuanced understanding of the students' conceptions and misconceptions of the idea of limit and what it might mean to come to understand the limit concept. Therefore, in a future offering of the course, the first author plans to design empirical tests that would reveal the impact the TDS and PBL approaches might have on the students understanding of limits. This would be an interesting subject of a new research paper.

[2] Such as the function $f(x) = \frac{x^2-9}{x-3}$.

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THE LACK OF ENVIRONMENTAL EDUCATION IN THE TRAINING OF ENVIRONMENTAL ENGINEERS IN COLOMBIA

Pedro Mauricio Acosta Castellanos[1], Araceli Queiruga Dios[2], Alejandra Castro Ortegon[3]

[1,3] Universidad Santo Tomás - Faculty of environmental engineering [2] Universidad de Salamanca Universidad de Salamanca · Department of Applied Mathematics.

Conference Key Areas: New Complexity quest in engineering sciences, new notions of interdisciplinarity in engineering education

Keywords: Environmental Engineer, education Ambiental

ABSTRACT

Environmental education has become an important tool for human formation, especially in basic cycles such as primary and secondary school, which tends to transform human actions on nature, based on multidisciplinary knowledge that supports decision-making, generating a change in social behavior achieving recovery, conservation and preservation of the environment. Higher education is more complex to treat environmental education, then, although it is increasingly common to see degree or undergraduate programs that have environmental content academic spaces in their curricula, these develop specific skills of each occupation, therefore, it is almost non-existent observe environmental education immersed in these curricula. In environmental engineering, although its name would be assumed to have introduced environmental education, were found evidence that in general demonstrate the opposite, a lack or nonexistence of this in its formation. Based on an analysis of the curriculum, objectives and graduation profiles, there was a lack of nuclei or academic spaces that involve environmental education in these undergraduate engineering, and it could be related that this deficiency is due to a certain extent that this career evolved in Latin America of sanitary engineering, which sought to address problems related to basic sanitation, product of the economic development characteristics of these countries, then, environmental engineering inherits too much the technique of the sanitary, leaving little space in the study plans for environmental and ecological issues.

1 INTRODUCTION

The university is defined in many ways, but every definition has within its structure aspects such as enrichment of knowledge for the common good; Salvador Moncada (2008) defines the university as "an academic community that rigorously and critically contributes to the protection and development of human dignity and cultural heritage through research, teaching and several services offered to local, national and international communities" . In universities, graduate programs are the first link in a chain of studies that will train the person integrally and integrates the role of the university from the outset, therefore, to the mission and vision of each institution of higher education.

Today, humanity faces apparent, irreversible changes: the result of bad actions and social development with little or no environmental liability, establishing a series of global challenges such as climate change and the degradation of natural resources [1]. These challenges are also the responsibility of universities and their programs. While wide definitions include and integrate environmental issues in them, Zabala (1999) defined the university as "a place where you should raise awareness about the human being who with his activity promotes social and environmental changes in recent years; It also fully trains people to be able to understand society and intervene in order to improve it." Environmental Education (EE) and Education for Sustainable Development (ESD) have become two currents within the comprehensive training in higher education who are looking for concepts and different ways to protect natural resources for future generations. The EE has a greater historical foothold against ESD, which is why countries like Colombia's find it more relevant compared to ESD [2] [3]. Colombia has opted for a policy focused solely on the EE, the Ministry of Education, as well as the Ministry of Environment and Sustainable Development of Colombia, decreed for this country the "Environmental Education Policy" [4] therefore, has left relegated for now the EDS.

Although EE lacks a single definition or consensus, it can be classified as heterogeneous and diverse and is concerned with basic primary education to independent university education, independent of the knowledge area, with a common, clearly defined core proposing the promotion of some type of change in the way people act towards the environment, outside of the focus or teaching strategy being employed. UNESCO (1980), at the Conference on Environmental Education, stated that this must respond to the complexity of the environment and its binding between biological, physical, social, cultural and socioeconomic factors. Similarly, it is common to see the EE emphasizing awareness and providing tools to acquire information about environmental sustainability, focusing on promoting ecological behavior and critical thinking against overconsumption [5] [6], Also focuses on providing information for intelligent decisions facing the environment and how to protect it. [7] [8].

At universities, the EE must take the student to know and understand their environment, in terms of both human actions and natural phenomena, and to learn from generating an action strategy to protect the environment. For this to happen it is necessary to teach students practical, theoretical, and innovative actions and tools aimed at improving the environment [9]. In this sense, many universities face a great challenge, because few involve environmental matters within their substantive or adjectival functions. In Latin America, environmental education is seen as something that only affects primary and secondary basic education [3], but not higher education. It involves large voluntary changes in reshaping curricula in graduate and postgraduate programs. Therefore, this change would recognize in the educational system the importance of the environment in people’s lives and the development of societies, thus implying the use of EE in curricula and the universities themselves [10].

Based on the previous description, one can infer the importance of environmental education and how it has joined the evolutionary process of universities, as well as the need that exists to demonstrate it in the curricula and training of people who are in these institutions. As previously mentioned, the chain of formal qualifications starts at the undergraduate level and ensures that such training could in some way define the future of the person in a certain job [11]. One graduate degree is environmental engineering, which emerged from the evolution of sanitary engineering and the specification of topics closer to the structure of civil engineering. Both types of engineering address environmental issues in their curricula, on the part of sanitary engineering, the area of environmental health. This area is broadly designed to analyze the effect of the use of toxic elements in the environment on human health [12]. Civil engineering includes issues of water resources [13]. Not much time has elapsed since the emergence of environmental engineering in Latin America: only in the nineties did the first environmental designations in engineering programs in Colombia appear, and in much of Latin America, the original name was sanitary and environmental engineering. Over time, the word “sanitary” disappeared from the discipline, as environmental issues began to carry more weight as countries with greater progress began to overcome the problems associated with the lack of basic sanitation. But the curricula continued to focus primarily on technique, inclined to this health genesis.

Environmental engineering is therefore based on technique, and its definition given by Engineer's Council for Professional Development - ECDP (Current Accreditation Board for Engineering and Technology - ABET) and found in the book Introduction to Environmental Engineering reads: "The environmental engineering is the profession in which knowledge of mathematics and natural sciences obtained by study, experience and practice is applied with judgment to develop ways to economically use the materials and forces of nature for the benefit of mankind ". So the education of environmental engineers has a very clear curricular core or training areas that meet the definition given by ECDP, as basic sciences, basic engineering, training and applied research and ethical engineering or humanism depending on the approach of the university offering the program; It is unusual to display the EE in the curricula of this type of engineering.

The objective of this research focuses on the lack of evidence EE in the training of environmental engineers in Colombia, based on reviewing the curriculum, objectives, vision and mission of these higher education programs. It was conducted on a sample of six programs of universities in Colombia who have this type of engineering, reviewing the curricula and consulting students about their perceptions, needs and interests focused on the EE. The goal is for the results to serve as input to improve these programs through updating, evaluating the possibility of incorporating the EE in the training/education of future environmental engineers so that they can become an agent of change and transformation in society against social and environmental challenges ahead.

2 METHODOLOGY

2.1 The environment in universities.

One could say that education, in general terms, seeks to provide validated knowledge to people as tools to solve contemporary problems, so it is dynamic and adaptive, able to lead us to generate new knowledge driving changes and improvements in society. In this sense, environmental education emerges as a product of historical context and the uncertainty of the future in social terms and in terms of existence as a human species, which we have faced since the late twentieth century. Universities are being forced to confront these challenges by applying schools of thought such as AD and ESD. Universities play an important role in the solution to the current socio-environmental crisis: the medium requires its members to prepare to meet the challenges brought, including climate change, degradation of natural resources, territorial disputes arising from the expansion of the agricultural frontier, solid waste generation, pollution of water sources among many others [14] [15]. Teaching and research should be the main agents of change to address the problems and challenges of society, addressing issues that relate to the environment in any educational context, as; responsible consumption, conservation of biodiversity, and the economy inter alia. This entails the promotion and strengthening of environmental education processes [16] [14].

It has been observed that higher education is not playing this important role, so the effect that it is having on students and graduates in terms of pro-environmental attitudes and solving these given problems is minimal. [17]. Universities therefore need to increase efforts to permeate all spheres of environmental action; teaching, research, operation and social responsibility [18] [19], acting in accordance with the global guidelines on environmental education as the Talloires Declaration, Bergen, Turin, the University Charter for Sustainable Development and many more [18] [20]. In line with these needs, universities committed to environmental issues have sought to create program participation, implementation, and management of environmental systems , such as ISO 14001 EMS, and create environmental academic lines and undergraduate and graduate programs, among many other things [21] [22]. Some degrees and branches of engineering dedicated to environmental matters are covering more and more space in universities. One of the most common degrees? in Latin America is environmental engineering, which has a wealth of curricular uncertainties that should be investigated to increasingly strengthen its graduates, so they can face the changing environment on a planet increasingly in need of solutions to its environmental problems [23].

2.2 Basis for evaluating the existence of EE in environmental engineering curricula.

To analyze environmental engineering curricula in Colombia, we took the recommendations of the ABET organization for the formulation of these programs and skills that the engineer must have, among them: "*Apply knowledge of mathematics through differential equations, probability and statistics, physics based on calculus and chemistry (including stoichiometry, equilibrium and kinetic)" "Master an earth science, biological science and fluid mechanics", "Formulating balances of mass and energy, transport and analysis of target substance in the air components, water and soil and between these*", "*Carry out laboratory experiments, analyze and interpret data in more than one relevant area of environmental engineering*" [24].

It also was taken as a premise that the study plan is the materialization of the curriculum and declares what is regarded as valid knowledge, dictating criteria of relevance and validity for the discipline, as well as reflecting the interests of the university or institution of higher education [25]. It is important to note that Colombia has certain peculiarities, which give a different context to this research, because curricular revisions, updating curricula, and the inclusion of innovative topics are rare occurrences, due to the lack of teachers or experts dedicated to these issues, especially in engineering programs [26] [25] [27].

For methodological development, public information was taken from a sample of 6 Environmental Engineering programs in Colombia, selecting recognized universities with high quality accreditation by the Ministry of Education. The environmental engineering program is currently offered at 46 universities in this country, but only 14 are accredited; Universidad Santo Tomás (USTA), University Business School (EAN), School of Engineering of Antioquia (EIA), University El Bosque (UBOSQUE), University of Antioquia (UDEA), Free University (UNILIBRE), Technologic of Antioquia (TDEA) Pedagogical and Technological University of Colombia (UPTC), Universidad Autonomy de Occident (UAO), Universidad de la Salle (USALLE), Universidad de Los Andes (UNIANDES), National University of Colombia (UNAL), University of Medellín (UDEM) Technological University of Pereira (UTP). High quality accreditation for higher education institutions indicates the quality of academic processes, both substantive and adjective, is voluntary and is governed by law, and ensures that both universities and programs meet national and international educational quality standards [28]. Of the programs outside of this list, tradition highlights that which is offered by the University of Boyacá, which is the oldest in this country [13].

Academic or subject areas were reviewed, as was the existence of environmental education in the objectives proposed by each university for environmental engineering. Once reviewed, the information was corroborated with students of these programs through surveys, verifying the inclusion of AD in their training.

2.3 Analysis of environmental education in environmental engineering in Colombia.

In a survey of 300 students in environmental engineering was performed in order to contextualize the respondents, the number of respondents per university was as follows: USTA; 70, UNILIBRE; 25, UNIBOSQUE; 65, UB; 40, UPTC; 70, UNISALLE; 30. It was necessary to disclose the information and definition of the EE by the Ministry of Environment, Housing and Territorial Development and the Ministry of Education of Colombia. This is important because it gives border conditions and frames the survey, since the EE can sometimes be distorted with environmentalism or curricular activities within subjects and only as a secondary or side effect is similar to an EE action. The definition for respondents was in line with the policy of EE Government of Colombia: "Environmental education should be considered as the process that allows the individual to understand the interdependence with its environment, from reflective and critical knowledge of its biophysical, social, political, economic, and cultural reality so that the appropriation of concrete reality can be generate attitudes of appreciation and respect for the environment in him and his community " [29]. Students were asked 18 questions, including 4 control questions to avoid bias. Questions fall into three groups: knowledge in EE, EE training in their curricula, and perception of the importance of environmental education in their training.

The age range of environmental engineering students surveyed is between 16 and 30 years. Of these, 93% are between 16 and 23, with the most representative respondents being 20 and representing 26.7% of those surveyed. This age range is characteristic of the Colombian student population usually finishes secondary education at age 15 and begins university education at age 16; in this case, it is typical for students to graduate as engineers at age 24.

3 RESULTS AND DISCUSSION

Curricula and subjects offered in all semesters were analyzed to determine which directly or indirectly address the principles of EE. Accordingly, some academic spaces were found where it is essential to use EE tools: for example, in the subject waste management, which is common in all programs of environmental engineering. This subject should include issues through environmental education as they are; source reduction, sorting, reuse, recycling and many other tools that seek to minimize the disposal of solid waste. Other academic spaces do this tangentially, especially in environmental management, through the teaching of ISO 14001, which is equally common in all of the reviewed plans of study. In the same way, subjects such as environmental policy, ecology and environmental impact were found, but on average they represent only 5% of academic spaces in the curriculum, with the Pedagogical and Technological University of Colombia with the most representation, at 8%.

Paritcularities were found in the curricula where there are academic spaces dedicated exclusively to EE and its promotion. Though it is important to note that it is unrepresentative compared to the rest, in this case the Pedagogical and Technological University of Colombia stands out with 4% was also noted, while its counterpart St. Thomas University and the Free University do not have exclusive spaces for training or promotion of EE. The summary of the quantitative analysis of academic spaces that directly or indirectly addressed in its structure the EE is found in table 1. It is important to note that there is an evident breakdown in the training process aimed at promoting EE, but there is remarkable harmony between the programs of all sample universities that focus on the same matters into own attitudes of EE, particularly the case of solid waste management.

Table 1. Analysis of the designated EE programs in environmental engineering sample academic load.

University offering environmental engineering		Number of subjects with a focus on EE	Number of Academic Credits with a focus on EE	% of subjects with focus on EE	Number of exclusive subjects for EE	% of subjects EE
1	USTA	3	12	5%	0	0%
2	UNIBOSQUE	5	15	6%	1	1%
3	UPTC	4	12	8%	2	4%
4	UNILIBRE	2	6	3%	0	0%
5	UB	3	12	5%	1	2%
6	UNISALLE	3	12	5%	1	2%

In contrast to the above, 99% of students think the environmental engineer must be trained with tools that give him the skills to transform the environment that is degraded by human actions through EE. Another question focused on students' futures as graduates: in this question, 94% of respondents wanted to be part of projects related to EE. In contrast shows that students corroborate the findings in the table two. Where there is evidence of a curricular deficiency is in the training of the environmental engineer based on the principles of environmental education: 72% of students expressed their desire for environmental education become part of the curriculum, while 17% indicated a possible interest or need.

Moreover, students indicate that environmental engineering programs lack tools to help prepare or train in EE: 65% of them think that their engineering programs do not have this, reinforcing this trend 48.9 % of respondents think that they have never been trained in environmental education strategies as part of their education in environmental engineering.

It is noteworthy that 26.6% of students claim to be prepared or trained in EE extracurricularly. They are voluntarily attending academic and non-academic spaces with content dedicated to EE. Among those most frequently mentioned are forums, seminars, courses and conferences representing 29.8% of respondents. Likewise, 69.1% of students in environmental engineering from universities in the sample say they have conducted environmental education activities: among the most frequent are reforestation, recycling days, lectures in schools, and plans for cleaner production. These mostly they relate to activities within subjects such as waste management and environmental management. In some cases, especially at the University of Boyacá, are carried out in a class called "environmental education".

Environmental engineering, like any other profession, must continuously adapt to the challenges of the environment, and even more so for being born in modern times where every decade represents unprecedented leaps in knowledge. This implies that it should evolve with the needs of the environment, but it seems that the processes of contamination and degradation of natural resources are winning. In this situation the environmental engineer must not only respond from its technical base, which is undoubtedly its support and backbone, but also from the ability he must have to prevent pollution by promoting friendlier attitudes to the environment, which seek to conserve natural resources and their sustainability, generating a synergy between a technical solution to the process of contamination and mitigation in magnitude using environmental education to those who generate pollution. A best practice observed in the research was the subject of solid waste management, where students begin learning the strategies for waste generators to minimize the amount they produce. These tools fall into the categories of behavior change and environmental awareness, which are primarily tools of environmental education. This finalizes the subject more to the technical side, giving the tools for designing structures for the use and disposal of the waste that a human population inevitably produces. In this case the student understands perfectly the importance of human actions to mitigate their impact on an uninhabitable environment (generating waste), but if they do not take actions that are based purely on environmental education, even with the technical tools, the cycle is unsustainable.

In all cases reviewed in the sample, a greater proportion of the curriculum is still related to basic sanitation, which responds to the particular needs of the country in recent years, as the coverage of water and sanitation in urban areas for 1995 was only 86.1% and 90.96% for 2010 [30]. However, according to the trend, it is expected that this stage of the country’s history has been overcome, since in 2017 the coverage of drinking water and basic sanitation in urban areas was 98.5% [31] [32]. This encourages the curricula of environmental change, adapting and rethinking engineering for the future characteristics of the country, designed to address an increasingly developed and marked need to protect the natural characteristics and potential, especially biodiversity and national water supply, since Colombia ranks 17th in biodiversity and 3rd in water reserves in the world and owns 50% of our planet’s moors, besides owning 53% of the territory in natural forests, among many other environmental riches [33].

Looking at this future perspective raises the need for more EE in the curricula of environmental engineering, putting them more in line with environmental and contemporary problems, perceiving the context of biodiversity and nature as an asset that must be protected by knowledge and education. This need is reflected in the results of environmental engineering student surveys. Undoubtedly, the engineer who is currently studying in Colombia wants to become a dynamic communicator of knowledge, highlighting the importance of proper use of resources, protection and conservation of unique natural areas in the world. This can be done through the implementation of EE in the curriculum, as an instrument immersed in the syllabus. It has been shown that currently, the curricula of this profession does not respond to the needs and demands their own students and will therefore arguably not be entirely relevant. It is necessary to clarify that the intention of this research is not to say that this type of engineering is not fully responding to the needs of medium or that it is not entirely relevant, but that it should incorporate environmental education more in its foundation as a cross-cutting tool to all learning processes taking into account the aforementioned example of the subject of solid waste , which is taught in the same way in all universities. These results should be compared broadening the spectrum of research of teachers, managers, graduates of environmental engineering universities and employers in order to know their perceptions compared to the information evidenced in this article.

4 CONCLUSIONS

We can say that the curricula of environmental engineering in Colombia are not relevant enough to meet the future needs of the environment or the demands or current tastes of students in this field, because while students and the country's outlook indicate the need for the environmental engineer to know and manage environmental education strategies, curricula incorporate only an average of 5% of space to these topics.

ESD is a type of education that has not been formally explored in Colombia, because the government policy focuses on the promotion of environmental education. Therefore, ESD is non-existent in the revised curricula.

It was possible to show that there are cases of successful environmental education in the training of environmental engineers and common to all universities that were included in this study, the most notable case is waste management and environmental management. Achieving harmony between EE and technique, this case can be studied in form and pedagogy to propose strategies of articulation between EE and other academic technical spaces, substantially impacting the education of these engineers.

It is important to continue research on this topic and streamline environmental engineering curriculum updating, so that it is relevant to Colombia and to be an aid in the process of sustainable development in which it is framed. Through ongoing evaluation and critical self-evaluation of this engineering, people can generate more knowledge and holistic views which foster proper management of natural resources.

It was shown that there is a lack of training in environmental education among students in environmental engineering, because in the curriculum review, only 1% of space in the curriculum was, on average, dedicated exclusively to EE while in about 5% of spaces on average, EE was partially covered, while among the students surveyed, 72% mentioned that environmental education should be part of the curriculum.

In reviewing the syllabi, it was observed that each university projects its mission or goals in engineering education, in some cases in Christian teaching, humanist education, pedagogy, and economics, among others, reflected in 100% the content of the subjects. If the environmental feature formed part of the mission or objectives of universities, this would also be within the syllabus, making it easier for teachers to engage and spend time on EE.

It was possible to generate a breakthrough in research of curricula in environmental engineering in Colombia. There are few, if any, studies like this, since there is no information similar to that raised in a database research. This is due in part to its short history and the lack of momentum to evaluate educational trends such as EE or ESD curriculum with an environmental focus.

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Combining the flipped classroom and simulation games in engineering education: a methodological survey

Muriel Algayres
Department of Architecture, Design and Media Technology, Aalborg University
Copenhagen, Denmark

Evangelia Triantafyllou[1]
Department of Architecture, Design and Media Technology, Aalborg University
Copenhagen, Denmark

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ABSTRACT

In recent times, there has been a considerable shift in the way engineering education is approached, with increased demands for active learning and methodologies that emphasize soft skills, such as ability to communicate effectively, identify and solve problems, and function on multidisciplinary teams.

Within this scope, two methods have particularly been of interest in recent years: the flipped classroom and simulation learning. Ample evidence exists pertaining to the efficiency of the flipped classroom methodology. Similarly, extended state-of-the-art review suggests that proper application of simulation games in engineering education has the potential to maximize the learning outcome and transferability of academic knowledge to the industry. However, combining the flipped classroom with other active learning methodologies is a more recent development which has huge potential.

This paper aims at examining to what extent simulations and the flipped classroom can be used in conjunction to support students' motivation, engagement and learning outcomes. It will present findings based on a scoping review of research incorporating both methods. This review highlights how combination of simulation and the flipped classroom ranks higher than either of these methods alone. It makes an argument towards the use of meaningful gamification to enhance this combined model towards a more efficient holistic learning experience.

[1] Corresponding Author
E. Triantafyllou
evt@create.aau.dk

1 INTRODUCTION

1.1 The flipped classroom

An increased interest has arisen lately in active learning in higher education, to ensure students' engagement and autonomy in learning, as well as learning outcomes which also incorporate 21st century soft skills [1]. Bishop and Verleger define the FC as "…an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom" [2]. Although early experimentation in the FC was made in secondary education in the United States [3], it became quickly a staple of higher education. Flipping the classroom meant an opportunity to transform the usually heavily theoretical first undergraduate years into active learning, accelerating the transformation from surface learning to active learning in students [4]. There is ample literature pertaining to the efficient use of the FC in science education (e.g. [5]), and the diversity of research reviews of FC in the past ten years initiatives reveals the interest for the method in the scientific and educational discourse [2].

1.2 Simulation in engineering education

Within the field of active learning in engineering education, simulations have also become the object of increased focus. We will define simulations as "an interactive representation of reality based on the construction of a model of a system of which we want to understand the working" [6]. Landriscina argues that simulation potentially constitutes a suitable instructional method, in which learning requires a restructuring of the students' individual mental models through interactions between the individual mental model and the simulation one [6]. Although Landriscina establishes a clear separation between simulation and simulation games, he also underlines that both frequently overlap by having specific rules, goals and scores. Similarly, Deshpande and Huang through an extended state-of-the-art review suggest that proper application of simulation games in engineering education has the potential to maximize the learning outcome and transferability of academic knowledge to the industry [7]. Therefore, although simulation and simulation games present some differences in terms of scope and agency given to the learner, due to the fact that research into these methods have shown interest both for simulation and simulation games, we consider both to be of interest for this investigation.

1.3 Combining simulation and the FC

Although both the FC and simulations have been of greater interest in the discourse regarding higher education, research into combining the two appears to be still at an early stage. Previous research in combining the FC with active learning methodologies such as problem-based learning has been successfully carried out (e.g. [8], [9]). However, it appears that there is a lack of research and reviews in combining other methods, such as the FC and simulation, and a need to identify the conditions of its implementation, technology used, and learning outcomes. The aim of this paper is to investigate the literature regarding the combined use of the FC and simulation in engineering and science education. In order to perform this study, we will review the literature using a scoping review method, to illustrate which research has been carried out in that field, and where research is still lacking on these subjects.

2 METHODOLOGY

In this paper, we have used Arksey and O'Malley's methodology [10], as expanded by Levac et al. [11]. The scoping review method uses the stages presented in the following sections.

2.1 Stage 1: identifying the research question

The focus of this research is to identify the circumstances under which the FC and simulation were used successfully in conjunction with each other or in the same course, and how both methodologies could be improved by being used in combination. To frame our investigation of the topic, we focused on the following research questions:

1. Which technologies and type of simulations were used for the implementation of simulations in the FC?
2. What were the educational outcomes of the use of simulations in the FC?
3. What is known of the conceptual framework used to incorporate simulations and the FC in engineering education?

2.2 Stage 2: identifying relevant studies

Arksey and O'Malley [10] suggest that a wide definition for search terms should be used. In light of the fact that some simulations are presented as simulation games [6], and that sometimes simulations are developed under a gamified environment, a large scoping review was done including all potentially relevant forms of game-based learning. The following research string was thus devised:
("game-based" OR "gamification" OR "serious games" OR "educational games" OR "simulation") AND ("flipped classroom")
The selection was then narrowed to select only articles explicitly pertaining to simulation, and then only to articles dealing with simulation in engineering education. The selected databases for this study were Scopus, Proquest, Web of Science, JSTOR and Google Scholar. Only peer-reviewed articles and papers, accessible in English, and in the period 2009-2019 (which coincides with the exponential development of the FC) were researched.

2.3 Stage 3: Study selection

Using the key search descriptors, 1356 articles were identified. After excluding duplicates, and articles studying active learning methodologies separately (FC or simulation separately and not in combination with each other), 70 articles were selected. These articles presented the combined use of the FC with either a simulation, a simulation game, or an educational approach relying on simulation such as the use of online virtual laboratories in the pre-class preparation phase. A further 34 articles focused on simulation in the FC, of which, after exclusion of study levels (elementary and high school) and subjects not relevant to this study (such as foreign language education and teacher training), a final 24 articles were selected, which focused in simulation in engineering education. Studies were excluded on the following motives: research that did not fully take place in the FC, or that focused exclusively on simulation in the learning process, theoretical papers and reviews, and papers that did not include an evaluation in class.

2.4 Stage 4: Charting the data

The data extracted from the selection of articles was mapped using the following criteria: Study ID, Title, Journal/Publication, Author, Year, Country of study, Technology employed, Category of gaming elements employed, Position in the FC, Study level, Subject studied, Size of class, Learning outcomes, Evaluated variables and study focus, Study methodology, Theoretical framework for the study.

2.5 Stage 5: Collating, summarizing and reporting the results

The final stage of the scoping review summarizes and reports findings.

3 FINDINGS

A final selection of 24 articles was made, representing 12 different countries. Although the last decade was studied, the oldest study is only from 2013, and 20 out of 24 articles were published in the past three years only (2017-2019). The majority of these articles concerned the field of computer science and engineering (7 articles) followed by engineering technologies (6 articles), applied sciences (5 articles), and chemical and electrical engineering (2 each).

3.1 Which technologies were used for the implementation of simulations of the FC?

A minority of four articles offered an examination of simulations used in the pre-class process of the FC. Three out of four offered simulations in conjunction with instructional videos and other learning material ([12], [13], [14]), whereas the last one [15] used game-based learning as a means of preparation through a programming simulation. Four articles ([16], [17], [18], [19]) offered a simulation experience that encompassed the whole of the FC experience, all of them by using simulation in conjunction with gamification to support the whole structure of the FC. However, most articles used simulation during the in-class time, and the objective of the FC is to allow students to prepare efficiently for class, usually through instructional videos. 16 articles in total reference this approach.

There is, however, no way of asserting if one type of simulation was more frequently used. Deshpande and Huang [7] establish three different types of simulation: drill-based, exercise-based, and problem-based. Drill-based scenarios, in which we include access to a virtual lab or VR, allow student to practise specific manipulations in the reproduction of the real environment, or to observe a specific phenomenon or process ([5], [20]-[26]). Exercise-based simulation focus on students finding the correct technique to solve a problem. Simulations included in pre-class preparation fall under this category ([12]-[17], [27]). Problem-based simulations offer complex scenarios, which allow students to explore multiple solutions and devise their own. They can take the form of mini-cases or project-based activities, including game production and design ([14], [18], [19], [28]-[31]). There is also no consistency in the technologies employed, which can include web-based simulation ([21], [27]), AR [22], simulation games ([15], [26]), machine simulators [24] or project-based simulation ([18], [19], [31]). The focus therefore seems to have been essentially in using the FC as a way to further the efficiency of the in-class simulation, allowing for extended tutoring time and face-to-face interactions.

3.2 Which were the educational outcomes of the use of simulations in the FC?

Three forms of evaluation and educational outcomes is observed in the selected articles. In 15 of the reviewed articles, the research investigated the students' performances, either through their grades, the pass rate of the class, or their knowledge in pre- and post-tests. 18 articles investigated the students' perception of the learning process, through their self-reported opinion of the efficiency of the method or interest in the studied subject. Finally, a minority of seven articles investigated more closely the student's living experience in the classroom by testing for motivation, stress level, engagement or cognitive load. More than half of the articles (13 out of 24) investigated two of these issues or more, three articles investigating all three of these aspects. All articles reported positive outcomes following the combination of the FC and simulation. Many articles report higher grades or higher pass rates in the classrooms, which used a combination of FC and simulation or a gamified environment ([16], [17], [22], [24], [26], [27], [30]), increased student satisfaction and interest ([5], [13], [14], [16], [21], [24], [27], [28], [30], [31]), and, when evaluated, improvement in students autonomy ([15], [16]), engagement and positive response to the class ([5], [16], [18], [28], [29], [32]). When evaluated against a different form of instructions, the combination of the FC and simulation yielded better learning outcomes than traditional lecture-based learning ([17], [22], [27]), non-flipped simulation [5], or traditional FC without simulation or gamified system ([12], [15], [18], [27]), both in terms of academic results and students' appreciation.

It should be noted however that few articles presented clearly limitation or negative outcomes to combining the FC and simulation. Two articles noted only a low and non-significant increase of interest [33], or understanding [23] in students. Similarly, only one study investigated the long-term impact on students' knowledge retention by doing a delayed post-test evaluation [22], this time with improved results in the three learning dimensions of knowledge, comprehension, and application.

3.3 What is known of the conceptual framework used to incorporate simulations and the FC in engineering education?

We finally investigated the theoretical background and theoretical framework to the selection of articles at our disposal. The majority of articles, 18 out of 24, referenced recent research in the FC. Six articles used the theoretical framework of research into gamification and game-based learning, and seven articles referenced research in technology-enhanced learning or e-learning. However, only a minority of articles did use cognitive theories in their research, looking for example into self-regulated learning [28], self-efficacy [27], deep learning and cognitive load theory [5], adaptive learning [12], and constructivist theory [32]. Only one article presented a specific theoretical model [29], in the form of the Activity-Oriented Teaching Strategy (AOTS), a structure which integrates in its development both the FC, project role-play for developing project artefacts, teaching by example, and student seminars. Moreover, some articles presented little in terms of theoretical background or conceptual framework ([14], [25], [26]).

4 DISCUSSION

4.1 Technology used in combining the FC and simulation

The articles presented in this scoping review show a wide variety of subjects and approaches to combining the FC and simulations, generally to positive outcomes. One study [20] insists on the high potential for combining the FC and simulation, as the former yielded more satisfying results than simulation alone. Our scoping review also identified the lack of specific focus on the post-class process, and in tools used to support the self-reflection on the learning process in students. Although a majority of articles, 18 of them, involve some measurements of the students' self-perception of the methodology, only four articles present focus on the whole of the FC process, especially by developing an online system meant to support students' engagement with the learning material, and appropriate use of gamification elements ([16]-[19]). There is therefore future potential into pursuing the use of simulation in the FC, and expanding upon it through a more holistic approach that would take into account the whole of the FC process, and through the development of tools that would facilitate the students' self-learning process.

4.2 Educational outcomes in combining FC and simulations

The scoping review shows positive results in terms of grade improvement and students' self-reported perceptions. However, the review showed that investigation into the learning experience itself was still limited. Few articles investigated students' motivation, engagement or attitudes towards the subject or towards learning. The result of the scoping review suggests that there is a significant gap in investigating students' motivation and engagement in the FC. Research into gamification in the FC offer many examples of such studies [34], which could easily be extended to the integration of simulation in the FC, or integration of simulation in a gamified FC. Finally, this scoping review also identified a significant gap into investigating the impact of the FC on students of different genders and economic situations. A single article [12] did a focus group on non-white non-male students and reported a more beneficial impact on female students and working students. In a context where the integration of more diverse populations of students represents a major challenge in higher education, specific investigation into the diversity of student populations still seems to be lacking.

4.3 Conceptual framework for the FC

The scoping review shows that the research into the conceptual framework to integrate fully the FC and simulations appears to be still lacking. A single article [29] offered an original theoretical model, and many articles did not offer a satisfying theoretical background. This lack of theoretical models for combining the FC and other active learning methodologies may explain the lack of interest given to the post-class learning process: as such, the FC experience still appears to be implemented in a disjointed fashion, with little continuity between the pre-class and the in-class periods, and even more so between the in-class and the post-class process. There is therefore potential both in developing more complete theoretical models for combining the FC and simulation, and in investigating its impact on students' motivation, aptitude for soft skills, and cognitive flexibility.

5 CONCLUSION

The FC may very well be one of the most emblematic efforts to overhaul traditional lecture-based learning in the 21st century. As efficiency of the FC is now thoroughly documented, the potential of combining the FC with other methodologies such as simulations is now starting to be documented. This review shows that the potential of such combination has been explored with success, with studies showing that the method was generally well-accepted by students, and resulted in higher engagement and more successful learning outcomes. Furthermore, the field still seems open to a variety of extended investigations: the impact of different forms of simulation, improvement in students' self-directed learning, and the learning outcome among students of different background, for example, should be explored in greater depth. The studies we investigated still approached the FC and simulations as separate methodologies, with the former facilitating the implementation of the latter. It must be expected that further development into combining active learning methodologies will result in greater incorporation, with the development of fully holistic educational model, relying on greater technological integration and improved use of data analytics tools.

6 ACKNOWLEDGMENTS

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Addressing gender as part of a Multifactorial Model of professional identity formation in a PoPBL engineering learning environment

A. BADETS
LINEACT, CESI
Rouen, France

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ABSTRACT

Previous studies on the interaction of gender and professional identity formation (PIF) in engineering curricula showed how PBL and group-work could affect female students' experience. An ongoing study on an engineering school's project-oriented, problem-based learning curriculum analyses the interactions of the learning environment and students' personal characteristics with their PIF. This article describes an attempt to draft a multifactorial model of PIF, analysing the relative influences of gender and other factors in the process.

Correlation tests and Multiple Correspondence Analyses were used to sort data collected from questionnaires to a cohort in the programme. Qualitative data from interviews with 31 of these students were also analysed using lexicometric tools.

Data presented in this paper suggest that:

- Environmental factors are more relevant than personal characteristics (including gender) to explain most PIF differences amongst students;

- Gender does affect PIF in two ways in this programme:

- Female students resort more to external resources (p-value=0.020) and tutoring (p-value=0.05);
- Female students express more career goals flexibility (p-value=0.017).

Three perspectives arise to use this draft of a multifactorial model of PIF to develop curriculum inclusiveness:

1. Address gender as part of a global scheme to address diversity via tools valuing individuals' qualities [7];
2. Address diversity management through tutoring, which is the most relevant factor for several indicators of PIF;
3. Use experience expression as a reflexive tool for students and teachers, and for research design purposes.

1 STUDY CONTEXT: ADDRESSING PROFESSIONAL IDENTITY FORMATION AND DIVERSITY IN A POPBL ENGINEERING CURRICULUM

1.1 CESI's PoPBL engineering curriculum specificities

CESI, a French multicentre school of engineering, has implemented a project-oriented, problem-based learning (PoPBL) curriculum in its work-and-study engineering programme since 2015. In this curriculum, based on group work in teams of six, new teams are created for each of the 12 projects the students conduct, and a member of the teaching staff tutors up to 6 teams at a time.

This study focuses on the cohort that undertook the 3-year engineering degree programme, from October 2015 to September 2018. In this curriculum, the students specialize through their in-company work (they spend 101 weeks in companies), and during the last year of the school curriculum, when they choose a major. This means students with very different backgrounds (two-year post-secondary degrees in fields as varied as chemistry, quality management, electricity, public works etc.) share the same training on the first 2 years of the curriculum.

The PoPBL dimension of the curriculum, with its team-based collaborative learning, forces these students to cooperate to produce deliverables and solve problems in multidisciplinary projects. Addressing diversity in this curriculum, where students have heterogeneous academic origins but have to work together, seemed an interesting starting point to try and analyse these students' professional identity formation.

1.2 Student diversity in education research and in the curriculum studied

Diversity is a field of interest in education studies, and it is often defined as a cultural, ethnic, socioeconomic, gender and/or ability heterogeneity amongst students that needs to be addressed, and that is related to questions of underrepresentation, inclusion and non-marginalization of all student profiles [1].

A first set of data shows that, in this engineering programme, there is indeed heterogeneity-related issues in the students' profiles, and not only academically speaking. As far as gender diversity is concerned, female students represent only 12.5% of the student cohort. In group works, a female student will be, most of the time, the only female student in her team. Furthermore, when enquiring their previous work experiences, or expectations, the results confirmed the cohort's heterogeneity[1]. For example, 30% of the students had started a career as technicians before going back to training, with the other 70% in their initial training; 60% of the students had a precise idea of their future jobs, when 40% were clueless about their career goals.

This heterogeneity is the reason we wished to address the relative influences of different personal characteristics in the process of these students' professional identity development. The students' characteristics whose impacts on PIF we questioned were both sociodemographic (age and gender[2]), and dispositional. Student dispositions are

[1] Data collected via a questionnaire to the full cohort of 587 students during their integration week.

[2] In France, no data on cultural/ethnic/religious diversity can be collected by individual researchers without legal authorization (granted mostly to commissioned survey groups), which explains the

a combination of intrapersonal factors like resources (knowledge and skills), motivation, and persistence, and might impact their behaviour and engagement in a curriculum [2], and play a role in their professionalization process.

When enquiring how this heterogeneity was addressed in this curriculum, we noticed that academic background heterogeneity was indeed addressed, with tutors creating homogeneous teams of students, “handpicking” them according to previous skills and backgrounds. Gender diversity and dispositional diversity (related to motivation, goals etc.) were, however, not addressed.

1.3 Gender in engineering education and professional identity formation

Why focus this paper on the impact of gender, as compared to other factors, on PIF? Women, in 2015, only represented 28,4% of all engineering students in France[3]. As Beddoes stated, “despite a nearly 40-year history of (…) interventions (…), women remain significantly underrepresented in engineering” [3]. Scientific literature in the field points the gender bias that affects female students in engineering education. More specifically, it was pointed out that group work in PBL environments significantly affected female students’ experience [4] [5] and professional identity development [6] and that female and male engineering students identified with different sides of the engineering set of activities.

The concept of professional identity formation is a very interesting framework when studying students’ engineering identities. In this paper, we define PIF as a social "becoming", supported by the development of a sense of belonging, and the recognition, by learners, peers and supervisors, of the learners’ abilities and legitimacy [7]. PIF is thus always multidimensional. Investigating its relations to gender implies studying the interrelations of gender and other personal factors, as well as environmental influences, in students’ identification, self-recognition, achievements and goals. Fowler [4] mentions the expectancy-value framework as key to questioning the impacts of diversity on student perception of the curriculum, their engagement and how engineering identity might develop differently amongst students. Hence the need to try and build a multifactorial model of PIF, that should allow us to precisely evaluate the relative influences of gender and other factors in the process of PIF.

2 SCOPE OF THE WORK AND METHODOLOGICAL APPROACH

2.1 Research goals and scope

With this study, we wish to:

- Evaluate the impact of this curriculum on male and female students’ professional development, to try and analyse the relations between their gender and their PIF,
- Investigate the interactions of gender diversity and student diversity as a whole in their professional development, to develop a model for understanding PIF,

limitation of sociodemographic data collected here, and the focus on dispositions rather that other personal characteristics.

[3] Source : *Sous-direction des systèmes d'information et des études statistiques* -SIES

- Address PBL curricula's inclusiveness, and the way to support the thriving of students of varied profiles in such curricula.

The PoPBL environment implemented at CESI is not a targeted program, which means it is not an institutionalized attempt to build an inclusive engineering environment [7]. It is a new curriculum implemented in a 35 year-old programme, with new teaching, learning and evaluating methods. The impacts it can have "diversity-wise", and the question of this programme being "diversity-inclusive" is an issue for inquiry by the author, but not for the curriculum designers[4].

The personal factors investigated that we hypothesized might impact students' PIF, and that we will cover in this paper are: their biological gender, age, previous experiences, goals and expectations. The environmental factors inquired were the students' training centre (the same training takes place simultaneously in 9 different locations across the country, with cohorts of different sizes), and project tutors.

The indicators of professional identity development addressed here are:

- Students' identification to an engineering posture (they were asked what an engineer was to them, and if they felt they were able to act like engineers during school projects),
- Students' self-efficacy in an engineering posture (they were asked about their confidence in their success in different tasks, full projects, and different roles in groups)
- Conscience of their development and feeling of recognition/legitimacy (they were asked what skills they thought they acquired, during various tasks and projects, and if they felt these skills were acknowledged by peers/tutors),
- Challenges and support experienced in the process and overall satisfaction.

Previous scientific literature on the field allowed us to define these intrinsic indicators of PIF (as opposed to external indicators like the acquisition of key engineering skills) as our main focus.

[4] The author, during the 3 years of data collection, was a project manager responsible for diversity-related awareness campaigns directed to secondary school students, as well as a researcher in education at the same institution.

2.2 Methodology and data collected

Five questionnaires were submitted to the cohort throughout the 3-year survey, with the following answer rates (*Table 1*):

Table 1. Data collected via questionnaires to the cohort of 587 throughout the 3 years

Questionnaire	1 Year 1 – October 2015	2 Year 1 – May 2016	3 Year 2 – November 2016	4 Year 2 – May 2017	5 Year 3 - November 2017
Number of full answers	587	102	232	228	155

Statistical analyses (flat sorting, Chi-square correlation tests and Multiple Correspondence Analyses) were used to sort the data collected from these surveys and allowed us to have access to global data and statistical analyses on the full cohort's experience of the curriculum.

To get more in-depths insight and nuance into the correlations noted in the cohort results, a sample of 31 of the students, from 6 different training centres delivering the same programme, took part to 68 interviews over the 3 years as well. These qualitative data were first categorized by the author, using literature-driven PIF indicators, as well as field-inducted ones. To analyse the frequency and strength of each category according to various personal and environmental characteristics, the lexicometric tool Sonal was used.

3 RESULTS

Although gender can be pinpointed as a relevant factor in students' career goals adjustment and use of resources, other personal characteristics that cannot be related solely to gender (students' expectations of the programme), as well as environmental factors, seem to play a bigger role in students' PIF than gender only.

3.1 Diversity as a difficulty

The first significant piece of data we would like to report here is the crucial importance students give to "others" in their development in this curriculum, whether it be as a tool to become themselves, or as obstacles on their way. Amongst the sample of students, 71% mention teamwork as a help during their first interview. Mutual aid and cooperation as tools to gain knowledge and leadership skills are the most mentioned resources to their development. But group work is also mentioned as the main difficulty encountered by the whole sample of students. What they find difficult with group work is the varied implication of the different team members in the projects, and the "non-professional" quality of their relations to each other, that is especially regretted by students identifying themselves with a manager-type engineer. Tensions arise from group work and from the diversity of students' engagement in the curriculum.

3.2 Factors that affect professional identity formation in this curriculum

When looking at all the factors that impact students' PIF, the cohort data collected suggest that environmental factors (*Table 2*) are most of the time more relevant than personal characteristics (including gender) to explain most PIF differences amongst students.

What the below-mentioned data (*Table 2*) imply is that being in one or another training centre, or being tutored by one or another tutor does have significant impact on:

- How the students will or will not identify to engineering identities,
- How they will or will not feel recognized as engineers by their peers and tutors,
- The challenges they will or will not perceived in STEM topics.

These PIF indicators are not related to any of the personal factors enquired. However, personal factors do have an impact on students' PIF as *Table 2* shows.

Table 2. Significant correlations (Chi square p-value) between environmental, personal factors and students' professional identity development indicators [5](tool: XLSTAT)

Related factors	PIF indicators	Identification to an engineering identity	Self-efficacy	Recognition as an engineer	Challenges in STEM topics	Support in group work	Career goals evolution	Support in tutoring	Satisfaction of expectations
Externa	Project tutor	0.050	0.045	0.012	NS	NS	NS	0.018	NS
	Training centre	0.033	0.045	0.007	0.001	0.023	0.048	0.018	NS
Personal factors	Previous academic background	NS	NS	NS	NS	0.024	NS	NS	0.049
	age	NS	NS	NS	NS	NS	NS	NS	0.044
	gender	NS	0.003	NS	NS	NS	0.017	0.005	NS
	expectations	NS	NS	NS	NS	0.047	NS	NS	0,029

Personal factors are the sole factors of influence on the overall student satisfaction of the curriculum, which is related to their previous academic background, expectations and age-range. Personal factors co-influence (with environmental factors) other PIF indicators: self-efficacy, the support encountered, as well as career goals evolution.

Multiple Correspondence Analyses (on cohort data) reveal that environmental factors can reinforce or diminish the effect of initial predispositions caused by personal factors. For example, both gender and tutoring can be significantly related to students' self-confidence. When comparing the relative influences of these factors (gender versus tutoring) on self-efficacy, via MCA, tutoring appears to be the most influential factor. So if we can relate to Fowler's finding [4] of female students' "lower sense of self

[5] NS is for « not significant », i.e. a p-value>0.05

efficacy" in STEM, tutoring affects this indicator even more strongly. Tutors can diminish (and increase) this gender bias. The same phenomenon occurs with teamwork as a support to students' PIF: though impacted by personal factors, such as students' previous experiences, this indicator is more impacted by environmental elements.

Gender does affect PIF in two major ways in this programme: it clearly affects students' career goals flexibility and their use of resources in the curriculum. When compared (MCA on cohort data) to environmental influences on students' career goals, gender is the most significant factor, and when compared to the impact of the training centres on the use of the tutor as a resource, gender is, again, the most significant factor. These are the only two significant gender differences that are not counterbalanced by tutorial posture or other environmental elements. The impact of this bias is confirmed by the sample's data: 3 out of the 31 people in the sample considered completely changing their career path and quitting engineering. The 3 were women. This piece of data, though not statistically significant, raises the issue of female students' persistence and well-being. Although data collected from the cohort does not underline such gender biased team dynamics as found in previous studies (Fowler's for example), gender does have an impact on students' experience in the curriculum, and their "becoming" engineers.

The other personal characteristics that are most significantly related to PIF indicators appear to be students of both genders' expectations and previous experiences. These personal characteristics are indeed the most relevant factors of impact on students' support experienced in the curriculum, and their overall satisfaction.

3.3 Impact of methodological design on data collection

We mentioned that, in the cohort-related data, environment is more relevant than personal factors to the expression of teamwork difficulties. We are however able to point out a major difference between data collected from the cohort and data collected from the sample (i.e. qualitative data). Indeed, the sample data appears to bring more nuanced, and more gender-related differences between students' PIF.

For example, in the sample of students interviewed, female students tend to express significantly more how they use teamwork as a rehearsal for their future role as managers and group coordinator. They also tend to mention more the difficulty to lead and more basically to put to work the teams of their peers, pinpointing the lack of "maturity" of their (male) peers and even, for two of the female students in the sample, expressing a feeling of being marginalized because of their engagement in the curriculum. All the while, male students tend to express how they use teamwork as a way to co-develop their knowledge, and as a source of social networking.

Gender differences, as well as other more implicit and subtle differences related to personal characteristics, arise in the qualitative data collection, which encourages us to question the impact of research design on the analysis of "sensitive" data related to identity and diversity. The biases related to the different "quality" of the data collected can be numerous. First of all, the author of this paper and research project is female, and takes part to affirmative actions aimed at building awareness on gender bias in engineering studies. Although this activity was never mentioned during the interviews, and the same questions were asked to male and female students, this bias is still likely. Moreover, more female students took part to the interview process than the cohort's female/male ratio accounts for. This can lead us to confirm that female and male students do not behave and engage in the same way in student/staff relationships in the curriculum, but it also forces us to carefully nuance the scope of the results related to the sample's data, as they are less representative than the cohort's data.

Just like most curricula may not yet be designed to embrace student diversity, we agree with Beddoes et al. [5] that "the dominant research designs and approaches may not be the best for capturing the experiences of minority groups or understanding gender in teamwork". Altogether, it appears that collecting qualitative data can be a very precious source of nuanced and more implicit information when dealing with such issues as professional identity formation and diversity, especially when trying to develop a viable model of the process.

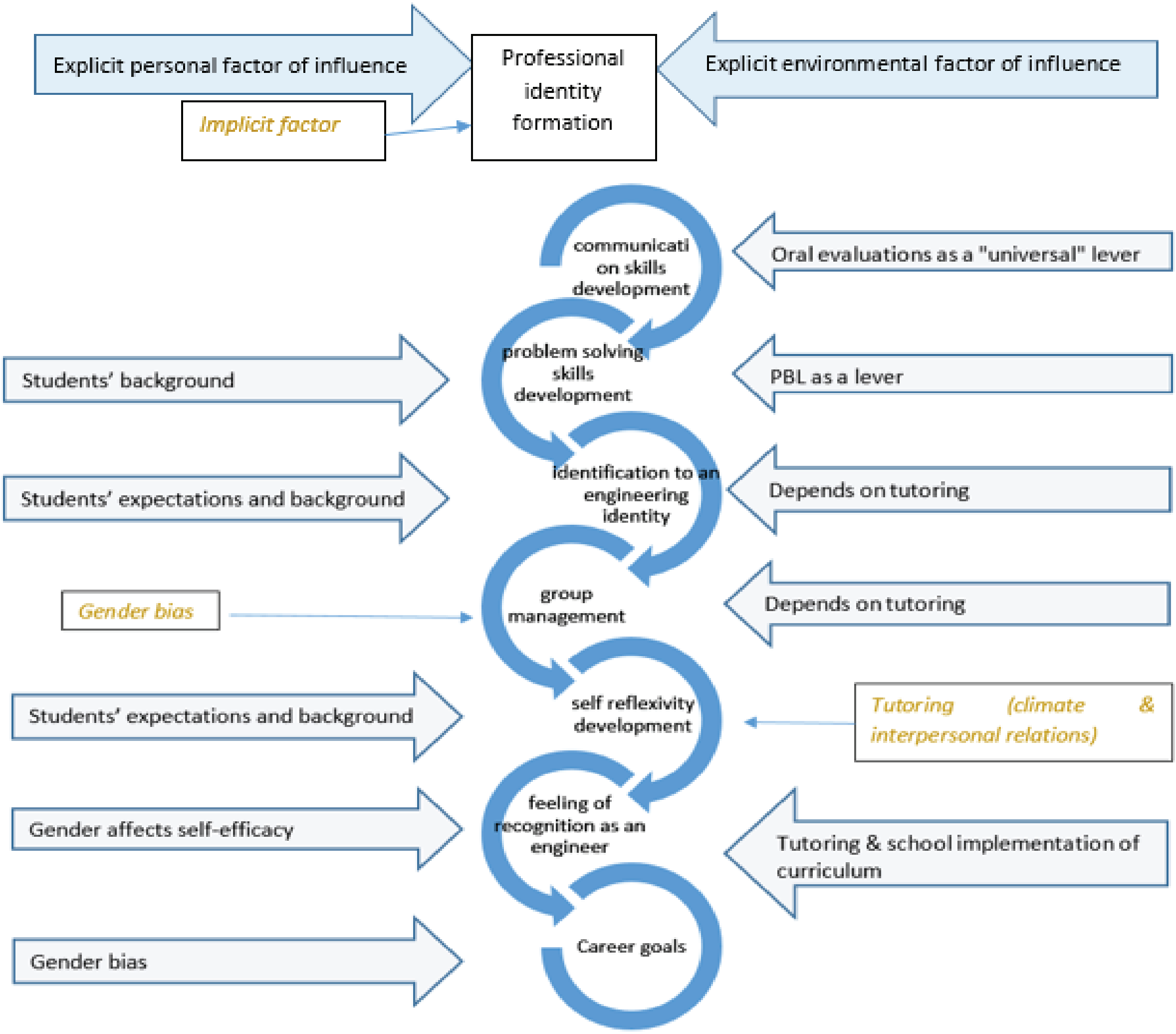
4 CONCLUSIONS AND PERSPECTIVES

4.1 The model of PIF in this curriculum

What the data collected show is that, although there are some "common" developments in all the students' professional identity formation[6], most of the PIF indicators that we analysed are either influenced by personal factors, including gender, or environmental factors. These diverse transitional paths can lead to a feeling of inadequacy of the curriculum (and, for one third of the cohort, an overall dissatisfaction) to some of the students, when their evaluation of the curriculum does not match their expectancies. The following figure (Figure 1) is an attempt to depict a model of professional identity development in this curriculum, which takes into account the relative influences of personal and environmental factors on PIF indicators, as well as the weight of explicit and more implicit factors of influence.

[6] We did not focus here on the "common" tools of developments, but the two following factors are mentioned by the cohort as "universal" tools to build one's engineering identity: oral evaluations and problem solving experimentation.

Figure 1 : A model of PIF in this curriculum - personal, environmental, explicit and implicit factors of influence



4.2 Perspectives to make (gender) diversity a support of PIF

The consequence of this heterogeneity in developmental paths, is that the curriculum designers, should they aim at tackling disengagement issues or tensions amongst students, should address gender diversity and dispositional diversity the way background diversity is addressed: by taking action. Indeed, tutoring teams are able to transform background diversity into a strength for each team, building up individuals' confidence thanks to previous experience. This implies tutors selecting team members "so that individual student characteristics and diversity can be considered" [7]. To transform student diversity into a support of PIF, diversity in all its dimensions (students' goals, expectations, motivation, learning styles, as well as their preferences

[7] Source: SEFI Position Paper on Diversity, Equality and Inclusiveness in Engineering Education https://www.sefi.be/publication/sefi-position-paper-on-diversity-equality-and-inclusiveness-in-engineering-education/

in terms of resources and tutoring) should be addressed and expressed, and not overlooked. An inclusive learning environment cannot be developed if diversity is not acknowledged and if biases are not made explicit, which seems the case for gender diversity in this curriculum. Engineers are often team leaders, and their communication and interpersonal skills are as important as their technical skills. Engineering Education should then use what we've so far learned about professional identity development and the impacts of diversity on it, to develop curriculum inclusiveness. The following strategies could be explored to do so:

1. Exploring activities to address diversity so as to change students' relationship to "otherness" and their expectations towards one another[8]. We would add using experience expression as well, as a reflexive tool for both students and teachers so as to make their skill sets, learning goals and (un)comfort zones more explicit and obvious and to encourage students to reflect on theirs and others' [4], and to allow tutors to adapt their tutoring to such feedback received.
2. A global scheme to address student diversity via tools valuing individuals' qualities [7], so as to avoid treating only part of the problem (dealing with gender diversity, but not addressing differences in expectations, and vice-versa). Addressing diversity in engineering training in all its dimensions to try and model the various characteristics that affect PIF is only a starting point to develop/design engineering curricula that allow students, in their diversity, to thrive and develop their confidence. What kind of tools can be used?
    - French researcher Roux [8] mentions the positive impact of "ritualized social practices" that allow "reciprocal control of the partners during the course of the tasks" in order to deal with student heterogeneity in group work.
    - As far as engineering projects are concerned in a PBL context, researchers at Louvain Learning Lab [9] suggest using « position » cards instead of fixed roles in teamwork so as to be more representative of actual engineering activities in real life projects, but also to allow more flexibility and ensure that interactions between students are structured and symmetrical.
3. Tutoring is key in addressing diversity management in such group work and PBL engineering education contexts. If students' freedom of choice in terms of building a team can be a very formative option in terms of team management, it also appears that task assignment and team composition by tutors can be a good way for students to develop critical interpersonal and communication skills, and for tutors to "disrupt the self-perpetuating feedback loop in which students gain skills and experience according to their pre-existing expertise" [4]… Which also means disrupting stereotypes, habits and biases as much as possible.

4.3 Conclusion

PBL is often presented as a learning environment that is most adapted to a wide variety of student profiles. But we can agree with Du et al. [10], that PBL itself is "not enough to be used as a recipe" for homogeneous student development in a curriculum.

[8] Atadero et al. 2018 [5] suggest using Student Trading Cards or Sketch-based interaction.

To accommodate the different expectations, academic backgrounds, learning styles, and to tackle disposition-related, as well as gender-related biases in the cohort, the PBL curriculum should be envisioned as a crucible where diversity is addressed and promoted; as an environment "where every individual is not only respected, but also feels safe and included"[9]. This might be achieved through tutoring as a mediation to the social interactions at stake. Some tutors in the curriculum studied have expressed their difficulty with the new professional identity they too have to develop, as tutoring and teaching are different activities that require different skills: they too need to adapt to the new curriculum. Addressing gender and more globally diversity and professional identity formation as a multifactorial model in a PBL environment is then also connected to addressing tutoring identity in a PBL learning environment. Student diversity might stop being a hindrance to students' well-being and their harmonious development if tutoring identity, and diversity management by tutors were to be systematically addressed at the institutional level of PBL curricula.

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Open Content Development in Engineering Education and Teacher Training

Prof. András Benedek
Budapest University of Technology and Economics
Budapest, Hungary

János Horváth Cz.
Budapest University of Technology and Economics
Budapest, Hungary

Dávid Sik
Budapest University of Technology and Economics
Budapest, Hungary

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Keywords: content development, new method of learning, online teaching and learning

ABSTRACT

The Open Content Development (OCD) model is intended to result in new content development of teaching methods and their implementation in practice. We aim to develop open – with active teacher/student contribution – content and to apply those contents in practice. The project, which was launched in 2016 with the support of the Hungarian Academy of Sciences, is part of a complex subject pedagogical methodological innovation project. The aim is to provide the possibility of modernizing the materials in technical education continuously and rapidly and to raise the pupils/students' interest on the other. Serving the modernization of the subject named 'System Theory for All', our project aims to develop an innovative method, relying on the principle of open access, allows the students to do everyday development activities in framework system (Moodle). The project has offered the opportunity of cooperation in developing learning content, and school books, involving the lecturers and students (75 persons) into the construction works on various micro-content manageable online with the help of the method. As a result of our work, in the online teaching-learning space, which was created according to the up-to-date principles of network learning, the Sysbook electronic platform has been introduced as well as learning units (micro-content) elaborated by 265 students that have been made accessible in an up-to-date electronic archive and search system for a broader range of users. During the latest 18 months, our further training

program preparing the application of the process in a full professional circle has been attended by 110 VET teachers working in 12 VET institutions. In our paper, we introduce the model of open content development as an innovation process, the elaborated dynamic, interactive micro-content and the results gained during practical tests done with students.

1 INTRODUCTION

The openness in educational content has been one of the significant developments over the last two decades. While ensuring open access to the towers, the conceptual issue of our project is to open the development process to all participants. Students are now assisted by a large number of educational portals that make their open content accessible (W1) In the process of digital transformation, content development based on interactivity seems an innovative method. The training content development has stable didactical features [1] and is partly connected to the endeavours which strive to shape the alternatives of the traditional training curricula in a learning environment determined by new info-communication technology in the learning [2]. Concerning the new didactical model supported by digital transformation became an essential precondition of the online assessment of learning and innovation to be able to evaluate the methodological impacts of the system and to prove our preliminary working hypotheses on the broader professional base [3].

Developing Open Educational Resources (OER) with engineering students' participation means potential for improving the content. According to the new kind of students interactions [4], the channels and community-making elements of interpersonal communication have transformed (especially in the web 2.0 environment). As we introduced in our previous papers the open access to learning contents and Digital Pedagogy [5] has made a considerable try to renew pedagogical thinking after the millenary and firstly [6] at the universities. Nowadays, in content development, the rapidly changing elements determined by digital transformation aspects, and the dynamics of the changes are challenging to be forecasted [7].

Our concept covers the elaboration and introduction of a learning material modernization model created in an online environment within secondary and higher education in a collaborative way. Using this process, our aim, on the one hand, is to provide the possibility of modernizing the materials in technical education continuously and rapidly and to raise the pupils/students' interest on the other.

2 METHODS

One of the essential elements of our project is that engineer teacher training, conducted at two different faculties of our university, and electrical engineers' training has been connected in terms of thematic and methodological questions. The project has offered the opportunity of cooperation in developing learning content and school books, involving the lecturers and students (75 persons) into the construction works on various micro-content manageable online with the help of the method. As a result of our work, in the online teaching-learning space, which was created according to the up-to-date principles of network learning, an electronic platform has been introduced as well as learning units (micro-content) elaborated by 265 students that have been made accessible in an up-to-date electronic archive and search system for a wider range of users. During the latest 18 months, our further training program preparing the application of the process in a wider professional circle has been attended by 110 VET teachers working in 12 VET institutions. In our lecture, we introduce the model of Open Content Development (OCD) as an innovation process, the elaborated dynamic interactive micro-content and the results gained during practical tests done with vocational teachers and engineer students.

Our first multi-levelled e-learning environment called *Sysbook* (W2) was included in our application. The constantly evolving *Sysbook* platform connects to the OCD model; this platform introduces the open learning resource elaborated about a certain comprehensive topic: About systems and management for everyone [8]. This platform (W3) presents the students' innovations, as well, and after an expert evaluation, the development results can be published here. In *Sysbook* several case studies show the application of system view. In the different examples it is investigated, what is considered a system, how is the system connected to its environment, what are the input signals and what are the output signals? How can the model of the system be built? What are the requirements set for the system? Which balance and energy considerations have to be applied? Can we control the system? How to control the system?

3 SUPPORTING FRAMEWORKS

We illustrate the implementation of our concept with three examples from the results of the project so far. *SysBook* has evolved from traditional engineering training and has provided an opportunity for methodological innovation. The *MC-HUNGLE* system provides explicit methodological support for micro-content developers. And creating a *MICROPEDIA* online platform will help you develop, archive, and deploy micro-content more widely.

3.1 SysBook

Considering the open approach, the students can contribute to the content of Sysbook. They can develop their contents related to systems and controls they are familiar with. After a review, this area can be supplemented with new materials. Till now, some examples are temperature control of a terrarium, speed control, model of the learning lab experiment, the model of motor, etc. (*Fig. 1*).

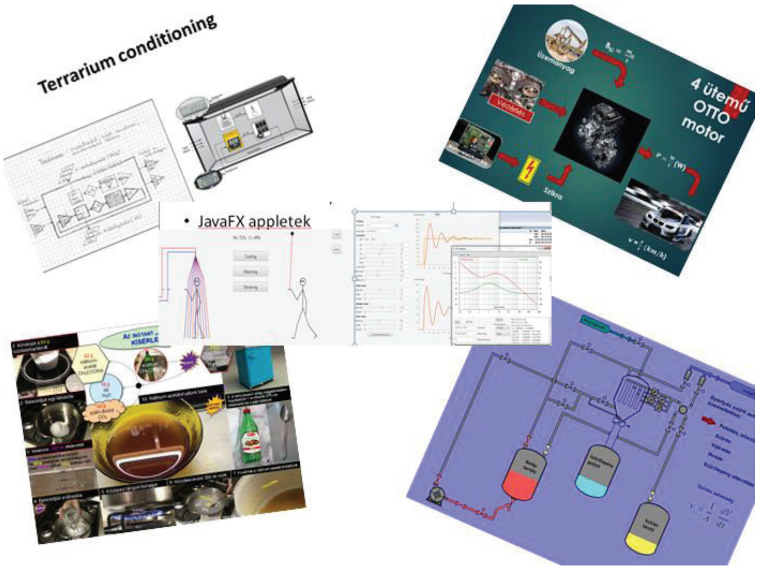

Fig. 1. Systems appearing in the *Sysbook*

Motivated computer engineering students created Java applet demonstrations in the field of control engineering during their summer internship programme at our university. These applets have been included in the “Control course” surface of *Sysbook*. Each applet is available both in English and in Hungarian, also linked with their PDF format instructions (*Fig. 2.)*. The topics and demonstrations of the currently published applets are the following: Frequency analysis, Fourier analysis, Bode and Nyquist diagrams of a system, Shower temperature control, Juggler (inverted pendulum), continuous PID controller (series and parallel), discrete and continuous Youla controller, Prediction for first-order systems.

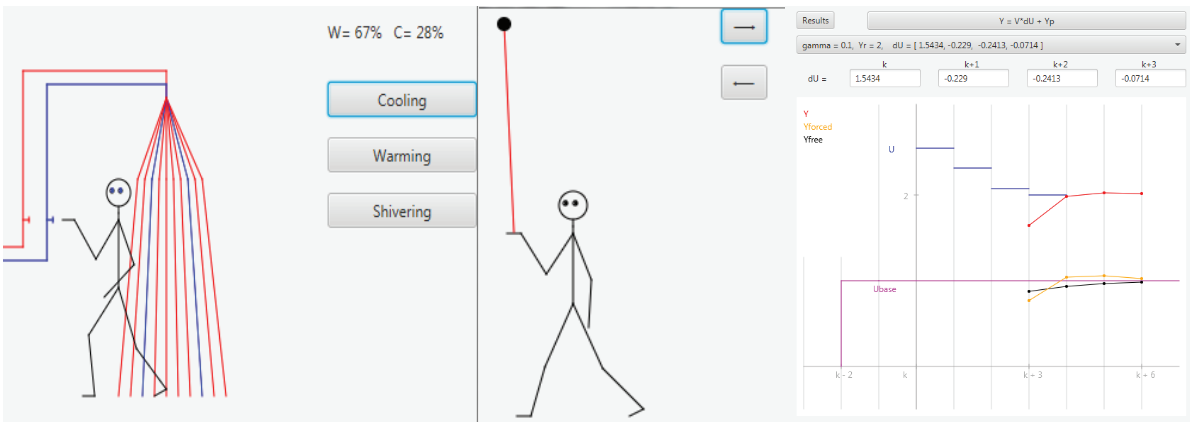

Fig. 2. Control Engineering Java applet demonstrations created by motivated students

Based on the OCD concept, we decided to design and develop a smartphone application which can help our students and teachers to reach our micro-content management systems. This decision was based both on the hypothesis of the research group and also on the current trends regarding the device usage in the Z and Alpha generation students. The “Bring Your Own Device” (BYOD) phenomenon where the word “Device” can also be replaced with “Phone”, “Tablet”, “Personal Computer” etc. getting more and more popular in the different educational institutes from the primary schools to the universities. A self-developed application would help to strengthen this phenomenon and give more power into the hands of the users.

First, we made literature and market research concerning the different smartphone operating systems and marketplaces. From 2010 to the end of 2018, the dominance of Google’s Android operating system has grown from 20% to the currently 86% share of the market. 13% belongs to Apple’s iOS platform. The last 1% includes the other remaining systems [9]. Then, comparing the two platforms we decided to choose the Android platform for the first target as it is more open, the development is free, and no special devices are needed to develop applications. Our application is based on a WebView component, extending its features by different smartphone and Android-specific options, such as using pictures of the camera, different sensor data etc.

The source code of Sysbook was optimized for compact displays, and smaller screens as the current smartphones have (*Fig. 3*). We also enabled to run some JavaScript code snippets which are showing the expressions of the different words included in the glossary of Sysbook. We are currently working on an improvement of the application, applying the commonly used gestures (swiping, pull to refresh, etc.) instead of clicking on the different hyperlinks in Sysbook.

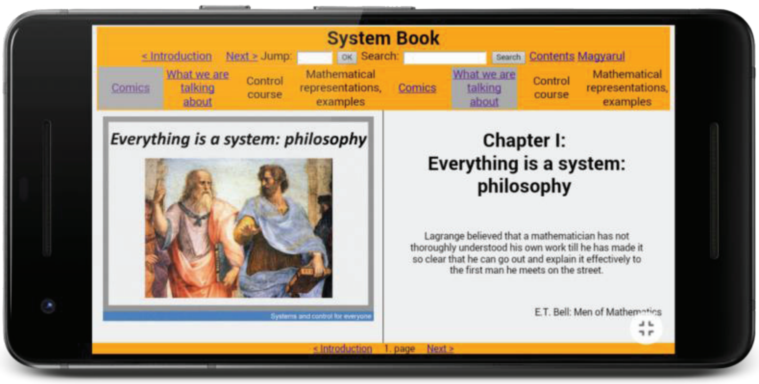

Fig. 3. Sysbook optimized for the smartphone application screen

In Sysbook there are four surfaces (levels): “Comics”, “What we are talking about”, “Control course” and “Mathematical representations, examples”. There are altogether almost 137 pages, in 11 different chapters. Two of the four surfaces can be shown on the screen, combining the left and right side also. "Comics" and "What we are talking about" levels are available for every page of Sysbook. These pages were written by academicians, professors and system experts for three target audience: to everybody; for different students, for the experts with different professions or the control specialists.

As the Sysbook is a base curriculum in different university subjects at the Budapest University of Technology and Economics, the student might come from the Faculty of Electrical Engineering and Informatics regarding the topic “Control Engineering”. Or the students also might come from the Faculty of Economic and Social Sciences regarding the subjects “System Theory for All” or “Digital Pedagogy”, usually engineering and economist teacher students. In the Student Area of Sysbook, the students can also design, create and publish their topics of interest as pages, micro-content in the area. After a peer review, these materials will also be available as part of the Sysbook.

3.2 MC-HUNGLE

Our second micro-content editing system called MC-HUNGLE can also be accessed using the smartphone application. MC HUNGLE is a LAMP-based (Linux, Apache HTTP Server, MySQL, PHP) Web 2.0 application, which can be opened using regular browsers or smartphone browsers also. The system is also used by the students of “Becoming an Engineer” at the Faculty of Electrical Engineering and Informatics and even by the partner institutes of our research group. This system is available currently only in Hungarian, but the internationalization of the interface is in progress. The main goal of the MC-HUNGLE system is to allow editing micro-contents with structured metadata supporting advanced search methods and explicit knowledge formalization. We designed our web application to offer the possibility to the quick and efficient elaboration of individual micro-contents without a high level of the mental load from users. As *Fig. 4* shows content editor page is simplified, allowing authors to work focusing on knowledge allocation.

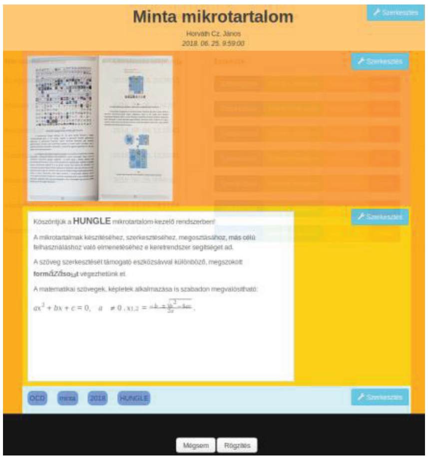

Fig. . Screenshot of content editor page from MC-HUNGLE

The title of the content unit should be expressive, concise, short. When creating a micro-content, we strive for clear, transparent communication. We can use an image or/and text block in the content unit. We suggest that an image should not be too complicated; it should not contain much more detail than necessary understanding. The text block should have a maximum of 1024 characters; the content breakdown should aim for the introduction, the body and the conclusion. Entering tags and labels is very important for successful content mining. We recommend at least three or more labels to each micro-content. Authors can use one word or complex expression for a tag. It is essential to know that metadata of the original author of the content unit is retained even after reusing by other users (teachers, students).

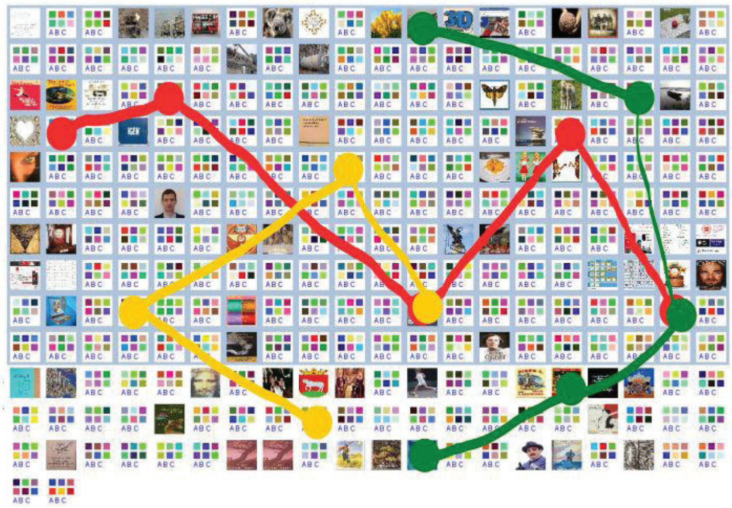

Fig. 5. Different ways to organize and structure micro-contents by MC-HUNGLE (groups (basic set, thematic group and domain) and knowledge tracks)

Micro-contents can be represented as icons and thumbnail images. With a suitable algorithm, we generate and attach a unique colour code to individual content units. Over a certain number of items, it is necessary to organize micro-contents. There are two simple procedures. First one is to collect different content units into a higher level of groups (basic set, thematic group and domain). Elements for a topic are received by teachers and students, and this collection can be offered to others. There may be an array of similar topics, but users have the choice of the best ones for them, or they can reuse existing sets in whole or in part. The left side of *Fig. 5* shows these levels. The second one is selecting knowledge tracks on a large set of micro-contents. In this case, the teacher usually collects a lot of content units for a lesson or a course. In addition to this option, the teacher designates specific content units to be viewed in succession formed to one or more knowledge tracks. On the right side of Figure 5. these knowledge tracks are shown. There are three knowledge tracks marked with different colours altered lessons. Note that some micro-contents may participate in other knowledge tracks.

3.3 MICROPEDIA

The newest results of our survey have proved our hypothesis according to which one of the possible ways of increasing teacher activity is to offer, besides methodological support in learning the theoretically instant material in the increasingly accessible online learning environment, the possibility to join in the Learning Management Systems (LMS). The new micro contents, except for their different forms and topics, showed a significant potential for using them in the teachers' preparation for their lectures and practical work with students. Using the new set of micro contents 2018-2019 we established an archiving system for distributing the result of content development (W4), the next *Fig. 6* shows a few screen pictures about the teachers' support portal:

Fig. 6. MICROPEDIA as a micro-content archiving system/portal (W4)

We integrated the MC-HUNGLE interface with our smartphone application (*Fig. 7*) where the users can create new micro-contents using the menu of the application, where for example they can attach a photo to a micro-content which was taken using the camera of the smartphone inside our app.

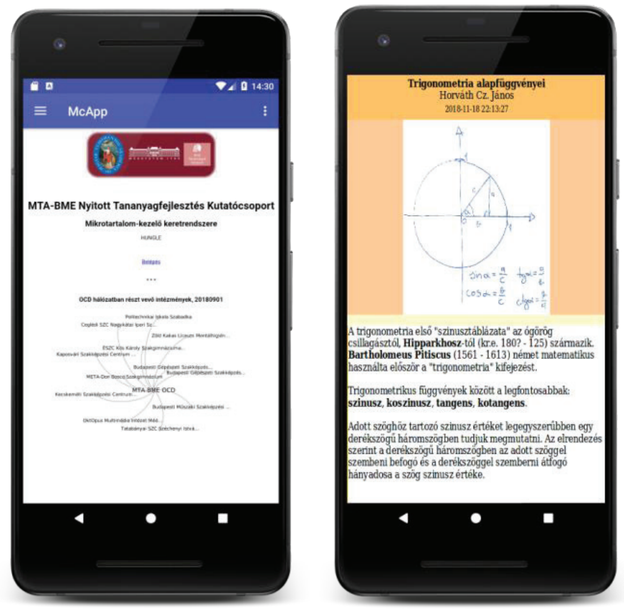

Fig. 7. MC HUNGLE micro-content editing system in the smartphone application and its menu

The third system is the newest one (available currently only in Hungarian), the OCD Micro-content management and community system. The system is a Drupal content management system based framework for managing different micro-contents, tutorial videos, lecture notes, tags etc. The users can register and login to the system, upload image-, animated image-, Prezi- or Youtube video-based micro-contents with the extended type of metadata such as title, description, tags: target audience, level, profession group, NVQ qualification. The teachers can evaluate the work of the students. Also, the students can rate the work of each other. This site collects all "digital free-hand" micro-contents. It means that a lot of users create valuable content units without any frameworks just using content authoring program (e.g. Power Point, Impress, Prezi). Digital diversity makes it difficult for computer-supported content analysis, but these are stacked for human use and classified as possible. The Drupal framework also helped us to optimize the screen for compact displays. Some integrated code snippets support to open the Youtube videos and the lecture notes with the application, and it is also possible to use the picture taken by the camera of the smartphone as the basis of different newly created micro-contents.

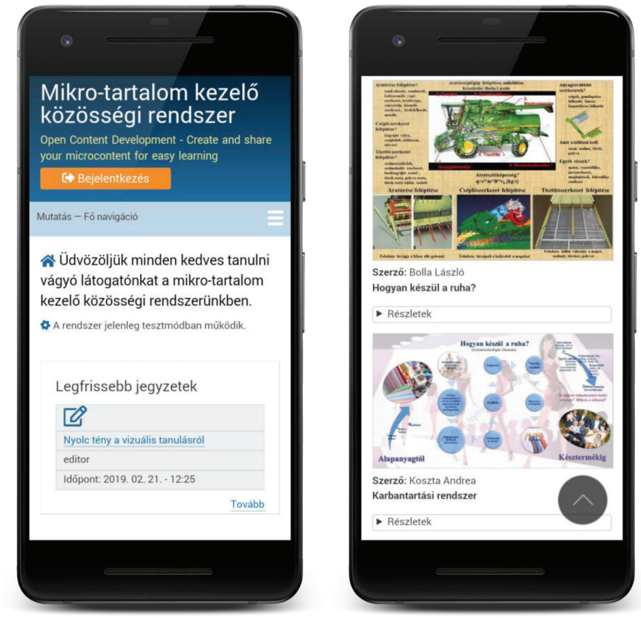

Fig. 8. OCD Micro-content management and community system.

Our achieved result is a native (Java-based), expandable Android application (*Fig.8*) with which the different users, students and teachers of the Open Content Development Research Group and Partners and also the students from at least two faculties at the Budapest University of Technology and Economics can reach, use and create their learning units, the micro-contents on their smartphones.

4 SUMMARY AND ACKNOWLEDGEMENT

According to the current procedural approach, applying such solutions at the level of open content development requires decisions at the institutional level. Utilizing the advantages of digital transformation and the fact that it allows accessibility in space and time, comfort and personal time management in acquiring the learning material, we succeeded to open the process of content development and make it possible for teachers and students to share new knowledge by collaborative work.

This project encouraged the faculties of an institution to „learn" in an environment where information exchange organised into an informal network supported by IT devices has an increasingly important role. The point of the concept was formulating active student's contribution as participation in the network and access to information as well as to the software packages were able to interpret data in various contexts, promoting cooperating and self-organised learning. This network concept, as the feature of active student's contribution, encouraged the new educational content development. The result of these activities integrated an original model of OCD (open content development) to formulate a real open environment where information exchange is organised into an informal network. The result demonstrates the tested concept of students' participation in the network and access to the micro-learning content packages that help to interpret information in various contexts.

According to the perspectives, the implementation of the OCD concept in engineering and teacher education has shown positive results based on first experiences. The new methodological process can be effectively integrated into teacher training as well as in teacher training. Based on the experience so far, the greatest achievement is the significant increase in teacher and student activity in content development, which is a significant innovation factor for the modernization and improvement of the rapidly changing educational content.

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https://er.educause.edu/articles/2017/3/transforming-our-libraries-from-analog-to-digital-a-2020-vision

(W2) http://sysbook.sztaki.hu/

(W3) http://sysbook.sztaki.hu/studentarea.php

(W4) www.mikropedia.hu

An online tool for a multicampus Master's Theses support system

I Blanckaert[1]
Educational developer, Faculty of Engineering Technology, KU Leuven
Leuven Engineering and Science Education Centre (LESEC)
Leuven, Belgium

Conference Key Areas: strong demand for democratic involvement in educational processes

Keywords: educational development, digital collaboration tool, change management, quality assurance

ABSTRACT

Six years ago, several higher education institutions offering study programmes in Engineering Technology underwent a thorough change, evolving from independent entities into an integrated multicampus faculty under a single governing board and a central faculty administration at KU Leuven, Belgium. Consequently, educational management structures at the new campuses were forced to adapt in order to remain functional while maximizing multicampus complementarity.

This paper describes the transformation process of the educational management support procedure for Master's Theses within the same programme at three different campuses. Under the coordination of the faculty educational developer, a new online collaboration tool was established as a portal to collect, check, select and assign Master's Theses proposals for campus coordinators, supervisors, students and industrial partners of the different campuses.

After one year of implementation, feedback from stakeholders identifies the support for sustainable and transparent collaboration as the main advantage of the new tool. Also, the transparent workflow with structured process steps within a single access point, as well as enhanced student participation were acknowledged. The future challenges for the tool, however, are to maintain its initial stimulant function for multicampus collaboration and to improve networking with local industrial partners between formerly single campus contacts.

Our results indicate how a software-tool embedded in an online platform can act as a leverage for sustained multisite cooperation, while indicating how both the use of ICT and human interaction need to be carefully balanced to establish a sustainable collaboration model.

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[1] Corresponding Author
I Blanckaert
Isabelle.Blanckaert@kuleuven.be

1 INTRODUCTION

In the year 2013, several institutions offering Master programmes in Engineering Technology in Belgium merged into the multicampus Faculty of Engineering Technology (FET), with 600 staff members and close to 6.000 students located at seven geographically dispersed campuses. Consequently, the organizational management support structures transformed from a single entity organisation towards a complex multiregional system, representing a challenge for faculty support services.

At FET, Master's Thesis projects are joint collaborations between students, research groups and/or industrial partners, designed to integrate disciplinary knowledge with academic and professional skills so that students may acquire and train several competencies within one research project. The organization, quality control, assignment to students and administrative follow-up of these projects is complex and the newly established campuses expressed the need for a new support system for Master Theses projects.

This paper describes the transformation process of the educational management support procedure for Master's Theses within the programme of (Bio)chemical Engineering Technology at three campuses at the multicampus Faculty of Engineering Technology at KU Leuven, Belgium.

2 BACKGROUND AND PREPARATION

There is little literature dedicated to educational support structures in multisite faculties [1]. Several authors, however, recommend a collaborative, faculty-driven approach facilitated by educational developers [2, 3] during the design of any new process, as well as to involve most – if not all – stakeholders [4]. In our approach, the different steps from design to implementation were carefully monitored by a faculty educational developer to ensure input from all stakeholders involved. The faculty educational developer acted as a liaison between the central Programme Committee and the local campus coordinators, project supervisors, students and industrial partners.

2.1 A new collaboration model

In the past, when campuses were independent institutions, staff members organized management systems for the collection, quality control and assignment of Master's Theses projects and optimized these for local needs. Each campus coordinator developed a system for their own student population, research groups and industrial partners, incorporating specific prerequisites for project ideas, their own choice of software and tools, and locally adapted assignment methods.

After the establishment of the multicampus faculty, each campus coordinator experienced an increased level of organizational complexity as their campus was now part of a larger entity. Colleagues from dispersed campuses were expected to function as a team, while their locally adapted management structures were not compatible with each other. As such, a centralized support system to manage project proposals in a coordinated and transparent manner was needed.

2.2 Adaptation of the software

Due to limited resources – both in time, money and available personnel – the Faculty Board decided to adopt an existing software-tool from another Faculty as a starting point. After some minor adaptations through iterative consultation rounds with the Programme Committee, the campus coordinators for Master's Theses and the software expert of the existing software-tool, the tool was considered supportive for the most basic needs of the multicampus collaboration model.

The tool consisted of a database support system for all campuses involved, embedded in an online platform and a single access point for all stakeholders, with the following consecutive steps: 1) the collection of project proposals, 2) the quality control of project proposals, 3) the ranking of projects by students according to their preferences, and 4) the final assignation of one project per student (*Figure 1*). Student data were uploaded in the system through an automated feed from the main university framework, ensuring the most actual information of all students enrolled in the programme. All process steps were managed via an adjustable timetable by the faculty educational developer.

In the tool, three key roles are identified (campus coordinator, thesis supervisor and student (*Figure 1*), each with its own access portal, and with a specific view and rights.

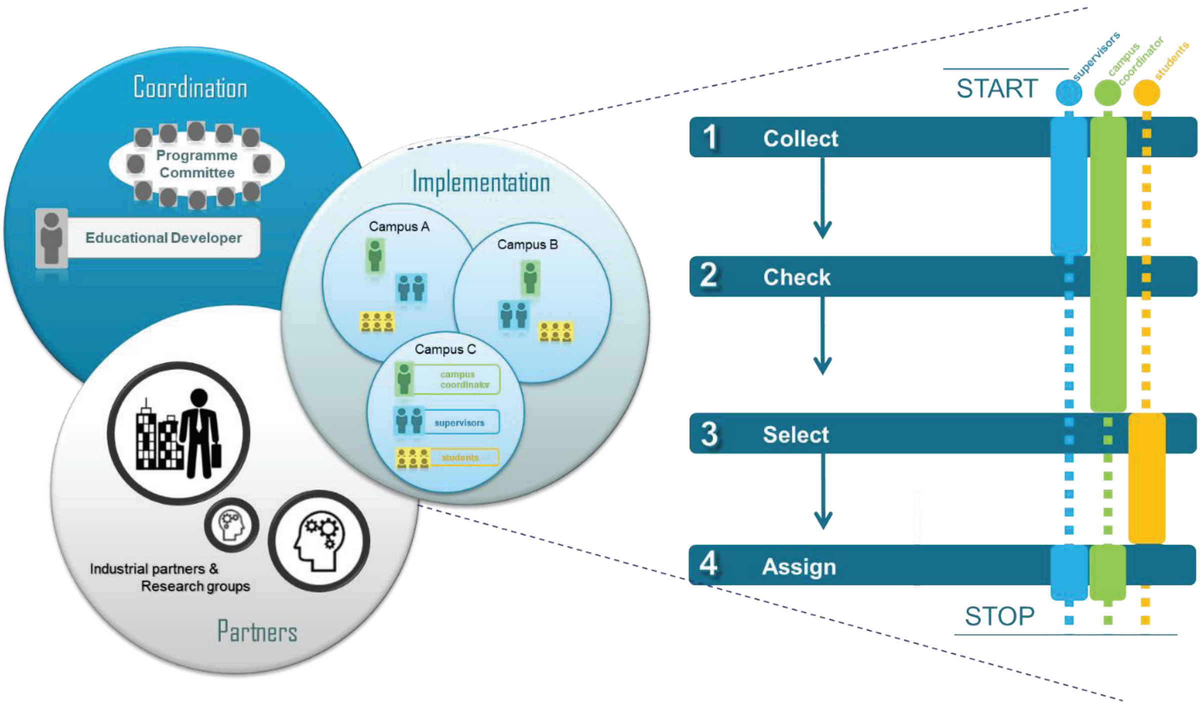

Figure 1 Collaboration model for all stakeholders (simplified presentation)

All faculty staff members and students had general access to the tool with their personnel login to consult. External partners were able request login details by the campus coordinator to gain access to the tool.

2.3 Workflow and democratic involvement

To encompass all tasks involved in the new collaboration model, and ensure transparency for all stakeholders on all campuses, a detailed workflow was drawn, including detailed information on each role. The resulting model mirrored the multicampus collaboration model for educational programmes that are simultaneously implemented on more than one academic site.

The uniform implementation of the collaboration model at all three campuses was coordinated by the faculty educational developer and the Programme Committee, by determining the prerequisites for proposal submission and the deadlines for the process steps.

During the process step for students to rank proposals according to their preferences (*Figure 1*, step 3), the democratic involvement of students was ensured by the establishment of a high level of transparency during the ranking of proposals. For this, the process step was divided into two subsequent sub-steps: first, an open consultation period for students to revise all possible project proposals, followed by the submission of preferences. During the consultation period, students were allowed to consult all project proposals in detail during a significant amount of time. Meanwhile, students were stimulated to attend information sessions or to contact supervisors and industrial partners or to discuss possible partnerships with fellow students without time-pressure. After the consultation round, the submission period starts, during which all participants can rank the projects of their interest while the preferences of their fellow students are visible. Students do not have to worry about a first-come-first-serve pressure, which would undermine the democratic selection process. During submission, the tool does not register the time when students submit their choices, or the amount of times they changed their minds.

Specific care was given to the dynamic assignment system to make sure the tool assigned each student with a final project that was ranked as high as possible in the preference list of the student (*Figure 1*, step 4). Assignation was organized in consecutive rounds, alternating automated and manual assignment steps (*Figure 2*). First, all students who appeared as a single candidate for a certain project proposal with preference “1” (i.e. their first preference) were automatically assigned to the project. Second, where multiple candidates appeared for one project as their first preference, the supervisor had to choose one student and assign this student manually to the project in the tool. All candidates and supervisors involved in this manual assignment step, were notified by an automated email sent from the tool. After all preferences “1” were assigned, the allocation process continues with the preferences “2” and “3”, following the same methodology. The assignment system was completed as soon as all preferences have been processed. Students who did not receive a subject, were invited to participate in a second allocation round with the remaining project proposals.

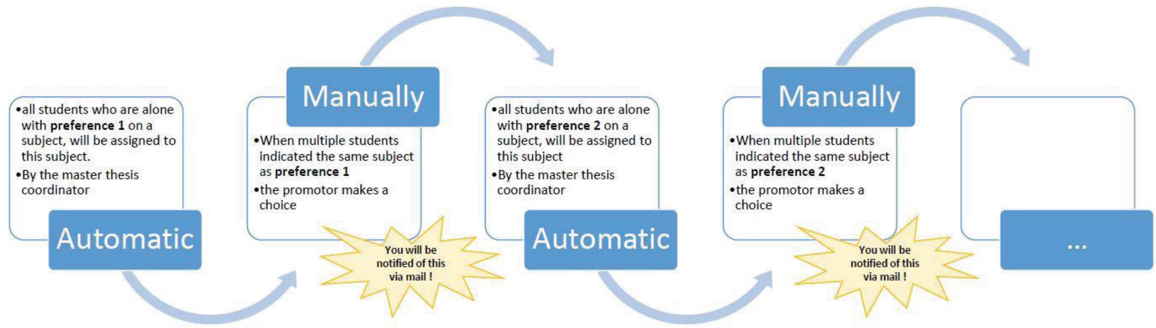

Figure 2 Assignment system, alternating automated and manual steps

2.4 Implementation of the platform

Before implementation, adequate documentation with guidelines for each key role was developed and published through the faculty website. The website included an overview of all process steps and deadlines. The platform was launched simultaneously on all three campuses in January 2016.

3 EVALUATION

During implementation, informal contact with stakeholders was maintained, providing continuous feedback about multicampus collaboration, process management, student participation and work field interaction.

3.1 Multicampus collaboration

The tool was found to strengthen multicampus collaboration through easy access to information about research activities from other campuses. As such, academic staff got acquainted with colleagues from other campuses, which then invigorated a sustainable multicampus partnership and network.

Stakeholders also testified that, while designing the future tool architecture for multiple campuses, the mindset for multicampus collaboration was stimulated. While discussing uniformity of deadlines for all campuses, for example, openness towards future cooperation was stimulated, and spontaneous communication between stakeholders was enhanced. As such, the mere idea of a shared tool already sparked multicampus collaboration even before it was even implemented.

However, to collaborate with colleagues from distant campuses is not always easy, and certain technical issues with the software slowed down the intensification of multicampus collaboration. Not every supervisor was immediately convinced of the advantages of such multicampus schemes and more time may be needed for this to grow.

3.2 Process management

The tool provided a standardized workflow with clear process steps, during which each stakeholder was aware of tasks and responsibilities. The tool was considered the backbone of a complex process involving multiple stakeholders at multiple locations.

The main advantage of the tool was that it collected all proposals within one platform, monitoring stakeholder accessibility through time slots that were opened and closed according to a predetermined and transparent timeline. This helped to perform the necessary tasks in an efficient way throughout the process. As a side-effect, it was possible to divide the work load among stakeholders, as the tool provided a clear view of the tasks that needed to be done.

Within this structured approach, the use of the tool remained flexible. As the campus coordinator had unlimited access to all tool functions during all process steps, this allowed him to overrule certain tool functionalities in function of occurring needs. Taking into account the necessary precautions and quality measurements, as was expected from all campus coordinators, this prevented the software-tool to dominate over interpersonal contact and ad hoc cooperation between stakeholders.

3.3 Student participation

During the selection period, the tool allowed students to see preferences of their fellow students, which enabled them to weigh their options and to manage their preference ranking of subjects. All students were allowed to edit their ranking as many times as needed as the tool did not register input time, nor the number of changes made. However, further investigation will be needed to measure the effect of this transparent student participation in comparison with other procedures.

In the approval and publication period, students were allowed sufficient time to contact thesis supervisors and external partners, without being pressed to decide quickly. In this, the tool created calmness in a process that may otherwise be quiet stressful for students, and stimulated students to obtain a project they are truly interested in.

3.4 Work field interaction

At the early stage of implementation, the effect of the tool on work field interaction was still rather uncertain, as not many external partners were informed about the new platform. However, it seems to be a rather promising aspect, as it could provide industrial partners and research groups with access to the entire student population of the Faculty through one single platform. More efforts may be needed to promote the platform among industrial partners. On the other hand, external partners may feel reluctant to work with supervisors from campuses they are not familiar with or they may want to select candidates themselves instead of through a tool. These aspects remain to be investigated in order to evaluate the possible impact of the tool on work field interaction.

4 CONCLUSION AND FUTURE PERSPECTIVES

A multicampus collaboration platform for Master's Theses was successfully designed and implemented for staff members and students in (Bio)chemical Engineering Technology at three campuses at KU Leuven, Belgium. The main advantage of this platform is its support for sustainable and transparent collaboration between all stakeholders involved in the procedure, including campus coordinators, thesis supervisors, students, industrial partners and research groups. The platform provides transparent procedures and a single login portal, creating easy accessibility and compatibility.

The results show how the implementation of a software-tool embedded in an online platform provides organizational support in a complex multicampus process, and how such a tool can act as a leverage for sustained multisite cooperation. The future challenge for this platform will be to maintain this leverage function, and to keep up the necessary investment of human resources in order to enable its effective use for students, academic staff and external partners. After the first year of implementation, the multicampus collaboration platform for Master's Theses has already been adopted within other Master's programmes within the Faculty and currently, its model is being analyzed for broader implementation within other Faculties of the university.

The observations documented in this paper confirm that the use of ICT can enable more effective use of resources, and provide wider exposure to students and teaching staff [6, 7]. At the same time, the preliminary results in this paper identify the complementarity of ICT and human interaction and the need to balance both to establish a sustainable collaboration platform. As documented in literature, the role of the educational developer during all process steps, functioning alternatingly as a facilitator, change manager and coordinator [5], enabled the necessary organizational support to strengthen transparency, the technological support to help multicampus collaboration, and the quality assurance to optimize data management.

5 ACKNOWLEDGMENTS

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First-year engineering students' perception of what makes a good study day

Pia Bøgelund[1]
Associate Professor
Aalborg University
Aalborg, Denmark
E-mail: pb@plan.aau.dk

Bente Nørgaard
Assistant Professor
Aalborg University
Aalborg, Denmark
E-mail: benteplan.aau.dk

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Abstract

The aim of this paper is to answer the question: What do first-year engineering students, in a PBL environment, identify as a good study-day and what can be said from a motivational theoretical perspective about this kind of day? The ultimate purpose of the paper is to inform students and teachers within engineering education (EE) about how to spur student motivation. Research into this field is very limited in an EE perspective.

Empirically the study is based on 8 groups individual students' own written descriptions of what they have experienced as being a good study-day.

The analyses identifies indicators of students' individual motivation and discuss what brings the individual students satisfaction and productivity. The study concludes that first year students are mainly motivated by mastering something new and supportive communities.

[1] Corresponding author

INTRODUCTION

This paper reflects an interest in first-year engineering students' perception of what motivates them to study. Research into this field is limited from an engineering education (EE) perspective and yet highly relevant in terms of the final professional quality of engineering students and the retention of the same, not to mention the educational and political awareness these subjects attract (Graham *et al* 2013, Thomas *et al* 2017).

The aim of the paper is to answer the following question: What do first-year engineering students, in a PBL environment, identify as a good study day and what can be said from a motivational theoretical perspective about this kind of day? The ultimate purpose of the paper is to inform students and teachers within EE about how to spur student motivation to, and maintain it at, the highest level possible.

The paper first presents the theoretical framework used to interpret the collected data, then we present the methodology used, and finally we go through the results and discuss them.

1 THEORY ON TOP MOTIVATED YOUNG PEOPLE

1.1 Theory on motivation

Theoretically speaking, motivation has been around for a very long time and been at the centre of attention within many fields, first and foremost psychology, but also within social sciences like business and management (see, for example, Higgins 2011). There is a vast amount of theories and definitions to pick from. Within the educational field, and especially within the engineering education (EE) field, the interest in motivational theories has traditionally been limited. To the extent that interest is now gathering around the motivation of young engineering students, the highly influential theory of self-determination (SD) has been a preferred frame of reference (Trenshaw *et al* 2014, Ohland *et al* 2015, Catz *et al* 2018). This approach underlines the importance of human needs to the attainment of motivation. Three basic needs in particular, namely autonomy, relatedness and competence, should be satisfied in order to bring the individual to a high level of autonomous motivation. SD theory operates with a scale of motivation ranging from not being motivated (a-motivated), through being extrinsically motivated to being intrinsically motivated (see Trenshaw *et al* 2014). In the literature, SD theory has mostly been applied in relation to the education of young people, with the need for autonomy being singled out as the most important need, and only a few studies have been carried out about college students and engineering students (ibid.). In these few studies, relatedness needs and competence needs are shown to be of most importance, leading to the conclusion that contextual factors strongly influence what kinds of needs are most important to satisfy (Trenshaw *et al* 2016). And since we are looking at engineering students in a specific PBL context, we would like to utilise a motivational theory a little less generic than SD and a little more focused on the contextual dimensions of motivation.

Hein (2013) is a motivational researcher who seeks to understand motivation from a contextual point of view, focusing on the motivation of creative and highly skilled employees. On the basis of her research, five different motivational types are identified, one of which is not motivated at all, but just there for the money. The other four profiles are motivated either by a work-related cause in itself, by the profession in two different ways or by keeping up a good work-life balance. The theory is, however, developed in a work context and not a higher educational context, so we might be able to use some of the methodology attached, but it makes little sense to regard first-year engineering students as more than potential creative academics.

Katznelson *et al* (2018) and Sørensen *et al* (2013) have conducted research on highly motivated young people inside and outside academia from a contextual point of view, which shows some promise for this study, which is why we will look further into their motivational understanding in the next section.

1.2 Motivation understood as interaction

Katznelson *et al* define their motivational understanding both in terms of what it is not and in terms of what it is:

"We do not consider motivation as something that is or is not. Something somebody just has and others don't have. On the contrary, we understand motivation as a dynamic and changeable size, which must be seen and understood in a concrete context and a specific cultural and historical context (Pless et al. 2015; Jackson 2006; Lemos 2007). ... [We understand] motivation as something that arises in the encounter between the young people's experiences, interests and motives for participation, what creates meaning for them, and the cultural practices and frameworks that prevail in the contexts in which they participate."

(Katznelson *et al* 2018, pp. 22–23)

According to this line of thought, motivation is understood as an interaction between the single young engineering student and the immediate situation and context at hand.

1.3 Five contexts that motivate young people

As regards top motivated students, Katznelson *et al* (2018) define five contexts in which highly motivated students find their motivation:

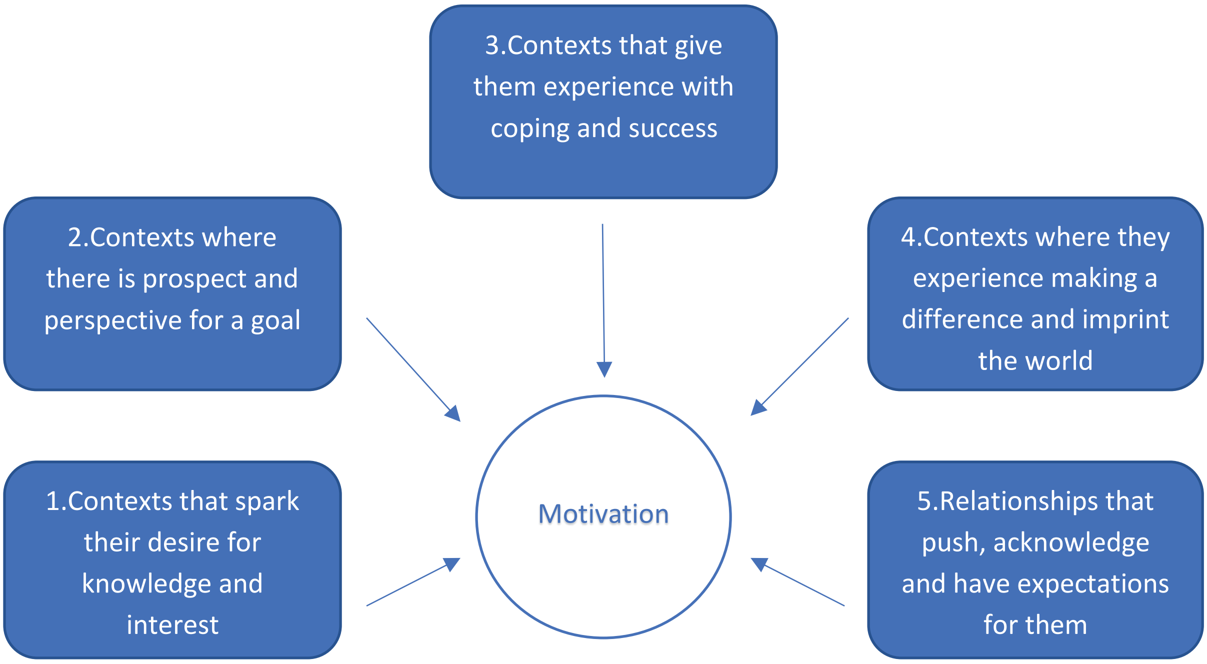

Figure 1. Five contexts that motivate young people. Adapted from Katznelson *et al* (2018).

Context no. 1 regards activities or situations in which the student is motivated by learning new knowledge; in context no. 2, the student is motivated by future prospects; in context no. 3, the student is motivated by mastering something new; in context no. 4, the student is motivated by putting an imprint on the world; and in context no. 5, the student is motivated by a community that supports the student.

While going through the results we will qualify these concepts, but first we want to introduce our data collection methods.

2 METHODS FOR COLLECTING DATA AND ANALYSING MOTIVATION AMONGST ENGINEERING STUDENTS

The study is conducted in a project and problem-based learning (PBL) environment at Aalborg University and analyses both individual and group perceptions and reflections on 'what makes a good study day'. The data were collected as part of a bigger research project on group motivation conducted amongst first-year engineering students within two different educational contexts – the combined educational subjects of biochemistry, environmental techniques and biology and the educational subject of techno-anthropology. Eight groups of students were singled out – four groups from each educational context. The groups either volunteered or were asked to participate in the data-gathering events. Three groups volunteered and 5 were asked. Thus, we tried to avoid systematically biased students, and maximised the chances of diversity.

The data comprised observation by videotaping, group interviews and written individual feedback from students.

The empirically data used for the analysis in this paper are entirely based on the individual written feedback, where 33 students from eight groups were asked – within 15 minutes – to write down an answer to the question: 'what is the best study day you have experienced?'. The question was formulated with inspiration from the research of Hein (2013). She used the same core question (best working day) to make people talk about their motivation for their work.

The individual descriptions of students' perceptions of a good study day are interpreted and decoded by the two researchers using the five contexts as a theoretical map – first independently and then jointly. Based on these conceptualisations and sense-making, the descriptions are illustrated in a quantitative image. The image map provides a quantitative overview of students' individual contextual motivation. To provide insight into, and give meaning to, the categories, representative quotes are selected within each category and disseminated. Furthermore, the 33 descriptions of a study day are analysed based on their group belonging. Thus, the eight groups are analysed through the lens of cohesion and diversity, and the two subjects of study mentioned above.

3 RESULTS – WHAT MOTIVATES ENGINEERING STUDENTS?

3.1 Graphical depiction of motivational contexts

Looking at the statements of the 33 students, in aiming to identify the different types of motivational contexts that they adhere to, the following picture emerges:

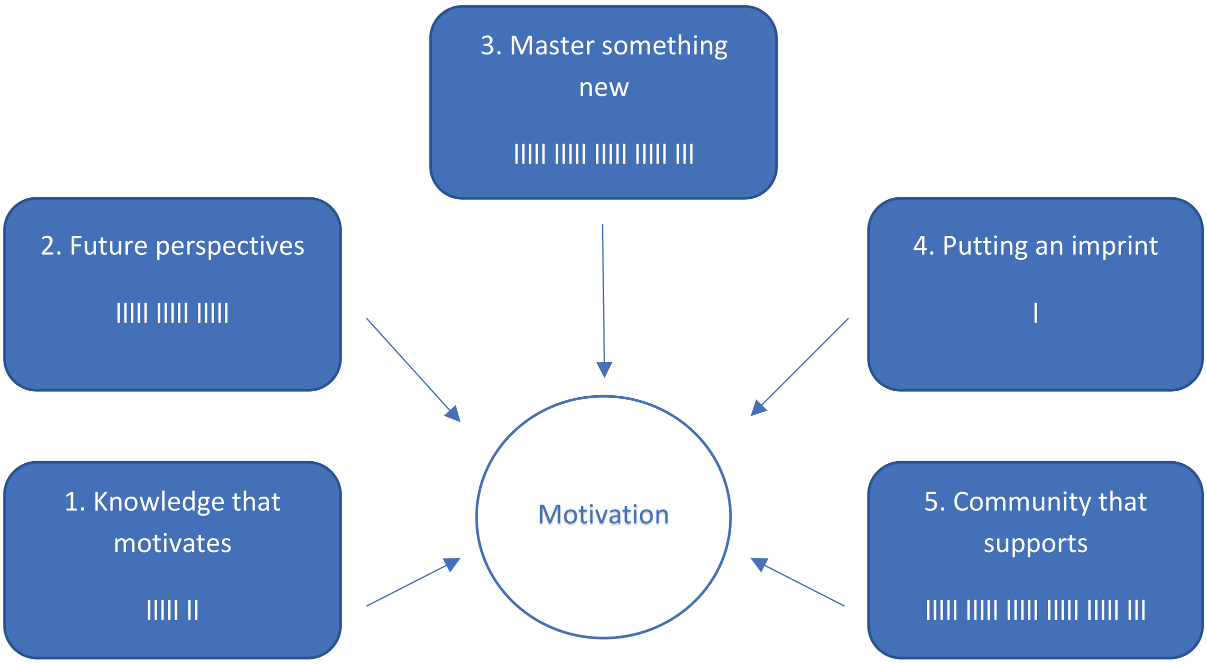

Figure 2. Graphical depiction of the motivational contexts of the 33 students. Each student adheres to one, two or three motivational types. Most students are motivated by two or three different types. Each 'I' constitutes a statement from a student.

As can be seen in the figure, the two motivational types that are most adhered to by the students are being motivated by community support – understood as either the group or the supervisor – and by being able to master or accomplish a specific task or challenge. Twenty-eight students mentioned community support and 23 mentioned mastering something new. Fifteen of the students mentioned being motivated by a clear future goal, seven mentioned acquiring new professional knowledge in itself and one student mentioned being motivated by putting an imprint on the world. Across the eight groups and two educational contexts, some differences could also be identified (see 3.3).

3.2 The five contexts as seen from a qualitative perspective

To give a more qualitative picture of the five different motivational contexts we have gathered some quotes that illustrate what the five contexts are about.

3.2.1 Examples of knowledge that motivates

Being motivated by the subject itself was mentioned by seven students. Typical comments:

"The ideas flew through the room"

"… [we had] a day where we found a really specific and exciting position within our main topic."

3.2.2 Examples of future perspectives that motivate

Six students mentioned being motivated by having clear long-term goals, linked to the goal of the project:

"… we got the project on track. We then agreed… on a problem statement ... "

"for the first time we had a common goal and mission, which was highly motivating"

Some of the other 15 students in this category underlined that not only clear long-term goals but also clear agendas and a clear direction of discussions as well as actually reaching a goal contributed to having a good study day:

"… Good discussions about potential ways one could go with the project ..."

"You come home and feel that we as a group have moved a good distance closer to the goal."

"... the days when we know what to do and have a purpose."

"... to reach a goal that we all agreed on."

3.2.3 Examples of mastering something new that motivates

What the students mention they master are different elements of the PBL process. Two students mentioned mastering a method for structuring the work process – the process of brainstorming and delimiting a problem formulation. Another two mentioned being able to work alone at home and accomplish what they set out to accomplish. One student mentioned being able to solve a difficult professional challenge in the lab. Eighteen out of the 23 students in this category talked about different aspects of being productive – finding a good balance between working hard and having fun, getting a lot done, securing a good working flow, being well prepared and efficient or accomplishing what was planned:

"There was a good balance between serious work and breaks"

"... a constant flow and a good productivity."

"I liked that we were so structured and got an effective job done."

Five students talked about succeeding in carrying out collaborative work:

"... we [have] had many days where we do not really know where we are going, then it can be really nice to suddenly feel that you are moving forward ... if you finally agree on something."

3.2.4 Examples of putting an imprint on the world that motivates

A single student made a remark that pointed in the direction of being motivated by putting an imprint on the world:

"I felt that I myself was totally turned on by the project, as we found a subtopic that was relatively groundbreaking in the field of the study, and generally just interesting."

3.2.5 Examples of community support that motivates

When the students talked about community support, they pointed to different aspects of social support. One thing that motivates is when the supervisor or the group as a whole is enthusiastic about what is going on in the group collaboration. Four students mentioned acknowledgement from the supervisor and three students referred to when everybody in the group was happy. A specific kind of happiness arose when everyone in the group contributed and “pulled in the same direction”. Eight students mentioned this particular trait of a motivating group collaboration. Nine students underlined that a well-structured group collaboration that supports each other’s activities and/or helps solve challenging professional issues is very motivating. One of these students said:

"On this one day, the feeling of perdition disappeared and all the frustrations were hidden away when we saw what each other was really capable of ..."

Social cosiness – having fun while working together – is also a high scorer, and was mentioned by seven students:

"… it is also those day, when it really has been fun to meet and work together – emphasising work."

Finally, five students underlined the creation of a generally nice atmosphere in the group as being very motivating.

"It was awesome, that we had created an environment where it was allowed to ask stupid questions and where we could help each other ... a feeling that we together improve each other."

3.3 Looking at the group context

Looking at the 33 students from a group context perspective it is noticeable that the group context has an influence on the ways in which each single student is motivated. Following the individual analysis it is not surprising that ‘mastering something new’ and ‘being supported by community’ also dominate the analysis on a group level. However, it is not random how these motivational contexts are mentioned within each group. There seems to be a pattern where group members either highlight ‘mastering something new’ or ‘being supported by community’ as the dominating motivational context, except for two groups that have a somewhat scattered outcome. Among the six groups that align internally, there is an even balance between groups focusing on ‘mastering something new’ and groups focusing on ‘being supported by community’. The groups thus reflect diverse values and underlying motivational context connections, which seem to have developed within each group as a dominating motivational context.

Looking at the groups from a subject perspective there seems to be a tendency for techno-anthropology groups to highlight ‘being supported by community’ as the primary motivational context, whereas biochemistry, environmental techniques and biology students have a tendency to highlight ‘mastering something new’.

4 WHAT CAN WE LEARN FROM THIS AS EDUCATORS?

Returning to the initial question – what do first-year engineering students, in a PBL environment, identify as a good study day and what can be said from a motivational theoretical perspective about this kind of day? – the analysis of the 33 students’ answers to this question show, through analysis according to Katznelson *et al*.’s motivational contexts, that students are most motivated by a ‘community that motivates’, which to a large extent can be related to collaboration processes and social relations within the group. But also, the ability to ‘master something new’ comes out with a very high score, which relates mostly to the students being productive and efficient. This is interesting as the students are first-year students and thus newbies in a PBL learning environment that implements a student-centred learning method. This method requires a high degree of self-determination, which it seems the students relate to, in the form of pursuing productiveness. Fewer students mention 'future perspectives' as a motivational context – e.g. obtaining a clear problem formulation or the experience of working towards a clear direction or even just a clear agenda. The feeling of structure and perhaps some degree of security seems important, as a PBL process might be experienced as an uncertain way of learning compared to a more traditional teacher-centred approach, which most students have been used to from high school. Less than a quarter of the students are motivated by the engineering subject knowledge itself. This may seem surprising, but for the first semester the PBL projects are new and the semester does have learning outcomes that contain PBL competences that the students must acquire. Only one student gave an answer that pointed in the direction of being motivated by putting an imprint on the world. Again, the context is first year students in a new learning environment, indicating that learning resources are focused on these matters.

The analysis of answers from students across the eight groups shows a balance between groups focusing on ‘mastering something new’ and groups focusing on ‘being supported by community’. This indicates the development of norms within the groups in regard to which motivational contexts are considered important. Looking at the groups from a subject perspective, there seems to be a tendency for techno-anthropology groups to highlight ‘being supported by community’ as the primary motivational context, whereas biochemistry, environmental techniques and biology students have a tendency to highlight ‘mastering something new’. Based on this, it may be possible to formulate a hypothesis that different academic subjects attract different students who are motivated by different external contexts or that the academic contexts themselves are biased towards one or other form of motivational context.

This study into motivational contexts indicates that first-year engineering students from a PBL environment, and based on their own descriptions of what they consider to be a good study day, are motivated by collaboration processes and social relations, and further the feeling of mastering something new, more than by future perspectives or the subject knowledge itself. This is of importance for us as supervisors and teachers in the first year to know and take into consideration when we aim to motivate our students.

5 ACKNOWLEDGEMENTS

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Implementing an e-learning mindset and e-learning skills among the teachers of a department

K.B. Bojesen
Technical University of Denmark
Lyngby, Denmark

P. Goltermann
Technical University of Denmark
Lyngby, Denmark

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Keywords: E-learning, implementation, learning management system, higher education

ABSTRACT

New technologies appear increasingly in engineering education and create a pressure on the didactic design to keep up in adapting. Some teachers take the lead and try out various e-learning tools, but the main question is **how do we lift an entire department from traditional didactics to a mindset and skills for e-learning didactics?** This paper will explore: What are the main barriers and drivers for e-learning teaching development – and how should we consider this in an implementation plan?

Many teachers in our department are well on their way in using e-learning elements and we have interviewed a representative range of teachers individually to identify the most relevant questions, before we in fall 2019 interview all faculty members (70 persons) individually and all external professors (33 persons) through a questionnaire. We will move all courses to a new and better Learning Management System in September 2019 and during this establish a common approach and implementation, using change management inspired by the ADKAR-model. ADKAR stands for Awareness, Desire, Knowledge, Ability and Reinforcement.

The benefits of improved learning technologies are obvious, just as there are many examples of stand-alone first movers in engineering education. There are, however, fewer studies dealing with the individual teachers' motivations for developing e-learning skills. We will in the future focus on how to motivate and support the majority of teachers in getting on board with e-learning teaching.

1 INTRODUCTION

The department and the university have both had a 100 % increase of students in the last 10 years and expect this growth to continue, just as the university is in the process of renovating and modernising the classic teaching areas and the study areas and at the same time expands the laboratory facilities significantly. The teaching and learning is therefore in a transition process and will be re-evaluated and most likely transformed in order to create an improved learning environment. An essential part of this transition is to change the mindset of the teachers and to incorporate the e-learning mindset and skills in the transition, which we will look into in this paper.

Learning technologies are increasingly making their way into higher education with great potential for enhancing learning [1]. However, it is also clear to us, that an e-learning mindset and skills to develop interactive and engaging e-learning has not quite reached the majority of teachers at our department of civil engineering just as it is the case at other departments and other universities [1]. In order to gain the many benefits from learning technologies, such as more interactive and engaging learning experiences, flexibility, scalability, internationalization and individual learning paths, we need a more widespread use. That is why this paper will focus on how to motivate and support the majority of teachers at a department in developing e-learning skills, getting an e-learning mindset and use e-learning in their teaching.

This is a work-in-progress towards defining a strategy and a plan of action for the department regarding e-learning. A main challenge in this project is the area of tension between setting goals for teaching activities and the Danish academic tradition of the teacher's freedom of method.

This means in our opinion, that we can argue a lot in favour of using e-learning and list all the benefits without a significant shift in the use of e-learning. As we see it, we need to address the teachers' barriers and drivers (motivation factors and needs) in order to get more teachers engaged in using e-learning and benefiting from the new opportunities.

Our stepping-stone in the drive of this shift is the launch of a new Learning Management System (LMS) that is chosen for its ability to support online and blended learning and offers a range of built-in learning technologies. The benefits from this shift requires, however, a change of habit for the teachers and their acceptance of letting go of their normal control of a course. Many teachers have already without coordination started using e-learning tools and activities in their courses, but the department still lacks a complete strategy and action plan for this development.

We are not presenting a tried and tested implementation strategy, but we will present and discuss the approach that we will use to establish the strategy.

2 DEFINITIONS AND SCOPE

The term “implementing e-learning” is widely used, but with various perspectives. It requires a definition and clarification as to what constitutes e-learning in the specific case. Furthermore, an implementation strategy for e-learning also has a wide scope from everything regarding technical issues and choice of system and tools to pedagogical principles, organizational readiness and change management. In order to clarify the scope of this paper we shall begin with defining our perspective on e-learning implementation at our department.

2.1 How do we define e-learning?

The term “e-learning” can be used for anything from the use of a simple digital learning tool to describing courses and educations that are entirely online.

Dimensions of e-learning can also be used for clarifying purposes as described by Wagner et al. [2] who list the following dimensions: Synchronicity (asynchronous or synchronous), location (same place or distributed), independence (individual or collaborative) and mode (electronically only or blended). These illustrate the nuances and variety of what constitutes e-learning.

Like the term e-learning, blended learning is also used as a very broad term. It comprises both face-to-face learning and some form of online learning in a “blend” that should seek to take the advantages from both forms to get the optimal blend [3]. However, in practice the term is often used for courses that make use of online learning activities as “add-on” to traditional learning, while maintaining traditional lectures.

At the furthest end of the scale, a vision for e-learning implementation in higher education can be where “virtualisation and remote working technologies will enable us to study at any university in the world, from home” [4] – meaning that entire educations and degrees will be made accessible online in the form of e-learning. This vision requires a university wide transformation.

At the other end of the scale (in the broadest sense of the term) one could argue that using a webpage for course information and an LMS for access to course material, timetables and for sending announcements is e-learning. We do not consider this simple use of an LMS for administration as e-learning.

In our definition the use of integrated learning technology such as quizzes, peer review and videos will constitute e-learning.

In our current vision for our department, we will focus on promoting and enhancing the use of effective blended learning, as this would maximise the range of pedagogical options.

2.2 Changing the pedagogical principles

Implementing e-learning involves a change in the pedagogical mindset.

"One of the most crucial prerequisites for successful implementation of e-Learning is the need for careful consideration of the underlying pedagogy, or how learning takes place online. In practice, however, this is often the most neglected aspect in any effort to implement e-Learning." [5]

In order to get the full advantage of e-learning through blended learning, the mindset and approach to teaching and learning would have to shift [6], where the teacher become a learning journey facilitator and let go of the traditional role as lecturer and thus let go of the control. This is a big change and requires both courage and a different set of skills than the classic teacher skills.

We expect this scenario to be the future for higher education learning, but it is not something that happens quickly or easily. Instead of setting the bar too high up front, a step-by-step approach seems prudent. For this reason, our first goal is getting all teachers accustomed to the basic use of our new LMS while inspiring them to experiment with the more advanced learning technologies that are accessible.

2.3 Implementing the change

There are many ways in which to address an e-learning strategy and implementation plan. The most important stakeholders are the teachers, the university and the students. From discussions with students, we know that they have a positive attitude towards increased use of learning technologies providing they are a real help in their learning, but we will not look further into the student perspective here, nor on the university situation. In this work-in-progress project, we will focus on the teachers as stakeholders, their motivations and barriers.

Our perspective on implementation will focus on the teachers' barriers and drivers for using e-learning. This will be the foundation of an implementation plan considering the principles of change management and exploring the various ways in which to support the teachers in getting the necessary knowledge, skills and experience in using e-learning.

3 METHODOLOGY

Based on a combination of literature review and our preliminary findings in the initial interviews with teachers at our department, we will identify the drivers and barriers for e-learning implementation, and propose a plan for developing e-learning skills and e-learning mindset among the teachers.

3.1 Reported experiences in other investigations

In a literature review on e-learning readiness factors in higher education [7] the authors conclude that skills and attitudes are the most significant factors in e-learning readiness. Another study [3] reported that the stated individual barriers in using e-learning are lack of time, lack of technological knowledge and skills, lack of incentives, lack of recognition for the work involved and organizational lack of policy, planning and support.

Lack of time and lack of knowledge, skills and experience are also mentioned as challenges in [8] & [2], where the last added that fear of student acceptance may be a barrier as well. Factors which are likely to increase motivation have been reported [4] as “the potential to reach new students and experiment with new technologies” whereas “inadequate technical support, time, and recognition of the work involved” is likely to decrease motivation.

The implementation process itself is well described by Blackburn [6], who points out the fact that “Change is often initiated by school administrators, not the teaching staff themselves.” This type of change often meets resistance because it entails a demand for acquiring new competences and spending time producing e-learning. Extra time that the teachers do not have. An imposed change in the fundamental ways of teaching is thus a barrier to be taken into account.

3.2 Initial interviews with teachers – preliminary findings

From our sample interviews with representative teachers – 6 teachers, one from each section at our department – we have gathered an overview of the drivers (*Table 1.*) and main barriers (*Table 2.*) that the teachers have for e-learning.

Table 1. Drivers

Intrinsic motivation - A desire to create the best possible learning design – better quality in learning - A desire to develop and a curiosity and interest in new tools and technology - A desire to be more efficient in course administration by using automated processes
Extrinsic motivation - Solving a problem (burning platform) that requires a new course of action - Reward and recognition - Dedicated resources such as time, money or support - Command (being required to do so)

Table 2. Barriers

Time - Finding the time – to learn how and execute (skills) - Lack of acknowledgement of time used - Time away from research
Change of habit - Hard to take the first step / getting started - Hard to do something different from what you are accustomed to do - Worry that it requires too much, need to rethink your entire course design
Fear - Fear of not being the expert from lack of experience - Fear of letting go of control - Fear of trying something new and out of comfort zone

Negative attitude towards e-learning
- Disagreement with the pedagogical principles of e-learning - An understanding of e-learning lacking the human interaction
Rules and practicalities
- Concern about living up to requirements (Current statement from our university is that the implementation of e-learning may not result in less face-to-face time between teacher and students). - Not all educational content is suited for e-learning

We will investigate further into the drivers and barriers drivers for e-learning implementation by individual interviews with all our teaching staff this fall. The results will help determine which of the factors are dominant at our department and help in targeting the most important areas in the implementation plan. The interviews will also provide relevant successful use-cases of different learning technologies and pedagogical methods that can serve as inspiration and knowledge sharing within the department.

4 IMPLEMENTATION AND CHANGE MANAGEMENT

Any implementation process is a change – and in order to succeed with the implementation, it is necessary to recognize the need for change management and the focus on helping individuals move from one standpoint to another. The ADKAR change management model is a way of understanding the steps in a change process [9]. ADKAR stands for Awareness, Desire, Knowledge, Ability and Reinforcement. An important point is respecting the fact that the steps are addressed in this order. Moving forward too fast without people accepting the current step will not lead to success.

In our case with the launch of a new LMS, we started creating *awareness* well in advance. We introduced the notion of a new LMS arriving soon at department meetings. The message came from our head of department to underscore the benefits and necessity of the change and the alignment with department and university strategy. From there on, we recruited “pilot” teachers from each section being the first to try out the new system for a semester while getting their ongoing feedback about issues that needed to be solved for a smooth transition to this new system. The next step of creating *desire* for the change is perhaps too ambitious. We focused on getting acceptance of change and overcome resistance to engage. At this stage, the pilots already played an important role as the teaching staff was presented with respected peers who had made the change to the new LMS and shared their honest opinion and experience of the required effort, benefits and necessary change of habits. At a department workshop for teachers, we combined *knowledge* and *ability* by presenting the basic guide to getting started with the new LMS and engaging the teachers in using the system right away and migrate their courses to the new platform.

Getting the teachers to practice their ability to use the new LMS will be our focus in the coming period combined with providing just-in-time knowledge, best practice examples and individual support. As more teachers become accustomed to the basic features, we will present them with the possibilities of the more advanced features. We also need to consider how to provide *reinforcement* to sustain the change and the continuous progress. How can we provide acknowledgment for teachers well on the way?

This implantation plan currently only focuses on implementing the new LMS. We wish to expand the scope to the broader sense of e-learning implementation.

Our plan is supported by Blackburn [6] in his best practice advice for successful implementation, which furthermore includes providing funding and support to teaching staff that are re-engineering their course designs, creating a Community of Practice (CoP), recognize and reward teaching staff who reuse open learning materials. Finally, to accept resistance as part of the process and be prepared to deal with it.

5 DISCUSSION

We believe that a successful implementation of e-learning will require an effort on many different levels and that we must allocate resources to support the process if we wish to increase the degree of success. Now that we have begun the process, our focus point will be on

- Offering just-in-time-support to teachers as well as reaching out and follow up on teachers getting started.
- Expanding on the help resources and guides for learning technologies and pedagogical principles for e-learning.
- Interviewing the teachers to get information regarding their experience with e-learning that can be used as showcases in knowledge sharing.
- Arranging short workshops that will dive further into specific advanced functions in the LMS and relevant e-learning tools.
- Cultivating communities of practice for e-learning at our department over time. This has begun with arranging network meetings for the “pilots” that were the first to use the new LMS.

We will during the process look further into approaches, which further support the drivers and reduce the barriers. The questions are, however, which initiatives beyond what we have already stated should be considered? What other possibilities might there be for giving incentives for using e-learning? Should we consider a type of reward as motivation?

”Extrinsic rewards can be used to motivate people to acquire new skills or knowledge. Once these early skills have been learned, people may then become more intrinsically motivated to pursue the activity.” [10]

It is a question of how such acknowledgement and rewards can be used best in an academic community.

6 FUTURE WORK

This paper represent our work-in-progress towards an e-learning strategy and plan of action. We have focused on the more practical side of an implementation plan for our new LMS, which in time should lead to more use of e-learning.

In a larger perspective, we are interested in the strategic framework for our department in regards to e-learning. The next step will be to define the criteria for success and how we determine progress. This raises the questions: What are the ways to do this – both in quantity and quality? Do we measure number of courses on the new platform? Number of courses using advanced features, such as group enrolment, peer review, videos, quizzes? Number of courses using Flipped Classroom? Number of entirely online courses? Furthermore, what is the best way to measure effect on learning outcome?

We can measure the effect of the new use of e-learning by comparing: Grades, number of students completing the courses, number of students dropping out, student satisfaction with the courses. Will that be sufficient?

Other relevant questions that we have encountered in this process are: What are the basics in pedagogical principles and didactics for e-learning? What does a teacher need to learn in order to be able to develop online or blended learning courses? Alternatively, from another perspective one could raise the question: Should all higher education teachers in time be able to produce e-learning – or would it be more effective to flip it – where the course design, structure and production is determined by an e-learning team and the teacher provides the contents?

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'Next, next, accept, run'

The difficulties of university software licences

Dorina Bór, Márton Galbács, Éva Etzler, Emma Lógó

BME, Hungary

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Keywords: usability, software, installation, student licences,

ABSTRACT

Giving free access (student licenses) to particular software packages is one of the greatest financial support one in their years of education can get from the university or software providers. However, it is worth taking a look at the circumstances of the installation process.

Students at Budapest University of Technology and Economics experienced some serious difficulties while installing MatLab, a multi-paradigm numerical computing environment, which is continuously used during the B.Sc. and M.Sc. studies.

This problem may cause some legal trouble because we all know the similarities between university students and electricity - they follow the path with the lower resistance. University governances should also definitely consider this when setting up their software license-system, as a sufficient number of students will choose illegal ways to get access to a software if it is easier than getting it through the university licence.

We examined mechatronics engineer freshmen (Department for Mechanical Engineering) of the university installing student-licensed MatLab on their own laptops performing (second level) TAP. An open source software, Inkscape was used during the experiment as a reference.

Our main aspects were: how time-consuming and how mentally stressful it is for students to acquire the software.

To get exact and numeric values of the latter, NASA Task Load Index papers were used after each software got installed.

1 INTRODUCTION

Usability testing evaluates ease of use [1], where real end users are testing hardware or software products whilst the process is being monitored by researchers. It does not perfectly mimic real-life use, but it is the closest one can get, and gives relevant results. This type of testing is best with five participants [2] as this way relatively few resources are needed whilst around 85% of the possible problems and stumbling blocks can be found. Usability testing is also not relatively new practise, earliest sources specifically about usability testing found during our research date back to 1993 [3].

In our research, we focused mainly on the installation progress of software. These days – when one has become so accustomed to software updates and new installs – it has almost become an automatic process one barely pays any attention to, unless facing difficulties, or when having to follow a specific, sometimes counter-intuitive process.

Such specific processes often make an appearance in the installation of software for student use. This article will be focusing on software packages intended for use by engineering B.Sc. and M.Sc. students, more specifically how these software packages can be claimed and installed.

Starting an engineering B.Sc. can be overwhelming considering all the new impressions, one of which is all the new software that is to be installed and put to use. The software can be divided into several sub-categories[4] such as freeware, single user licences which are linked to site registration, software distributed by the university, multi-user licences etc.

When starting university, students of the Budapest University of Technology and Economics (Budapesti Műszaki és Gazdaságtudományi Egyetem, BME) do not get onboarded in a sense that they get a full software package or complete instructions on how to obtain all required software for the respectable faculty, instead there is sporadic information given by the university along with some student-to-student guides. There are many possibilities for legal downloads for software like MS Windows and Office, Ansys, Wolfram Mathematica, Autodesk Inventor, Catia, Creo, SolidWorks, MatLab etc., which all have very different processes for acquiring the licences.

In this paper the aim is to bring forward the process of the MatLab installation, and to point out the many stumbling blocks that can pop up during the process. There is a site operated by the IT directorate of the university, which was specially created to describe and help with the process of the MatLab installation, however multiple ways are listed on how the software can be installed legally, none of which is clear-cut.

For this research we performed a usability test on the MatLab installation progress. Participants were asked to think aloud while performing the installation, while it was emphasized, that it is not their performance that is measured, but rather the reoccurring problems in the installation process.

2 METHODOLOGY

The aim of this study was to measure the following characteristics of the installation process of MatLab with student licence at the Budapest University of Technology and Economics:

- installation time;
- frequently occurring errors;
- and the strain the process puts on students.

The study took place at the Budapest University of Technology and Economics, building Q. Six participants were included, who studied mechatronics and were in the beginning of their second semester of B.Sc. the time the study was performed. We analysed the study's sixth participant's case later; the whole task was competed by five people. All but one of the participants were male, with relatively high experience in the field of informatics.

We informed the participants about the purpose and details of the study and assured about the safety of their personal data and that not their performance, but the installation process is being investigated. We also informed them about the scientific method, which was used: level 2 Thinking Aloud Protocol.[5]

The circumstances of the study were equal in all six cases: the same room and wired Internet connection was used. (MatLab can only be installed using the university network or VPN). Minimum two of us were present to obtain objective results.

To complete the installation process with this kind of licence, one must possess a registration to a university server. Since this registration process has an estimated lead-time of two to three hours, we asked the participants in an e-mail to complete this registration in advance. This preparation did not affect the testing of the installation procedure.

The participants used their own laptops for installation purposes, we compensated the variances in download and installation time, that arose from the performance-differences of the computers during the analyzation.

We used a questionnaire in order to collect information about the awareness about student licences provided by the University. We wanted to find out whether participants have known about the following free student software before the study application: Windows10, Office365, MatLab.

Since none of the participants were familiar with the TAP method before the study, we added a training exercise to the research. We asked the study subjects to think aloud while downloading and installing a free screen and voice recording software, ThunderSoft Screen Recorder[6], the recordings of which were the main source of information and data (time, recorded video of the screen and the voice of the participant) for the analyzation. We used another voice recording device (a mobile phone) as data authentication.

This training task was not recorded. The recorded and examined study contained the download and installation of two software packages: Inkscape [7], an open source drawing software (used as a sample to estimate the temper and attitude towards software installing of participants) and MatLab, the main subject of the study, a multi-paradigm numerical computing environment developed by MathWorks.

We sent an e-mail to the participants, which included the two webpages, from where the examined processes started. To each exercise belonged two worksheets: one for the subject, which included the detailed steps of the exercise and one for us on which the common mistakes (guideline was created pre-research based on our personal experiences), successfulness of the participants and notes were marked.

After each exercise we asked the subjects to fill in a Nasa Task Load Index paper [8] (translated to Hungarian by us), which measured the participants' subjective opinion on the exercise and on their own performance.

Finishing both tasks, we asked participants to grade the study itself and the our attitude. We also graded the subjects according to the following aspects: experience with computers, tiredness after the tasks, attitude to the tasks, attitude to (incidental) failures, efficiency of the TAP method-usage.

We fed the collected data into a spreadsheet software, which was used for analyzation as well. The analysation was led through the frequently occurring mistakes of participants (rated with checkboxes) and successfulness of the participants (rated on bars 1-5; 1 – could not absolve the task; 5 – perfectly completed without help).

The whole recorded time/participant was divided into: Inkscape time, MatLab time and NASA TLX time, which was not counted as valuable working time. Both the MatLab and Inkscape times can be divided into 'thinking' and 'loading' time. Since the 'loading' time depends on the computer, the study concentrated on comparing the pure 'thinking' times of the two software packages. We also examined the correlation between the experience with computers (the researchers' subjective opinion on participants) and time (participants spent on finding the way of installation).

The evaluation of NASA Task Load Index papers was essentially the visualization of rating scales.

3 RESULTS

The data collection resulted in 6 hours, 26 minutes and 55 seconds of screen videos and voice records. The notes made of analysing these data take up six A4 pages.

Since the participants used their own laptops for the study, it was important to eliminate the ascending differences. The solution for this problem is to compare the previously defined 'thinking' times instead of all the times needed for each software.

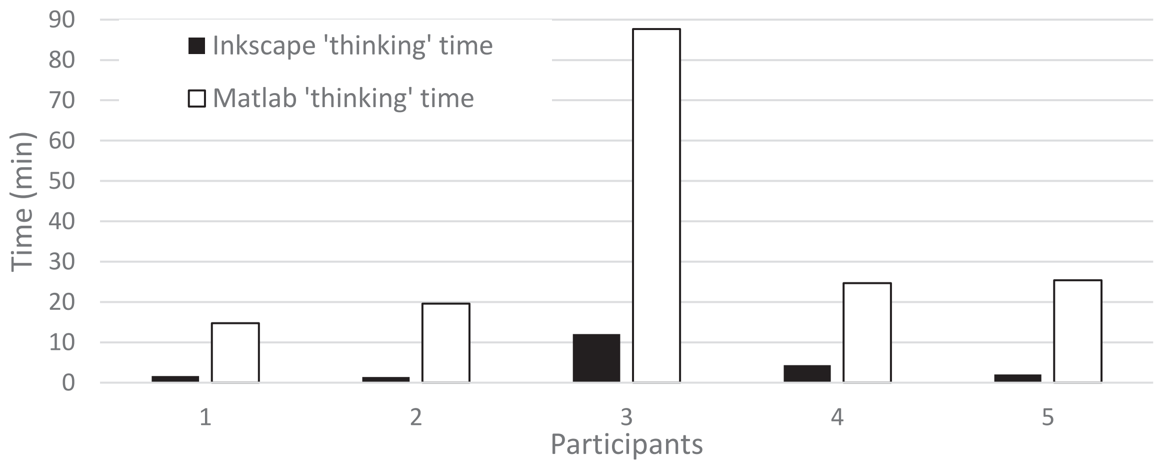

Fig. 1. Comparing Inkscape and MatLab 'thinking' times

An important part was to evaluate the results of the NASA Task Load Index paper, since one of the study's most important aims was to examine the strain the process puts on students. The results show, how participants felt about the installation process of each software.

It was also interesting, which of the pre-determined mistakes in the installation process, based on our personal experiences occurred most frequently.

Mistake	Frequency
Gets lost in the guilde on the website of the BME IT directorate	4
Can not log into the @hszk.bme.hu e-mail account	4
Gets distracted by the 'set location' pop up window on the website of Mathworks	3
Gets confused about the licence assignment	3
Gets confused about the warning sign showing the end of the licence period on the website of the BME IT directorate	2
Does not tick 'I agree' when signing in to the BME accadmin account	2
Does not find his e-mail address on the BME accadmin interface	2
Does not know his password to his @hszk.bme.hu e-mail account	2

Table 1. Pre-determined mistakes in the installation process

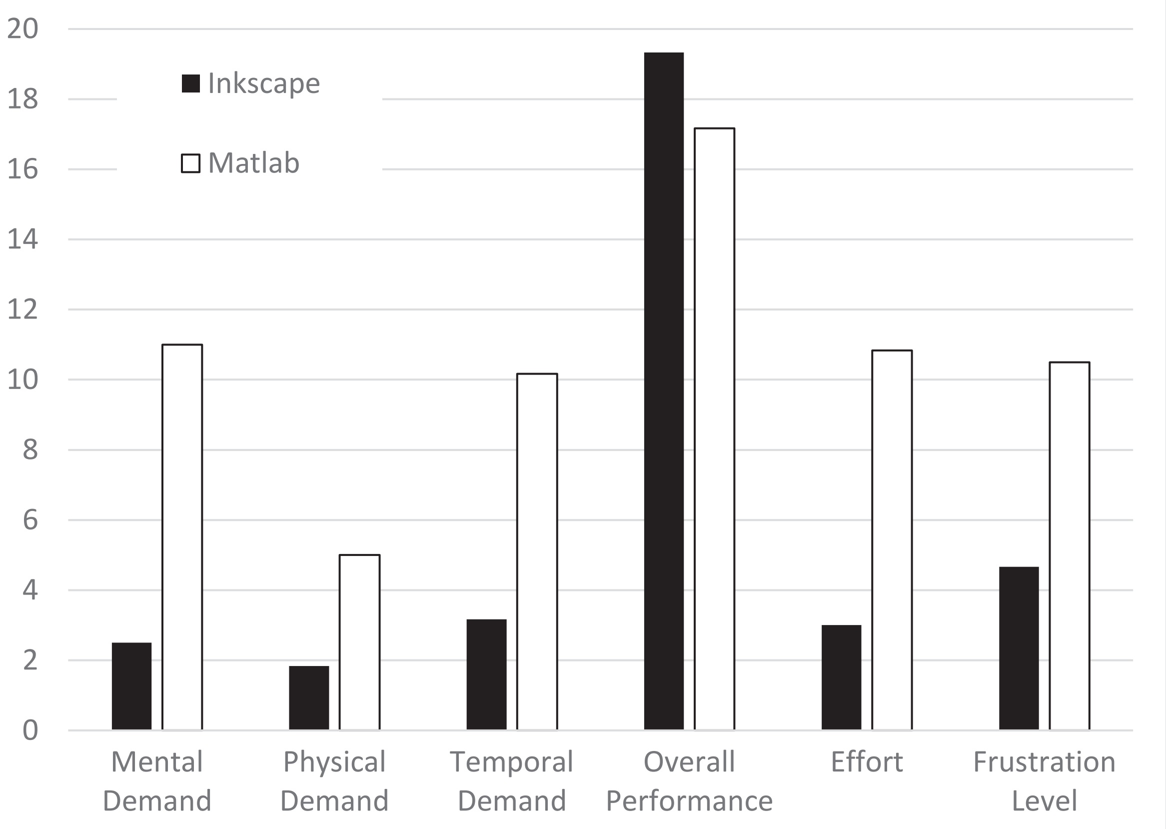

Fig. 2. NASA Taskload Index: average values of particpants' answers

No other mistake with the frequency of more than one occurred during the study.

The main steps of the installation process were rated on a bar.

0	1	2	3

where:

0 means the participant could not complete the process

1 means the participant could do the task, but with a lot of help

2 means the participant could do the task, but needed a little help

3 means the participant could do the task without any help

Task	Average score
Finds 'ways of installing MatLab for students'	2.6
Logs in to his accadmin account	2.2
Creates Mathworks user account	1.6
Verifies his Mathworks account	3.2
Downloads the installer from his Mathworks account	2.8
Logs in to his Mathworks account inside the installer	3

Table 2. Average scores of task bar gradings

In one case, rating the e-mail verification process (containing logging into the hszk e-mail account), we used a longer bar (with 5 options for rating).

This chart shows that no real correlation between the subjective value we assigned to each participant from the aspect of experience in the field of informatics and the 'thinking' time of each software.

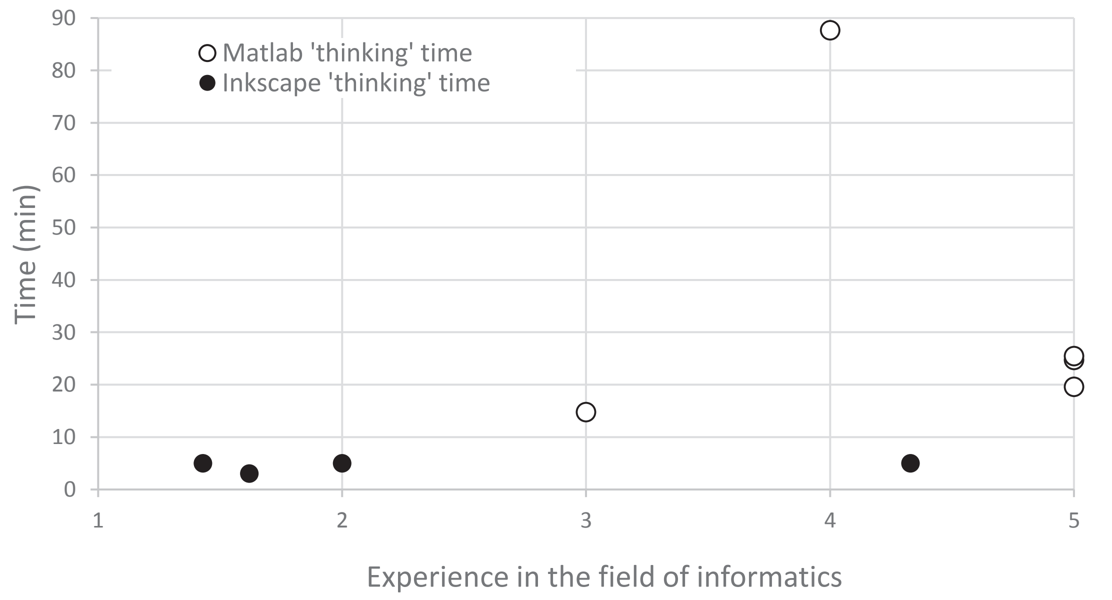

Fig. 3. Correlation between experience in IT and 'thinking' times

4 DISCUSSION

We concluded this study because we had found it extremely difficult to install this software on our computers and wanted to help the next generation of students by identifying the main problems of the installation process and making suggestions to improve it. The above discussed problems encountered by the participants which occurred during the installation process could be derived from some well outlined sources, mainly associated with the IT infrastructure of the university.

First, the students had to receive information about the existence of the university's MatLab student license. It would be considered trivial, whilst this information is manly spread verbally and by some posters around the building of the Institute of Mathematics.

After making the decision to install the software on their computer an overcomplicated guide about every possible way of the installation process is provided on the site of the BME IT directorate. The guide lacks the description of some non-trivial steps of the installation and lead the participants to a set of not quite ergonomic webpages. Furthermore, the guide is only available on the university's local network (or via VPN), which is quite inauspicious taking the usual 90-120 minutes length of the installation process into consideration.

During the installation process the students have to use several accounts and login credentials associated with different departments of the university. This caused serious drawbacks for the participants, who confused these accounts and could not find out what their passwords were since none of them used a password-manager. Some steps of the process, particularly requesting access to the mail server and changing the password associated with the webmail service require up to 2 hours (added to the usual 90-minute installation length), or even more on weekends. This is enough time to make the students rethink their decision about the installation or just simply forget about starting it at all.

Finally, after all these hurdles the otherwise ergonomic website of MathWorks made it quite difficult for the participants to find the download icon for the installer. We even had a sixth participant who completed the whole licence acquisition process and only applied for the research to get help finding this icon.

After downloading the installer the installation ran smoothly until the point where they could choose between two ways to associate the university student license with the installed software: by logging in to the software with their account or by typing in a licence key that is provided on the website of the BME IT directorate. The first method is totally sufficient and the presence of the second one in the installation guide only made the participants hesitate.

These difficulties could possibly lead university students to illegal solutions, causing financial disadvantage for the university, the software developer and their own legal endangerment.

Whilst organizing the results and clarifying the suggested installation process an exploit was found. The BME Matlab licence works by associating a licence based on the email address of the registered MathWorks account. Therefore, everyone in possession of an email address ending with ‘bme.hu’ is eligible for a BME Matlab licence. However, students have two of these email addresses the one from the Student Computer Centre (Hallgatói Számítógép Központ, HSZK, @hszk.bme.hu) and the one for the BME Microsoft Office Student licence (the @edu.bme.hu). Acquiring an additional Matlab licence for the same student but with the @edu.bme.hu email address was successful implying that every student of BME could have at least two.

For the future, we suggest the simplification of the credentials associated with the students by giving students one university email address (@edu.bme.hu), which could be used to manage every and any IT system connected to their studies. We also imply the creation of the matlab.bme.hu website with a simplified, univocal guide for students on the frontpage about the installation process that is accessible not just on the university network. We would like to cast light on the problem of multiple licences. For now, we suggest the use of the @edu.bme.hu email address for students to acquire the licence simply and without having to use outdated, not ergonomic, confusing websites.

This research could be used to provide methodology for other software installation usability tests. We fulfilled our main goals with the research by confirming that the current method of installation is not optimal, by determining the main obstacles and by finding a more straight-forward way for the installation. Our suggestions will be sent to the responsible personnel at the Institute of Mathematics, and hopes are that by cooperation, the installation process can be reviewed by the start of summer 2019.

5 CONCLUSION

As a summary, we performed the planned TAP interviews, recorded and analysed data. We found no correlation between the subjective experience of the participants in IT and the ‘thinking’ time of each software. The ‘thinking’ time for MatLab was on average 10 times longer than that of Inkscape and the participants subjectively found it to be more difficult. We found that the information about the licence and the installation process is mainly spread by student-to-student communication rather than via emails and websites from an official source. We discovered missing steps in the installation guide that could be considered the main reason for the long installation. The several accounts and credentials the participants had to use during the installation confused them. The problem of multiple licences for students was revealed during the end phase of the research. The not suggested second acquisition process took less steps, time and was similar to an ordinary student licence activation, like Autodesk’s.

For the future, we suggest the simplification of the credentials by managing every and any IT system connected to the university with one email address. We propose the creation of matlab.bme.hu to provide an optimal guide for the installation. For now, we imply the use of the @edu.bme.hu email address for the acquisition of the university’s MatLab licence.

The research could be continued by designing the matlab.bme.hu website and measuring the number of its visitors and the number of MatLab licence activations.

Despite all the problems this study discussed about the installation process of MatLab, the availability of this software is a great support from the university for students. With just a few changes introduced in the installation process, the rate of students using the university's MatLab license legally could see a substantial increase. We hope to see these changes in the future and that our study provides help for all the involved personnel.

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Utilizing student feedback for improving learning outcomes

Examples from a master course on ship vibrations

SB Bornhöft, Sara[1]
Hamburg University of Technology
Hamburg, Germany

FvB von Bock und Polach, R. U. Franz
Hamburg University of Technology
Hamburg, Germany

CTG Thon-Gairola, Caroline
Hamburg University of Technology
Hamburg, Germany

JH Hoth, Julian
Hamburg University of Technology
Hamburg, Germany

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ABSTRACT

Course evaluation has become standard in higher education organizations. However, when evaluation is not aligned to course design and development, its results are underused and its realization is rather routine than purpose driven. In order to improve student learning, a master course on ship vibrations at a German university was redesigned considering the conduction of online surveys at the beginning and end of the term. Starting point of the redesign of the here analyzed course was the observation that in preceding semesters students didn't perceive the course's practical relevance, showed poor motivation and didn't achieve satisfying levels of learning outcomes. Therefore, three new didactical elements were introduced: computer assisted assignments, lecture related home study assignments and guest lectures. Students were asked about motivation and prior knowledge in the beginning of the course and evaluated the new course elements, the course's professional relevance and their achievement of learning outcomes in the end. Linking the data via self-generated identification codes allowed us to assess intra-individual learning. The results show that there has been considerable improvement concerning the perceived professional relevance, but only moderate improvement regarding learning outcomes. This offers the opportunity for further development of the course. In the concept paper, we discuss different means of increasing professional relevance in naval architecture courses and describe the process of design, evaluation and redesign of this course, which can be seen as good practice for evidence-based teaching development.

[1] Corresponding Author
SB Bornhöft
sara.bornhoeft@tuhh.de

1 INTRODUCTION

Course evaluation has become standard in higher education organizations [1]. However, when evaluation is not aligned to course design and development, its results may be underused and its realization is rather routine than purpose driven. This may lead to discontent with the whole process of evaluating teaching and learning among both teachers and students. Its main purpose, to enable improvement of teaching and learning, may fall behind [2].

In order to improve student learning, a master course on ship vibrations at a German University of Technology has recently been redesigned. Starting point of the redesign were the results of previous course evaluations, where students reported a perceived lack of practical relevance of the course, and the observation that students showed poor motivation and didn't achieve satisfying levels of learning outcomes. Therefore, three new didactical elements were introduced: computer assisted assignments, lecture related home study assignments and guest lectures.

Following the idea of "system alignment" [2], the use of existing evaluation data and the collection of further feedback data from students was integrated into the process of the course's redesign. In addition to existing evaluation data from previous semesters, survey data were collected online at the beginning and end of the term. Students were asked about their motivation and prior knowledge in the beginning of the course. Furthermore, they evaluated the new course elements, the course's professional relevance and their achievement of learning outcomes in the end. Linking the survey data via self-generated identification codes allowed assessing intra-individual learning and change of attitudes towards the course [3]. These data were used to evaluate whether the introduction of the three new didactical elements had brought about the desired effects: an increase in professional relevance of the course perceived by students, an increase in students' motivation and a raise in levels of achieved learning outcomes.

In this concept paper, we describe the case of the course on ship vibrations and the point of departure for revising the course design. We discuss different means of increasing professional relevance, motivation and learning outcomes and explain our choice of new didactical elements. Moreover, we describe the process of design, evaluation and redesign of this course, integrating the collection and analysis of student feedback data. Aim of this article is to present one example of good practice for evidence-based teaching and learning development in engineering education.

2 REDESIGNING A MASTER'S COURSE ON SHIP VIBRATIONS

2.1 Context of the course

"Ship vibrations" is a mandatory weekly course in the first semester of the master program "Naval Architecture and Ocean Engineering" at a German university of technology. It comprises a lecture and a recitation section and is normally attended by 20 to 30 students. The course aims to build up students' knowledge on the principles of ship vibrations, on its fundamental causes and sources that lead to non-comfort or even structural damage, on its consequences and possible mitigation methods. Concerning professional skills, it is the course's learning objective to enable students to detect vibration-prone components on ships, to model the structure by appropriate system analysis, to select and apply suitable calculation methods and to assess the results. Referring to social competencies, students are expected to be able to communicate and cooperate in a professional environment in the shipbuilding and component supply industry after the course. All learning objectives have a clear emphasis on the professional relevance of the course.

2.2 Point of departure for redesigning the course

Originally, the course's syllabus was split into two parts that were conducted by two separate institutes. Due to insufficient coordination between the institutes and frequently changing teachers in the past, there was a lack of coherence of contents. Furthermore, previous course evaluations showed that students didn't perceive the course's contents as professionally relevant, and attributed the course with low levels of applicability for industrial processes. This clearly contradicted the course's learning objectives focused on professional relevance. Referring to Biggs' approach of constructive alignment, students did not perceive the course as meaningful for themselves [4]. This context probably explains the observation that students didn't show high motivation for the course and had unsatisfying examination results.

In the winter term of 2017 the course was handed over to one of the two institutes which offered the opportunity for redesigning the course by clearing up the courses syllabus and increasing coherence of contents. Moreover, there was an obvious need to align learning objectives, teaching methods and the final examination format. In cooperation with the university's center for teaching and learning, the teacher responsible for the course formulated three main goals for the redesign, referring to the initial situation described above:

(A) to increase the practical relevance of contents and methods taught in the course and students' perception of it,
(B) to increase students' motivation for the course, and
(C) to enhance learning outcomes.

Referring to Edström's "desired outcomes of engineering education" [5], these goals touch several layers of outcomes and follow the overall aim to align educational and professional practice. Improving learning outcomes here refers to knowledge and skills improvement, application-orientation and the production of "graduate engineers capable of purposeful professional practice" [5]. In order to reach these goals, several teaching methods were considered to be implemented.

2.3 Concept for the redesign

Literature suggests several factors that motivate students in higher education. Establishing relevance, among other factors like "establishing interest" and "teaching for understanding" [6], is seen as central, so there is a strong relationship between students' perceptions of relevance and motivation. Especially, linking theory and practice and applying theory is seen as motivating for students [6]. Thus, creating professional relevance and including exercises, that give students the opportunity to assess their understanding, can be seen as tools increasing motivation.

Due to the digital transformation of society and industry, there's a strong need for engineering education to include new technologies into the curriculum [7]. Students are demanded to develop digital competences during their studies in order to be prepared for their future jobs. Digitalizing assignments and practicing with software that is used in relevant industries therefore can be seen as one way of creating professional relevance.

Another possible method of linking professional practice and theory in higher education is the inclusion of guest lectures into the curriculum. Guest lectures of professionals from industry or academia, who visit a course are seen as effective tool for courses “with a clear industry relevance” [8], because they can “bring the real world into the classroom“ [9] and illustrate the professional relevance of course contents to students.

Based on these findings, we chose three didactical elements to be introduced to the course (see *Table 1*). In order to intertwine theoretical and methodological inputs with examples referring to professional real world problems, as a first step, in the first term after taking over responsibility for the course, alumni, practitioners and researchers from the field of naval architecture were invited to give guest lectures. The introduction of guest lectures should increase the practical relevance of the course, illustrate the applicability of contents taught in the course and thus raise the motivation of students. In addition to the guest lectures, optional lecture related home study assignments were offered to the students to give them the chance to self-assess their understanding prior to the final exam. These were intentionally kept of limited extend, in order to lower mental hurdles for the students to complete them.

In the second term after taking over responsibility for the course, obligatory computer assisted assignments were introduced to the recitation section. Both types of assignments should complement the calculation assignments that were conducted manually during the recitation sections, in order to deepen the students’ learning of contents and calculation methods and thereby better prepare them for the final exam. Moreover, by using software for calculations with finite elements, which is applied as a standard in marine industry, the introduction of computer assisted assignments was one means to increase the practical relevance of methods taught in the course.

Table 1. Redesigning the course: Introduction of new didactical elements

t_0 (two separate institutes are in charge of the course; student cohort 0)	t_1 (one institute takes over responsibility for the course; student cohort 1)	t_2 (one year after restructuring responsibilities for the course; student cohort 2)
course is based on traditional teaching methods (lecture section: theoretical input phases by teachers from two institutes; recitation section: students work on calculation assignments manually)	(1) introduction of guest lectures to the lecture section (2) introduction of lecture related home study assignments	(maintenance of guest lectures in the lecture section and home study assignments) (3) introduction of computer assisted assignments in the recitation section

3 EVALUATION OF THE REDESIGN – UTILIZING STUDENT FEEDBACK DATA

In order to find out, whether the implementation of new didactical elements led to the desired effects, the evaluation of innovations was planned parallel to redesigning the course. In detail, the evaluation should answer the following questions:

- Do the guest lectures, computer assisted assignments and home study assignments lead to an increased professional relevance of the course perceived by students?
- Does the introduction of guest lectures, computer assisted assignments and home study assignments raise students’ motivation for the course?
- Do the computer assisted assignments and home study assignments help students to deepen their understanding of the course contents and finally lead to improved learning outcomes?

3.1 Method of data collection

The standard course evaluation conducted at this university at the end of every term offered first insights to opportunities for improvement of the course, but could only partly give answers to the questions formulated above. So it was decided to collect extra data. Since the three questions refer to a change in perceptions, affective and cognitive dispositions of students, we firstly decided to collect student survey data and secondly to collect data at several points in time, in order to address the timely component of the questions.

We conducted online surveys with “Limesurvey” – an online tool for which our university owns licenses – at three points in time. Survey (1) was conducted 18 months after student cohort 0 and six months after cohort 1 had finished the course. The second and third surveys were conducted with cohort 2 at the very start and end of the term (see *Table 2*).

Table 2. Evaluating the new didactical elements: Conduction of surveys

t_0 (two separate institutes are in charge of the course; student cohort 0)	t_1 (one institute takes over responsibility for the course; student cohort 1)	t_2 (one year after restructuring responsibilities for the course; student cohort 2)
standard course evaluation data are collected at the end of the term	(maintenance of standard course evaluation) (1) online survey with students of cohort 0 (18 months after the end of the course) and students of cohort 1 (6 months after the end of the course)	(maintenance of standard course evaluation) (2) online survey with cohort 2 in the beginning of the term (3) online survey with cohort 2 at the end of the term

In the two surveys conducted with the second student cohort, students were asked to generate a personal identification code, which enabled us to compare the data from two points in time and assess intra-individual learning and change of attitudes towards the course, without identifying students as individual persons. We followed the recommendations given by Direnga et al. [3] for the design of the self-generated code, in order to enable matching a maximum of data. After having collected the data, they were analyzed with descriptive statistical methods.

3.2 Content of the online surveys

Focus of the survey conducted with the students of cohorts 0 and 1 was a self-assessment of the increase in knowledge on ship vibrations and programming skills attained during the course and an overall assessment of the professional relevance of the course. Since a successful stimulation of intrinsic interest is seen as a clear indicator for the establishment of relevance [6], we used sustainable interest in the topic of ship vibrations to grasp the motivational impact of the course. Students were asked whether it had inspired them to continue looking into the topic of ship vibrations in future. In addition, some open-ended questions gave the students the opportunity to give feedback on what aspects of the course helped them learn, what impeded their learning, and what suggestions for improved learning in the course they had. In addition to that, cohort 1 was asked to evaluate the guest lectures referring to their contribution to the professional relevance of the course and the home study assignments referring to their helpfulness for understanding the topics of the course.

The first survey with the students of cohort 2 was conducted during the very first session of the course. We collected data on the students' self-assessment of knowledge on ship vibrations and programming skills before the start of the course, on their perceptions of the overall professional relevance of the course in advance, their motivation and their expectations for the course. Focus of the second survey with this cohort of students, conducted in a session one week before the end of the course, was a self-assessment concerning the achievement of learning objectives, especially the attainment of knowledge on ship vibrations and programming skills, again an overall assessment of the professional relevance of the course and an evaluation of the guest lectures, the home study assignments and the computer assisted assignments referring to their impact on the professional relevance of the course and on understanding. Again, as an indicator for motivation, students were asked about their intentions to keep in touch with the topic of ship vibrations in future and for their open feedback on learning conditions within the course.

4 RESULTS

The response rate of cohorts 0 and 1 was quite low (n_0=8, n_1=3) which can be explained by the fact that it was conducted many months after the students had finished the course. Their interest to give feedback after such a long time is assumed to be rather low, while others might have left the university already. Due to the high selectivity of responders, the results of this survey have to be interpreted very carefully. Compared to that, the response rates of cohort 2 were satisfactory due to the conduction of the surveys during lecture time ($n_{2.start}$=19, $n_{2.end}$=18). Unfortunately, only nine cases could be matched on the base of the self-generated codes, so we could only measure intra-individual learning and change of attitudes for nine students.

In order to answer the questions formulated above, the results of all surveys are sorted by the three main goals of the redesign: the perceived professional relevance by students, their motivation and their understanding of course contents.

4.1 Professional relevance perceived by students

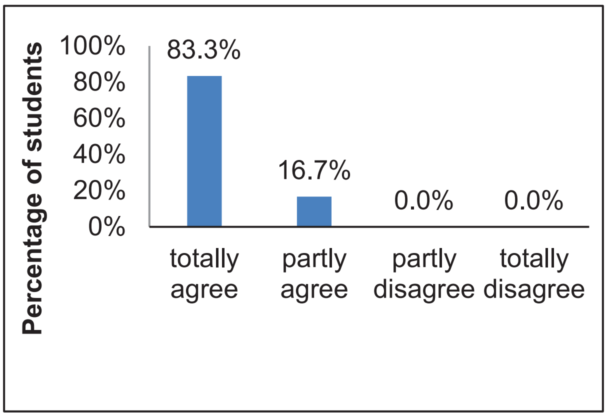
After having finished the course, students from all cohorts were asked to rate the relevance of the course for their professional career on an 11-point-scale from 0 (not relevant at all) to 10 (very relevant). In addition to that, the students of cohort 2 were asked the same question in advance ("In general, how relevant will the course be [*resp.: was the course*] for your professional career in your opinion?"). Students from cohort 0, who had neither experienced guest lectures nor computer assisted assignments or home study assignments, attested the lowest perceived relevance with a mean of 5.88. Students of cohort 1, who had experienced guest lectures and home study assignments, report an average relevance of 9.0, but this average is only based on the answers of two students. Students of cohort 2 reported an average perceived relevance of 6.6 at the start and 7.4 at the end of the term. Interestingly, matching the data from both surveys, shows that there has nearly been no intra-individual change of perceived relevance. For those students whose data could be matched, only an average individual change of -0.33 scale points is measurable. So they even stated a slightly lower perceived relevance after having finished the course.

The evaluation of guest lectures concerning their professional applicability and relevance shows quite satisfactory results for cohort 2, whereas only one person from cohort 1 answered the relevant questions. Nearly all students from cohort 2 agree totally or partly, that the guest lectures showed applications of the topics of the course in different fields and that they were useful to understand the relevance of the course for their professional career (see *Figure 1*).

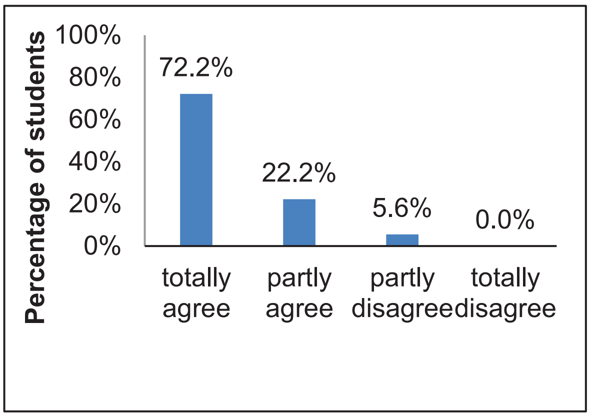
Figure 1. Evaluation of the guest lectures: Answers of cohort 2 (n=18)

"The guest lectures of alumni and scientists…

…showed applications of the topics of the course in different fields."



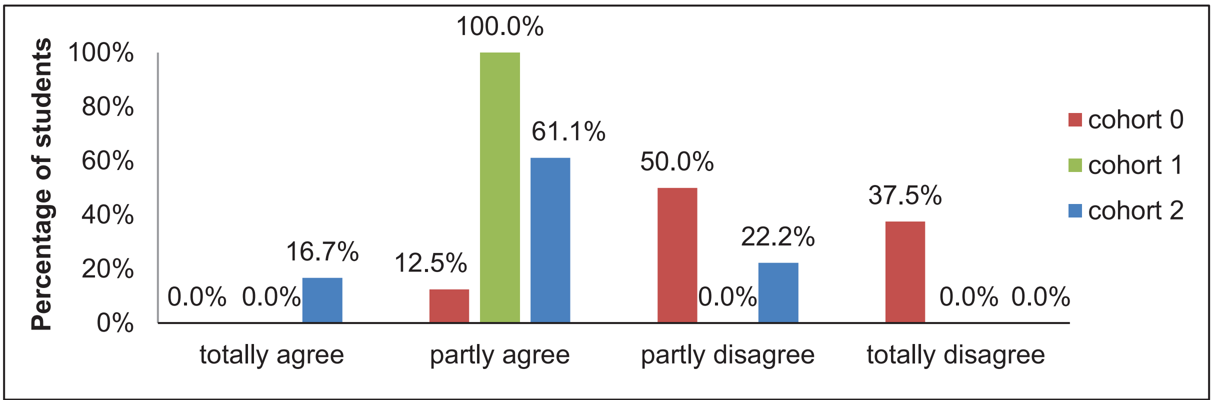
…were useful to understand the relevance of the course for my professional career."



4.2 Students' motivation

All students were asked, whether the course inspired them to continue looking into the topic in future (see *Figure 2*).

Figure 2. "The course inspired me to continue looking into the topic in future."
Answers of cohort 0 (n=8), cohort 1 (n=2) and cohort 2 (n=18)



The answers to this question can be interpreted as an indicator for how motivating the course was for students referring to how interesting the contents are still after having finished the course. The results show that whereas a majority (87.5 %) of students from cohort 0 partly or totally disagree that the course inspired them, all students from cohort 1 and a majority of students from cohort 2 (77.8 %) agreed partly or totally, that the course inspired them.

4.3 Students' understanding of contents

Several questions were asked in all surveys to find out how students self-assessed their personal knowledge and skills development during the course. Students from cohorts 0 and 1 were asked in retrospect whether their knowledge and skills increased during the course from their point of view (on a 4-point agreement scale). Students from cohort 2 were asked to self-assess their knowledge and skills levels on an 11-point scale in the beginning of the course and at the end. By that it was possible to calculate the difference between the two points in time.

Concerning the development of knowledge in mechanical vibrations, the first two cohorts already show positive results – in both cohorts all students agree totally or partly that their knowledge in mechanical vibrations increased during the course. This result can also be found, analyzing the data from cohort 2. Asked to estimate their level of knowledge in mechanical vibrations on a scale from 0 (no knowledge at all) to 10 (extensive knowledge on a high scientific level), students located themselves on average at 4.6 in the beginning of the course and at 6.5 in the end. Matching the data from both surveys shows an average rise in scale points of 2.2.

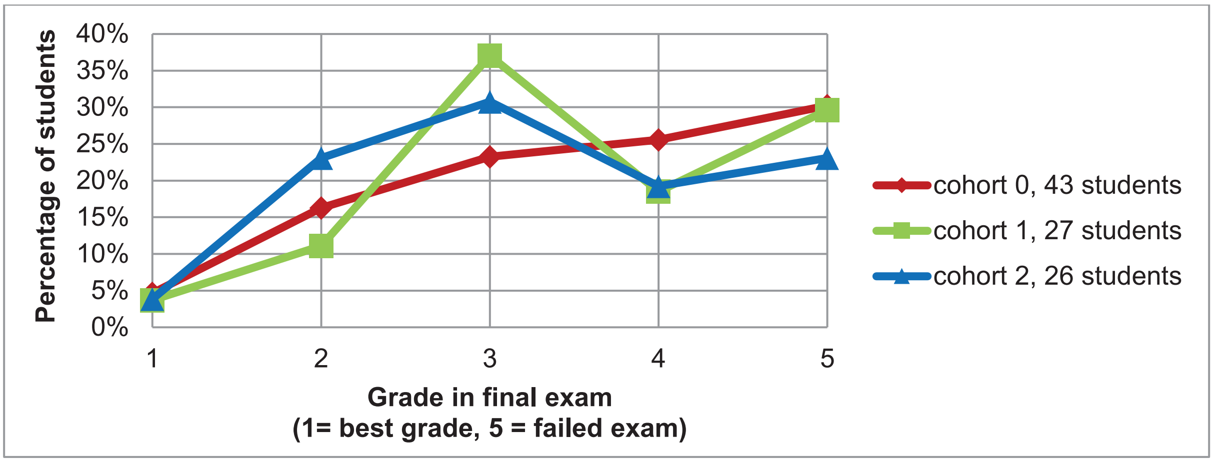
The results for the self-assessment of programming skills are quite different. Whereas more than half of the students from cohort 0 and 1 disagree partly or totally that their programming skills increased during the course, a slight rise in estimated programming skills can be seen for cohort 2. On a scale from 0 (no skills at all) to 10 (extensive skills on a professional level), they located their programming skills at 3.4 in the beginning and at 4.6 in the end of the course. The average intra-individual rise in scale points lies at 1.0.

Besides the overall self-assessment of knowledge and skills, we wanted to find out whether there was a positive impact of the new didactical elements on the students' understanding of course contents from their point of view. Being asked whether the guest lectures helped understand the course contents, at least half of the students in both cohorts 1 and 2 partly or totally agreed. A bigger majority of at least 92 % of the students of cohorts 1 and 2 agreed partly or totally that the home study assignments helped understand the topics of the course. However, being asked whether they improved their programming skills because of the home study assignments, at least half of the students in both cohorts disagreed partly or totally. The results are slightly more positive concerning the computer assisted assignments, which were only offered to cohort 2. 92 % of the students agreed partly or totally that the computer assisted assignments helped them understand the topics of the course and 69.3 % agreed partly or totally that they extended their skills-set because of the computer assisted assignments.

Further indication for the usefulness of the assignments was given within the open comments where students gave their feedback on the overall learning conditions of the course. Both in cohort 1 and 2, students emphasized the helpfulness of the exercises for their learning and advised to include even more computer assisted and home study assignments in the course.

The positive feedback is also partly reflected in the grades of the final exam. The exam results of all three cohorts are displayed in *Figure 3*. With an increase of didactical methods (from cohort 0 to 2) the percentage of better grades increased as well. Especially in cohort 2, a higher percentage of students passed the exam. However, it remains to be investigated in the coming courses whether the indicated improvement is due to the positive effect of teaching methods or due to natural variation.

Figure 3: Distribution of grades of the three evaluated cohorts in the final exam

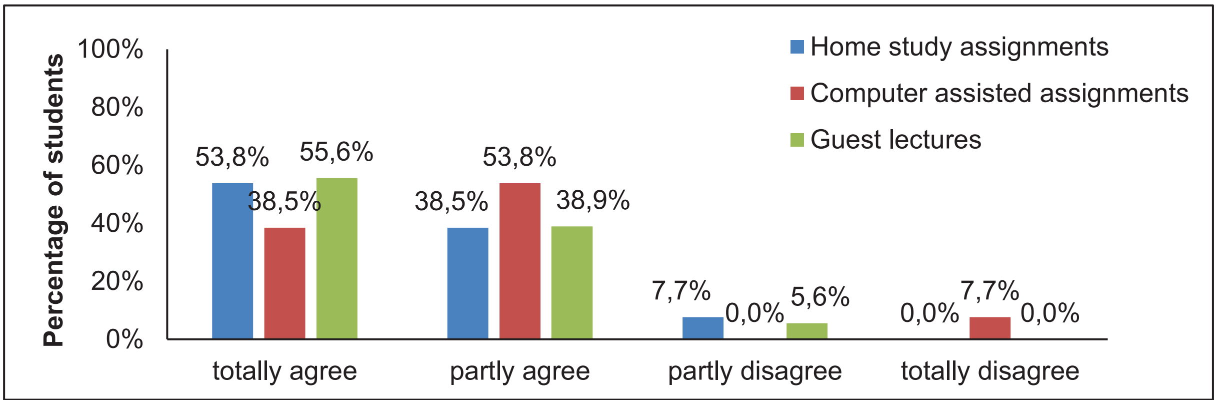


5 DISCUSSION AND OUTLOOK

The results of the surveys give a mostly positive picture concerning the evaluation of the new didactical elements. On average, those students who experienced guest lectures, home study and computer assisted assignments perceive the course as more professionally relevant than those who did not. A majority of students from cohort 2 agree that the guest lectures have beneficial effects on the professional applicability and relevance of the course. More students stated that they were inspired to keep up with the topic of ship vibrations, when they experienced guest lectures, home study assignments and computer assisted assignments, compared to students who did not. Referring to students' understanding of course contents – both knowledge of mechanical vibrations and programming skills rise during the course, speaking for cohort 2 – it cannot be said without doubt that the new didactical elements played a central role here. Moreover, both relevant knowledge and skills remain on a fairly low level, so the course design can still be improved.

However, one lesson we learned concerning the new didactical elements is that the guest lectures play an especially important role. Basic data analysis (see *Figure 4*) and experience from the course leads us to the assumption that the guest lectures' impact might be rather high.

Figure 4. "(…) helped me understand the topics of the course."
Answers of cohort cohort 2 (n=18 for guest lectures; n=13 for assignments)



Compared to the other two course elements, the highest percentage of students (94.5 %) agrees totally or partly that the guest lectures helped them understand the topics of the course. We consider the guest lectures to be highly effective because they facilitate students' access to the course topic, especially because they were held by guests from industry and former students of the course, they enable students to better understand course contents, raise their motivation and activate them.

Generally speaking, a positive impact of the new didactical elements on all three goals – perceived professional relevance, motivation and, with limited validity, deeper understanding – can be assumed on the base of the data analyzed. However, we find that the study methodology still needs to be adjusted to better serve our study objectives. The longitudinal survey design we applied for cohort 2 is a first step towards more clarity about the impact of the didactical innovations on learning outcomes. But still, even in this case, we cannot eliminate the impact of unobserved factors that might have had an influence on all three goals, like learning in other courses or more personal factors of the students [10]. Moreover, out of 19 respondents from the first survey only nine could be matched with the data from the second survey, so we only had evidence on intra-individual learning for very few persons. Thus, since we are planning to continue analyzing learning outcomes in this course, firstly, we will have to think about further possible factors of influence, and secondly about an evaluation of the adequacy of the self-generated code format.

To find out more about students' understanding and learning outcomes, as a next step, the examination format will also have to be evaluated concerning its alignment with learning objectives and teaching methods.

Learning outcomes, assessed by students themselves, have improved in this course, but results also show that the didactical design of the course and its evaluation need further development. Still, the students' feedback we received via a number of surveys gave us detailed information that will help us to create "a meaningful and motivational context" [5] for students, and the methods we applied to design, evaluate and redesign the course can be seen as one example for evidence-based teaching development.

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Diversifying Epistemological Narratives in Design Discourse

Proposed Storying Methods on Place, People, and Affordances in Bali

Alastair Brook
Doctoral Researcher
Cork Centre for Architectural Education, University College Cork
Cork City, Republic of Ireland
E-mail: 118225218@umail.ucc.ie

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ABSTRACT

This paper frames the theory behind a longitudinal study and live action research approach, intending to be conducted with academic students and craftspeople in Bali, Indonesia. This study will take place through a de-centralised and de-institutionalised platform, co-created by myself and members of the West Balinese community, who aim to iteratively construct a Learning Centre with students and craftspeople.

This collaborative construction project will establish a socially interdependent knowledge system between students, craftspeople, and wider community- within which, stories of culture, society and place are created through designerly discourse and the ‘act of doing’ [1][2][3]. The physical architectural construction will become a signifier of these stories- detailing method, theory and onto-epistemological meaning, translated into legitimate sources of knowledge and data production [1][4].

It is hoped that the Learning Centre construction will signify a ‘true’ and ‘real’ narrative of Balinese culture, society and place. By including more voices and ‘ways of knowing’ in the construction and knowledge production process, we hope that students and craftspeople will benefit from a diversification of onto-epistemological meanings, practices, and ways of thinking within both academia, craft, and the wider community[5].

This aim is formed in response to the Eurocentric capitalist modernity that has been assimilated into Balinese institutions, and the touristic commodification of Balinese craft [7][15].

By exemplifying the relational qualities of Affordance-Based Design (ABD), Decolonising Design (DD), and ‘Respectful Design’ ideology, this paper aims to outline how affordances within an architectural structure can signify stories of culture, society and place, co-produced as new knowledge.

1 INTRODUCING THE METHOD

1.1 Engagement with Being, Knowing, and Doing

This paper works towards an onto-ethico-epistemological research method for application in rural West Bali, between international and local students of design, architecture, or engineering, and situated Balinese craftspeople. A de-centralised and de-institutionalised platform has been co-created between myself, fellow research peers and these local communities in Bali. This platform has active partnerships with Balinese universities and educational organisations. This platform also has active involvement with community organisations within West Bali. It is the intent of this platform to engage students from these universities with craftspeople from West Balinese communities in designerly discourse and 1:1 scale construction of a Learning Centre, through which activity the onto-ethico-epistemological research will take place.

Being
Ontologically, this method recognises that we practice the design of ourselves- we design our world, while our world acts back on us and designs us back [6][7][8]. More specifically, this study explores a non-formalised process that models an ontological design loop- in which the student and Balinese craft communities participate in the design of themselves [6][7]. This would be captured through the co-production of stories related to culture, society and place, which are signified through the physical construction of a Learning Centre.

The student community in Bali could consist of students who; may be of Balinese origin studying within Balinese universities; or may be international students participating in Semester Abroad or Summer School programmes conducted by a third party. The Balinese craft community could consist of craftspeople who; may have completed formal education or higher education; may have learnt a skill or trade through vocation; may not be of Balinese origin; may be of all ages; may be multi-generational or 1st generation craftspeople; and may work with traditional, contemporary, or mixed methods. Ethically, this method sets out to perceive moral-ethical tensions within the current designerly discourse in Bali between these two groups, and establish intentionality to develop iterative interventions through open participation [8][10][11].

Knowing
Epistemologically, this method hopes to share designerly 'ways of knowing' and 'doing' between academic students and Balinese craftspeople, through an iterative process of designerly discourse and 1:1 scale construction. This physical architectural artefact, and its affordances, will signify stories of both Balinese and non-Balinese culture, society, and place, and co-produce new knowledge related to the social, structural and material properties of place. An affordance is the provision of something from one system to another [12][13]. In this study, it is hoped that adaption of architectural affordances will signify new knowledge production through cultural, social and place-based reciprocity between students and craftspeople.

Doing
Practically, assessing adaption of affordances within the physical architecture could be achieved through observing:

- If/how a newly shared methods and materiality are used within construction, and what narratives they convey about a peoples' culture, society and place.
- If/how the construction affords more sustainable futures, and less moral-ethical tensions, based on the sharing of cultural, social, and place-based narratives.

This brings into focus the relational reciprocity between students and craftspeople in the co-production of knowledge. Within this process, students and craftspeople are encouraged to understand and question their motivations and goals related to cultural upbringing, societal norms, and place-based biases- which may impact their 'ways of knowing' and their interpretations of the world. Research methods similar to photo-voice, cultural probes, user-created personas, and focus groups will be used to collect stories which, in their own right, are legitimate sources of knowledge and data.

These stories become embedded within the methods, skills, and techniques of architectural construction, and relate to the cultural, social, or place-based provisions of the physical form. Observing change in these provisions may suggest change in the diversity of onto-epistemological meanings, practices, and ways of thinking within the student and craft communities. The hypothesis rooted within this study is that a change in diversity will lead away from the Eurocentric capitalist modernity assimilated into Balinese institutions, and the touristic commodification of Balinese craft.

1.2 The Marriage of Two Worlds

In addressing the above topics, I must also locate myself with an understanding of my own motivations and goals. I am a white, anglo, male- with my own 'ways of knowing' associated with my cultural, social and place. As such, I approach my study in Bali with limited understanding of the indigenous communities in the region. I hold an undergraduate and postgraduate degree in Industrial Design, have industry experience within graphical marketing and branding, and study doctoral research within the field of Architecture. Therefore, my projection of certain academic ideologies onto rural West Bali must be recognised as bias and assumptive, and my motivations as a data collecting researcher must also be recognised. In doing this, I hope to open respectful and reciprocal dialogue with the local West Balinese communities.

Bali is small Hindu-Buddhist society that has been continually forced to seek its own identity within changing frames of reference [14]. The current era of capitalist modernity and globalisation has been catalysed by unsustainable tourism in Bali. This is changing indigenous values, traditional cultural meanings, and ways of thinking, that have been derived over centuries alongside indigenous design [7][15]. As the Balinese begin to adopt western terms of economic productivity, supply and demand, and commodification of culture, so too do they adopt Eurocentric capitalist design within the island's popular culture and academic institutions [7][15][16]. Such a drastic transformation is causing population resettlement in both urban and rural areas- creating threats of economic and physical insecurity, and eroding cultural traditions [15][17].

However, there is a growing movement in Bali working against these symptoms, highlighting the harmful effects of tourism in the region, and sharing the entrepreneurial voices of rural, indigenous Bali through 'sustainable tourism'. Sustainable tourism gives back to rural areas through economic opportunities, support of cultural craft, and community projects. My collaboration with this movement in Bali aims to both; revitalise and transform rural communities in Bali through youth and community empowerment initiatives; and, help diversify architectural education and profession through shared experiential activities, culminating in the 1:1 scale construction of a Learning Centre. The construction of the Learning Centre will connect students and academic institutions, both in Bali and worldwide, with local craftspeople.

The Learning Centre itself will provide educational classes to Balinese youth, and economic opportunities for Balinese entrepreneurs through ‘sustainable tourism’ initiatives.

1.3 Tying the Relational Knot

By examining the relational reciprocity between students, craftspeople, and the architectural artefact, it is possible to outline how affordances can signify stories of culture, society and place, and describe how affordances can be used to map any change in the onto-epistemological meanings, practices and ways of thinking. This can be expressed by exemplifying the relational qualities of Affordance-Based Design (ABD), Decolonising Design (DD), and ‘Respectful Design’ ideology.

Affordance-Based Design
ABD documents the relational system between Designer, Artefact, User, and other external stakeholders, within the design process [12][18].Rather than focusing upon function (input > transformation > output), ABD focuses on performance by documenting what affordances are provided between Artefact-Artefact and Artefact-User, and what properties are selected between User-Designer and Designer-Artefact [12][13].

Decolonising Design
DD is a process that questions who speaks within design discourse; challenging privileged, Euro-dominated academic institutions, and asking who produces knowledge and who benefits from that knowledge production [16][19]. DD focuses on the sustainable long term relations between artefacts and what they create in the world, rather than creating short term problem solving artefacts [5][20].

‘Respectful Design’
‘Respectful Design’ is derived from Aboriginal Australian world views, and positions design in relation to systems of the natural world and the social world [21][22]. This is because design relates to everyone, in any geography, through our genetic ancestry and connection to ‘place’ [22][23]. ‘Respectful Design’ not only listens to human peers, but knowledge that is shared back by our environments- whether it be forests, seas, or corporate boardrooms [24]. This is not just an indigenous spiritual belief, but science [23][25].

These various ideologies can help us address the relational qualities between the different stakeholders in the design discourse and construction process in Bali, and ponder more generally on the questions, “who designs, and why?”.

2 DESIGNER, ARTEFACT, ~~AND USER~~

2.1 Who Designs?

In short, we all design *communally.* Our actions are bound, more or less, in our sense of place and our ancestry, and how they influence the ways we ‘know’ and ‘do’. Our sense of place comes not only from our geography, but from the knowledge that our environment shares back with us. These environments can be anything from; the home, the tundra, the school, the mountains, the church, the woodland, the laboratory, the workplace, the campfire etc [24]. Design can be practised by listening and responding to these environments, and the knowledge that they share [26]. Different ways we can receive knowledge from these environments include:

- ‘Authority’, such as education, upbringing, or media, that are trusted based on their source. This type of information can be bias, superficial and/ or privileged [16][19].
- ‘Experience’, such as personal action, inferring applied information that is discovered through time repeated experiences.
- ‘Tradition’, such as ancestral action, that is adopted based on previous application. Traditions have both excused our own violence through a sociological mechanism of myths, rituals, taboo and prohibitions [27], and formed age-old, common, and beneficial practices which respect valid, rigourous, academically sound, and useful indigenous knowledge [24][28].
- ‘Revelation’, such as a knowledge from a spiritual entity, that is believed out of faith. This can illustrate just how different the worlds are that we live in, depending on which revelation we accept or reject outright [29].
- ‘Logic’, such as causal effect, inferring philosophical plausibility (If A, then B). Correlation, however, does not always mean causation (B does not always mean A).
- ‘Science’, such as a controlled experiment, that has not been disproved. This experiences things in a methodical, conscious ways that allows us to make reasonable contrasts to other kinds of phenomena [29].

These different ‘ways of knowing’ have developed as a co-evolution between our genetic influences and cultural environment [25][30]. This is categorised as gene-culture interaction, or ‘gene-culture coevolution’ [31][32]. Our genes have a causal effect, through the neurological structure of our brains, on two major influences outside of our body:

1. They ‘select’ external properties in the environments outside of our body, that they interpret as beneficial to longevity and wellbeing [25][33]. In this respect, designing is fundamental to being human, as to design is to; interpret and interact with the social, structural and material properties of our environment, which prefigures our actions [6].
2. From birth, we neurologically mirror the needs, desires, and actions of others. This means that our own ‘self’- our meanings, feelings, and thoughts- are formed in relation to others. This occurs by interpreting and imitating their intentions- their interactions, responses and behaviours- as a determining factor in our own actions [27][34][35]. This can be defined as a communal reciprocity or collective unconsciousness, such as academic, societal, cultural or religious beliefs

Therefore, many individuals can communally act together in the design of themselves through a connection to place, environment, and the other [9]. In this process, ‘user’ becomes synonymous with ‘designer’, as we are both the designers and users of an environment formed through a collective unconsciousness with others. Through relational research and design methods, the focus can become that of a *conscious* interdependence between individual, collective, and environment [7][36].The reciprocity between the individual students and craftspeople in Bali, and their collective community, attribute meaning to the architectural artefact they create- as they are all both physically invested in its creation, and psychologically invested in its use. [37][38]

2.2 And Why?

Why, and how, we design is dictated by our collective ‘ways of knowing’. The wider Balinese community can be seen to practice the design of themselves in an ongoing self-creation [6][7][8] that stems from their collective 'ways of knowing'; authority (indigenous schooling and community upbringing), tradition (caste system, non-capitalist and cooperative ideals), revelation (Buddhist spirituality and Hindu beliefs) and logic (causal effects of unsustainable westernised modernity in the region). The craftspeople of West Bali may, or may not, be consciously aware of their interdependence with the larger unconscious collective of the Balinese community. Yet, their motivations for 'why' and 'how' they design is influenced by a collective intent bound up in culture, society and place.

The same is true for the collaborating international and local Balinese students, whose design motivations are influenced by collective intent bound up in their respective culture, society and place.

Similarly, the same is true for the motivations behind my own involvement, and that of the community led organisations I am engaged with. My own motivations as a researcher and a designer, taken in isolation, affect my interpretations of the broader collective work being carried out by the communities of West Bali. In reflection of the wider motivations to *revitalise* communities through *youth empowerment,* and *help* students and professionals through a *change* in *cultural and social* settings, I must address the possibility of this project being labelled as 'Design for Social Good'.

'Design for Social Good' has been critiqued as a method for privileged middle class individuals who wish to help others through 'quick fix' solutions [19][20], implementing 'Selfish Altruism' or a 'Potlatch' style of altruistic donation. This states that, whilst we give to others, we also exact power, esteem, and social status in return in an act of superiority and dominance; "I can afford to make a donation to you" [25][39]. However, this research project focuses upon the motivations behind the student and Balinese craft communities' design of itself, aiming to give research and design power to the Balinese people, and to initiate a respectful and reciprocal sharing of knowledge.

Research methods similar to photo-voice, cultural probes, user-created personas, and focus groups will be used to share stories between the students and craftspeople in an attempt to understand their motivations. These methods will use a variety of playful triggers- tangible or non-tangible objects and mediums [40] - to express the interpretations, meanings, and motivations behind the social, structural and material properties of the architectural form. Both the architectural form, and these tangible/intangible objects, are signifiers of stories which interpret onto-epistemological meanings, practices, and ways of thinking within the student and craft communities. It is hypothesised that:

1. Interactions between students and craftspeople will diversify their 'ways of knowing' through relational reciprocity of cultural, societal and place-based stories.
2. This will elicit new interpretations and behaviours through exposure to new environments, authorities, traditions, revelations, logics etc.
3. New interpretations will cause a change in the collective cultural, societal and place-based stories between students and craftspeople.
4. Changes in these stories will be mapped through the affordances offered by both the final architectural form, and the tangible/intangible objects used within data collection.
5. It is hoped that any change in affordances will offer provision away from Eurocentric capitalist modernity, towards more sustainable futures for Balinese architectural education and craft.

3 "PRACTICE MAKES PERFECT"

3.1 Knowing by Doing

As Fry [2] interprets Heidegger [3], "what is known is lodged in the practical performative act, as it is expressed by the hand as exercised skill" (p.93), and knowledge is produced between the subjects and the architectural artefact through the act of doing [6]. It is the affordances of an architectural artefact that determine the act of doing [12], and therefore knowledge is signified between the subject and the architectural artefact through affordance. These affordances are dependant on the different ways that we 'know' and 'do', interpreted and imitated through the interactions, responses and behaviours elicited between us and our world. This creates a cyclical and iterative process of communal knowledge production through 'doing'- where artefacts prototype our local world, and our local world prototypes artefact back [5][6][7][41].

I hope to mirror this iterative prototyping process through a live action research cycle of planning, acting, observing, and reflecting. Students and craftspeople take action through designerly dialogue and iterative 1:1 scale construction. They may then observe and reflect on stories of culture, society, and place signified within this relational and reciprocal process. Through the use of research methods similar to photo-voice, cultural probes, user-created personas, and focus groups, it is hoped that students and craftspeople will be able to express their stories as legitimate sources of data and knowledge, shared through the communal act of doing.

4 CONCLUSION

Ontologically, this method acknowledges the cyclical and iterative process of communal self-design; that we practice design through our relation to place and to each other and, in turn, we are designed by our designing and by that which we have designed.

Ethically, this method recognises the moral-ethical tensions that currently exist within Balinese education and craft, and questions the motivations of external design discourse in West Bali. Through open participation in design discourse and 1:1 scale construction, it is hoped that shared 'ways of knowing' will engage students and craftspeople in an iterative cycle of thought and practice. This will hopefully establish intentionally to develop interventions that tackle these moral-ethical tensions.

Epistemologically, this method looks at the relation between knowledge, culture, society and place, as expressed through stories signified within the social, structural and material properties of architectural form. The relations between these subjects offers new opportunities for diverse knowledge production, from which we draw on different interpretations of our world and what it affords us.

This provides a platform for the suggested onto-ethico-epistemological method that, practically, hopes to induce a change in diversity that will lead away from the Eurocentric capitalist modernity, towards more sustainable futures for Balinese architectural education and craft.

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Transitioning an engineering classroom from traditional lectures to a partially-flipped format

G Buskes[1]
Melbourne School of Engineering, The University of Melbourne
Melbourne, Australia

I Shnai
Lappeenranta University of Technology
Lappeenranta, Finland

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ABSTRACT

Traditional university teaching methods are grounded in the delivery of content via passive, didactic lectures that are largely seen as an efficient but not necessarily effective means of mass information transfer. Higher-order, deeper-thinking activities and the application of concepts are reserved for the domain of small classes such as tutorials.

The “flipped-classroom” approach shifts the role of the lecture away from basic knowledge transfer to a facilitated, more participatory problem-solving environment. Basic knowledge is transferred via creation of online learning modules utilising short, focused videos. Moving lectures to such a mode of delivery shifts the onus of learning basic material to students, allowing them a level of independence to take ownership of their own learning. Teacher-student interaction in lectures is potentially increased under such a situation and provides ample opportunities for active learning activities.

This paper presents a structured approach to transitioning a third-year engineering subject with 150 students from a traditional lecture format to a partially-flipped classroom, adapting research-based templates from the five phase ADDIE model - Analysis, Design, Development, Implementation, and Evaluation. The first four phases are described in detail as applied to the subject, including analyses of the subject and learning environment, design and development of learning materials, and implementation of the platform for delivery of video lectures and feedback. The final phase refers to the experimental set up and evaluation of results, where the authors assessed resource-effectiveness and measured students’ confidence, engagement, satisfaction and video preferences in order to determine the efficacy of their approach.
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[1] Corresponding Author : G Buskes g.buskes@unimelb.edu.au

1 INTRODUCTION

Higher Education is currently undergoing wide-spread transformational change driven by innovative technologies and concepts that fuse personalised, collaborative, open, interactive, and visualised learning. The educational transformation is underscored by overall digitalisation trends which have profoundly affected the way people interact with, have access to and use digital information for learning. Such universal shifts have forced changes in traditional methods of delivery of content and the educational environment itself. Specifically, substitution of traditional, didactic lectures by online digital videos has led to decreased lecturing time [1,2], enabling an increase in scalability in terms of the number of students that can be accommodated and allowing flexibility in terms of their study schedule. Video lectures can be made available for an unlimited number of students and activities can be arranged more often and with smaller groups of students, which increases the potential for teacher-student interaction. In addition, teaching time can be reduced, specifically time devoted to simple repetition of the same content from one year to another whereas repetitive instruction in the video should be avoided [3].

The Australian education system has readily embraced the new technology and incorporated digital resources into students' education from an early age. The flow-on effects of this are now being seen at the University level, with students inherently possessing a familiarity with accessing and digesting such information, becoming so-called "digital natives". Despite the fact that fully online courses are not wholly accredited in the higher education system in Australia, innovative course designs and educational technologies range from very basic integration of digital tools to complete transformations of the teaching approach. Although the level of implementation can vary in different universities, the critical question teachers face is the same: are these course design approaches effective in terms of improving students' learning experiences? In considering this question, teachers must also attempt to evaluate in advance if such course design can be realistically implemented, which teaching and technological support is needed and if it is resource-effective and scalable in the long term.

The "flipped classroom" concept has recently emerged as a methodology that encompasses multiple different modern education strategies [4]. The flipped, or "inverted", classroom definition ranges from basic to more advanced versions. The originators of the approach, Bergmann and Sams, distinguish for the flipped classroom what has been traditionally done before class, in class and after class at home [5]. The definition that is used by the authors of this paper is that the flipped classroom refers to preparation with digital materials before class and activities in the class [6]. The structure of the flipped classroom is therefore in this case a combination of two components: passive lectures and active in-class work. The passive lecture component is typically delivered as a series of short video lectures that focus on basic information transfer and are placed online before the class. The in-class time is then devoted to activities that facilitate a more participatory problem-solving environment, helping students assimilate material and better develop complex skills.

Despite evidence of learning advantages from inverting the classroom in such a manner, teachers mention a substantial list of barriers and recommendations for flipped classroom design improvement [7]. The primary barrier identified is the significant investment in time and cost by the teacher to create the resources to support the flipped classes, without a clear idea of the sorts of savings such an investment will provide in the longer term. Furthermore, there are no clear guidelines or support systems that a potential implementer can adopt to measure the learning outcomes to his/her standards, which is crucial specifically for inexperienced teachers.

In this paper, a structured flipped classroom design approach is presented in the context of an Electrical Engineering subject for third-year Bachelor students at a large university in Australia. The approach taken was to use an adapted ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model [8] in the flipped classroom design, the "Flipped Classroom Design Approach" (FCDA). The FCDA utilises a guided template for redesign which was partly filled before the start of content development for the new version of the subject and is covered in detail in Section 2 of this paper. A detailed resource-effectiveness analysis is performed in Section 3 using classical investment modelling [9], which assesses the economic viability of the designed flipped classroom. This analysis quantifies how the flipped classroom implementation, and specifically video production, utilises existing resources.

2 FLIPPED CLASSROOM COURSE DESIGN APPROACH

In order to transition the subject to a more interactive and innovative learning experience, the "Flipped Classroom Design Approach" (FCDA) was used, considering the preference of the lecturer to employ a Video-based Learning (VBL) approach. Overall, the FCDA template includes 3 stages (plus an initial "reason to flip" stage) which reflects the ADDIE model and is shown in *Fig. 1*. The design approach taken was the result of a scoping review based on 100 most cited papers on flipped classrooms and practical experiments, available online together with an online course [10] and implemented in a number of other courses in Lappeenranta University of Technology (LUT) and universities of the CEPHEI consortium. VBL embedded into the flipped classroom concept empowers potential in resource savings despite its initial costs. Together with an appropriate design approach it can become a sustainable and economically viable way of delivering content for a subject.

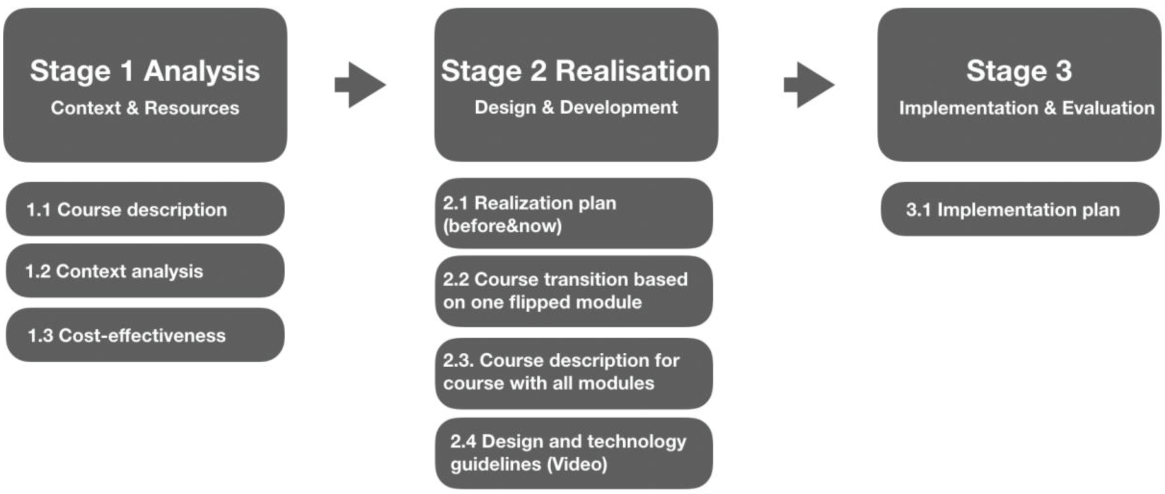

Fig. 1. FCDA template stages

2.1 Stage 0: Reasons to flip the classroom

In addition to the wide-range of published evidence of improvements in learning outcomes from switching to a more active teaching environment utilising flipped classrooms [4], The University of Melbourne recently made a number of recommendations about strategic directions to pursue in the areas of curriculum structure and development, teaching, learning and assessment approaches. In particular, Recommendations 1-3 of the Flexible Academic Programming project focused on the role of lectures as the dominant teaching delivery method at the university and the need to rethink their number, format and content. With the evidence showing a decline in students' attendance at lectures over a typical semester, it was clear that the current lecture environment, while being a less-than-ideal learning environment, is also not conducive to student engagement and may further be an inhibitor to building a sense of cohort. With this in mind, it was decided to transition a third-year engineering subject from a traditional lecture format to a partially-flipped classroom.

2.2 Stage 1: Analysis (Context and Resources)

The subject that underwent the flipped classroom transformation is a third-year, Bachelor's level subject with an enrolment of 150 students. The subject develops a fundamental understanding of the concepts behind and tools used for the analysis and design of analog and digital electronic systems and is administered by the Department of Electrical and Electronic Engineering. It is also a core requirement for those majoring in Mechatronic Systems. A traditional teaching method was previously employed, consisting of 36 hours (3 x 1 hour lectures a week for 12 weeks) of lectures focusing on basic knowledge transfer with some worked examples and 24 hours (1 x 2 hours a week for 12 weeks) or practical workshop classes. The expected total time commitment for such a subject is 170 hours over the semester and is inclusive of all contact time and private study. Students enrolled in the subject are in their third year of study, however they have unlikely had any exposure to a flipped classroom in their undergraduate studies to date. It was not seen as necessary to alter the intended learning objectives for the subject.

The learning environment is a typical 200 seat lecture theatre for lectures and a laboratory seating 32 students for the practical workshop classes. Students typically work in groups of 2 or 3 on practical or tutorial-style problems in these classes and are guided by two teaching assistants. Due to timetabling constraints it was not possible to change any of the venues for the redeveloped iteration of the subject.

2.3 Stage 1: Resource-effectiveness model

The *Resource-effectiveness* model acknowledges economic viability of the flipped classroom implementation. To assess its resource-effectiveness, the costs required for its design, development and implementation are estimated together with the possible pay off period. Economic viability was assessed via classical investment modelling, known also as *capital budgeting analysis* [9]. Investment modelling estimates future cash flows generated by an investment and uses Net Present Value (NPV), which shows total project value, Internal Rate of Return (IRR), which describes the discount rate at which NPV would be zero and Discounted Payback Period (DPP), which shows a period of time after which the investment pays off [11].

The approach was adapted from the resource-effectiveness analysis for a flipped classroom implementation [12], which reveals a pay-off period from 3 to 6 years depending on two different video creation cases and was taken as a basis to set the input data for the current study. The specifications of the input data are presented in *Fig. 2*. The parameter values were acquired by observations and interviews with the lecturer of the subject.

Parameter	Description
Professors time	Preparation + Recording (planning, discussing via meetings)+Integration in the course
PhD Student time	Preparation + Recording + Editing+ Integration
Video duration (of pure video)	Duration of the resulting video material
Compressibility rate	The rate of corresponding lecturing time to the time of the video material substituting it
Repetition rate	The number of times the video material is used per year
Infrastructure costs	The costs of required supporting equipment and software
Professors salary	Official registered salary of the participated professor
Assistant salary	Official registered salary of the participated assistant

Fig 2. Specifications of input data to determine cost-effectiveness

2.4 Stage 2: Realisation (Design and Development)

The preparation for the subject redesign commenced in September 2018, with the subject beginning in March 2019. Taking into account available resources and time commitments, it was decided to make a partial transition of the large 150-student classroom into a video-based flipped classroom form.

Videos were planned to be the main component of the course redesign - 20 short video episodes were produced, reflecting 17 topics. They were recorded over one month in the School of Engineering's professional studio at The University of Melbourne. The video recording space is equipped with a professional camera, lighting, green screen and audio-support equipment. Following recording, videos were edited in software in collaboration with a PhD student over the next 4 months using Final Cut Pro X. The general design of the video constituted an introduction and conclusion graphic of around 7 seconds each, shown in *Fig. 3*. The introduction and conclusion included the university name, subject number and name, while the conclusion also included LUT as a collaborator. The main body of the video had a white background (substitution for green screen) and approximately 1-2 minutes long discrete clips smoothly merged together, where each reflects one slide, respectively. Each video required approximately 5 hours for its development, with editing constituting the majority of the PhD student's time, whereas preparation, recording and integration took approximately 20% percent of the total development time.

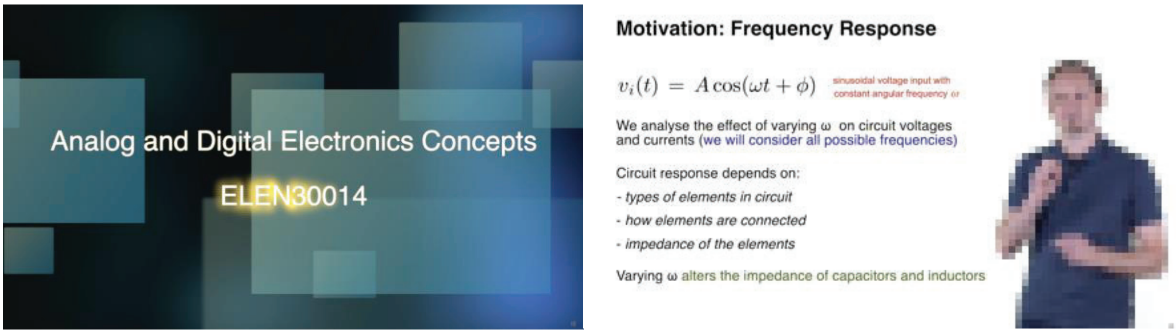

Fig 3. Screenshots from the designed videos (lecturer intentionally pixelated)

According to a number of research studies, the optimal video length varies from 3 to 20 minutes, with most finding it to be in the 10–15 minute range [2,4,13]. In this case, each recorded video approximately reproduced the information content of one traditional 45-minute lecture and ranged in duration between 06:21 and 14:59 minutes with the average being 9 minutes. In total, 3.5 hours of video was recorded. The *Compressibility Rate* of video lectures was identified as ranging between 3–7 and a value of 3 was used in the cost-effectiveness analysis as the worst-case scenario.

Migrating the basic information transfer of the theory to the online videos in the flipped classroom design allowed the lectures to be reformatted to a more interactive nature. It was deemed that a 30% reduction in the necessary lecturing could be achieved - from 36 hours of lectures in the traditional form to 24 interactive lectures as shown in *Fig. 4.* The remaining twelve hours of traditional lecture time, which had already been timetabled, were transformed into optional unstructured discussion sessions and maintained the total contact time for the subject. These sessions essentially became the consultation time for the subject that would normally be held by the lecturer at other times. All other time commitments in the subject remained unchanged.

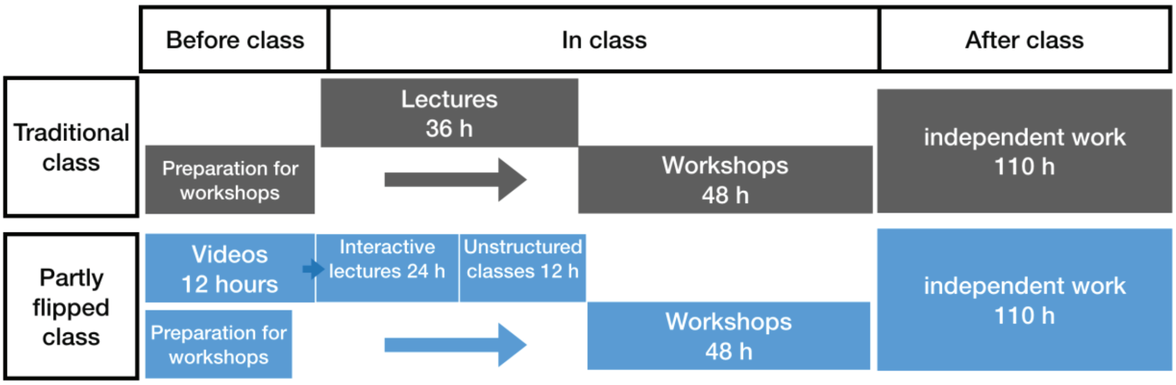

Fig. 4. Comparison of the traditional and flipped class structures

2.5 Stage 3: Implementation and Evaluation

The course implementation and evaluation methods were planned in advance in a general form. It was decided that videos would be hosted on YouTube and embedded to the open source platform EdPuzzle, which lets instructors add questions and comments in the videos. It was planned that the videos would be integrated and open for the students one week before the topic so that students have time to view them before the class. The questions in the videos were aimed to test students' understanding of the concepts and in some videos instruments of measuring their confidence in solving a particular problem were integrated. For example, students were posed an example problem at the beginning of the video, asked how confident they are to solve it, shown the video and then asked again on their confidence to solve it. The videos were also divided according to ones which the students were required to watch without skipping sections and ones which they could skip. EdPuzzle data analytics can reveal the detailed video-watching behaviour of the students, including how they watch or do not watch each chunk of the video. In addition, it was planned to evaluate students' skills in the class, their overall satisfaction with and preferences for different types of videos. There were no changes in grading for the subject.

3 RESULTS

3.1 Resource-Effectiveness

One of the indicators of resource usage for video development is the *development ratio*, which is the proportion of time spent for video recording to the video duration. The higher the development ratio, the higher the associated costs for video recording and editing [12]. In our resource-effectiveness analysis we consider one case of video production under two scenarios of *repetition rate* in future years as shown in *Table 1*.

Table 1. Flipped classroom viability analysis under two scenarios

Parameter	**Scenario 1**	**Scenario 2**
Repetition rate	1	4
Compressibility rate	3	3
Inputs		
Total video duration, hours	3.5	
Professor time (recording), hours	22	
PhD student time (recording and editing), hours	107	
Costs		
PhD student work-related costs, Euro	1834	
Professor's work-related costs, Euro	880	
Total investment (excluding infrastructure costs), Euro	2714	
Revenues		
Saved lecture time, hours per year	10.5	42
Savings, Euro per year	420	1680
Results		
Development ratio	**36.85**	
Net present value (NPV), Euro	1684	14878
Internal rate of return (IRR)	13%	162%
Discounted payback period (DPP), years	6.6	1.6

Scenario 1 describes the conditions where the videos will be elaborated once a year and scenario 2 where the videos will be elaborated four times a year. Under both scenarios, video elaboration is profitable: NPV is above zero, IRR is substantially higher than the discount rate used (1%), and DPP is 6.6 years and 1.6 years respectively. Principally, the flipped classroom viability analysis justifies the economic viability of flipping lectures with video material, in addition to the obvious educational benefits of providing a more active learning environment.

A development ratio equal to 36-minutes per minute of video corresponds well with observed rates in practice of other universities [12] and means that employing the videos only once a year is enough to pay off the initial costs within 7 years. With increased experience in production of video material, and/or a reduction in the complexity of the videos, an even more favourable development ratio could be achieved, which would make the flipped classroom even more economically attractive.

4 DISCUSSION

A number of observations were made from the video development component of the flipped classroom

- Video editing specifically is a very time-consuming approach and the type of video being produced should be selected wisely. The initial time estimations of producing the videos can increase by 1.2–2 times during the process, depending on the complexity of editing required.
- Video integration in the chosen online platform requires specifically designated time and good planning.
- Errors in the videos can attract special attention and could be more damaging to student learning than mistakes in the class, which can be easily corrected.
- The timing of the release of online videos is crucial to ensure students are prepared for the in-class sessions.

Due to constraints and long lead-times in the university subject approval process, it was not possible to alter the assessment components of the subject. It is planned to introduce an assessment component to encourage more student engagement in the lectures and reward the prior watching of the online videos. Also, teaching venues could be selected in the future to be more conducive to the new format of the active-learning lectures.

The evaluation component of the flipped classroom implementation, in terms of student surveys, feedback and academic results is only partially available at the time of writing and will be the subject of a follow-up publication. Preliminary results indicate that despite some initial issues with understanding the flipped classroom format and timed release of the video lectures, the students have readily engaged with the concept and have had improved confidence when tackling problems.

5 CONCLUSION

Adopting the structured “Flipped Classroom Design Approach”, based on the ADDIE model, to a third-year undergraduate engineering subject produced a flipped classroom that supported an increase in the number and breadth of in class active-learning opportunities. In addition to the known pedagogical benefits of moving to a flipped classroom model, this study used a profitability analysis to put to rest one of the major concerns of teachers when it comes to migrating to a flipped classroom model by justifying the economic viability of flipping the lectures with video material. If the videos produced are utilised more often, the economic viability of the approach is even more pronounced and demonstrates its tolerance to influential factors suggesting notable flexibility in video elaboration.

Given that it was an initial deployment of the flipped classroom, the lessons learned employing the structured FCDA under the ADDIE model could speed up the process for transforming other subjects in the future. The remaining part of the evaluation, using student survey data and measuring the effects on the flipped classroom on student engagement and academic results will be disseminated when they become available.

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Developing growth mindsets in engineering students:
Work-in-progress on a systematic literature review

A.L. Campbell[1]
Academic Support Programme for Engineering and
Centre for Research in Engineering Education
University of Cape Town
Cape Town, South Africa

I. Direito
Centre for Engineering Education at University College London
London, United Kingdom

M. Mokhithi
Department of Mathematics and Applied Mathematics
University of Cape Town
Cape Town, South Africa

Conference Key Areas: Diversity in Engineering Education; Lifelong learning; Talent management

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ABSTRACT

Engineering programs can be very demanding, particularly in the first years where students often encounter challenging coursework. Dropout from engineering studies has been linked to 'fixed mindset' beliefs that make students more likely to give up when facing new challenges. Extensive research evidenced that students with a 'fixed mindset' believe that intelligence is an innate and fixed trait. In contrast, students with a 'growth mindset' believe that intelligence can be improved with effort and drive, and are then less likely to disengage when confronting difficult tasks. Interventions to develop 'growth mindsets' have been successfully implemented at primary and secondary schools. However, there seems to be a paucity of interventions with university students studying engineering. In this work-in-progress paper, we will present findings from a systematic literature review of engineering, education and psychology databases to answer the question, 'What interventions to develop growth mindsets have been implemented with engineering students, and what measures have been used to assess the effectiveness of the interventions?' Preliminary findings

[1] Corresponding Author
A. Campbell
Anita.campbell@uct.ac.za

suggest that the number of interventions aimed at strengthening growth mindsets in engineering students is still small. We present a categorization of interventions together with the measures used to assess the effectiveness of the interventions. The findings will be useful for engineering educators who want to encourage students to have the benefits associated with a growth mindset, such as greater resilience after setbacks and willingness to take on challenges and stick with them when difficulties arise, and support their academic success.

INTRODUCTION

To meet stakeholder expectations, engineering educators are expected to produce graduates with a broader range of skills and attributes than in the past. The extra demands on students in a rapidly changing learning environment, and increased diversity within engineering programmes, makes it more likely that some engineering students will encounter setbacks in their studies. Students with fixed mindsets believe that intelligence is a fixed trait [1] and may feel that they are not the 'type' for engineering if success does not come easily. Growth mindsets defend against disengagement from studies when encountering challenges, such as failed assignments, because success is believed to be a result of improving intelligence and ability through applying appropriate effort.

Since failure is part of the creative process, and growth mindsets promote learning from mistakes, developing growth mindsets in engineering students should be an aim of a modern university that wants to graduate engineering students capable of using creativity in their future careers. While many interventions to develop growth mindsets in schools have been reported [2, 3], there seems to be few interventions with university students studying engineering. In addition, while growth mindset beliefs in engineering students were found to be associated with active learning strategies [4], growth mindsets were not predictive of course marks, unlike studies involving school-aged students [5]. This systematic literature review addresses the research question: *What interventions to develop growth mindsets have been implemented with engineering students, and what measures have been used to assess the effectiveness of the interventions?* The results will help engineering educators plan growth mindsets interventions based on previous research that is specific to engineering students.

METHOD

We followed the procedures for a systematic literature review involving engineering education research outlined in [6]. A comprehensive literature search of the following electronic databases was carried out before 2 April 2019. This work-in-progress paper reports on the findings from journal papers and conference papers.

Search terms were created to find studies that met the following conditions:

1. The research design involved an intervention aimed at developing growth mindsets.

2. The interpretation of ‘growth mindset’ aligned with Carol Dweck’s theory of mindsets.
3. The intervention involved engineering students in tertiary studies (college or university).

The exact search terms used are presented in Table 1.

Table 1. Search Terms Used in Databases.

("growth mindset" OR "incremental mindset" OR "malleable intelligence" OR "implicit theories of intelligence")	AND (“engineering student*” OR “engineering class”)	AND (intervention* OR experiment* OR compar*)	NOT “middle school”

Note: a suffix of * allows for multiple endings, e.g. comparison, compare.

The inclusion and exclusion criteria, with rationales, are presented in Table 2.

Table 2. Inclusion and exclusion criteria

Category	Inclusion criteria	Exclusion criteria	Rationale
Publication type	Peer-reviewed journal and conference articles.	Not peer-reviewed.	Quality assurance of the research; more credible results.
Publication language	Publications in any language found from database searches with English search terms.	Article not able to be translated into English, or translation quality weak.	The number of translations required were small; including more studies increases the value of the review.
Participants	Engineering students and students sharing classes with engineering students.	Not involving engineering students as the group targeted for the intervention.	The research question targets engineering students.
Purpose of intervention	The intervention aims to develop growth mindsets, or changes in mindset are reported.	The intervention does not aim to develop growth mindsets, or there is no assessment of students’ mindsets.	The research question focuses on developing growth mindsets.
Theory used	Dweck’s theory of growth/incremental and fixed/entity mindsets.	A use of the term ‘mindset’ different from Dweck’s theory.	The research question focuses on Dweck’s theory of mindsets.
Outcome measures	An assessment of the effectiveness of the intervention is made.	No assessment of the intervention is made.	The research question asks for measures for assessing the effectiveness of the intervention.
Date	Published before 2 April 2019 and after 31 December 1982.	Published after 2 April 2019 and before 1 January 1983.	Data collection stopped once analysis of results began. Dweck’s work on growth mindsets was not available before 1983.

Duplicate studies, either within a search or between databases, were removed. When it could not be determined from the abstract if a record met the inclusion criteria, full texts were scanned. A spreadsheet with details of each study was compiled.

RESULTS AND DISCUSSION

The number of included and excluded records (non-duplicates) based on the criteria in Table 2 are presented in Table 3. This work-in-progress paper reports only on results from journal articles and conference proceedings. The full project will include results from all sources found in the databases.

Table 3. Number of duplicated, included and excluded records

Database	Total records	Duplicates	Excluded	Included
Engineering Village	16	2	9	5
Scopus	63	8	53	2
PsycARTICLES	30	0	29	1
ERIC	1	0	0	1
Education Database	14	1	13	0
ScienceDirect	5	0	5	0
PsycINFO	4	0	4	0
Wiley Online Library	2	1	1	0
Academic Search Premier	1	0	1	0
Directory of Open Access Journals	1	0	1	0
ECO Papersfirst	0	0	0	0
ECO Proceedings	0	0	0	0
JSTOR	0	0	0	0
Proceedings (OCLC)	0	0	0	0
Total	137	12	116	9

A total of 137 journal and conference proceedings records were returned from searching 14 databases. Twelve duplicate records were excluded, leaving 125 records. In total, 116 records were excluded, many for multiple reasons. The first-noted exclusion reasons were: no intervention (62), not involving engineering students (24), not involving growth mindsets (24), no assessment of mindset (2), and no full text for a paper that couldn't be included based on the abstract alone (1). Table 4 summarises the details of the nine included records [9 – 17]. The two oldest included records [14, 15] involved universities and authors from the United Kingdom. The other seven records all had American authors and were based in universities in the United States. The only abstract in language other than English was translated using Google Translate and then excluded. Restricting the search terms to English may have limited the findings.

The dominant intervention pattern was sharing mindset ideas with students (through readings [9, 10, 12, 13], videos [10, 11] or lectures [14, 15]) followed by discussion or reflective writing, including students writing advice for other students. This pattern was evident in seven of the included studies [9 – 15]. One of those studies [15] also used two other interventions: a 'crib sheet' of alternative strategies when a computer programme fails (to counter the fixed mindset approach of re-trying the same strategy or giving up when stuck), and feedback of assignments stating that students who put in time and effort usually succeed. The remaining two studies [16, 17] used open-ended projects or assignments as a means of encouraging growth mindsets by valuing alternative strategies rather than a single correct answer.

Table 4. Summary of Included Records

Paper	Research design	Details of intervention	Findings
[9]	Qualitative. Five-part intervention. Reading and discussion.	Reading group with two authors and eight students met five times in a semester to discuss their reading of Dweck's book *Mindset*.	Students reconsidered past interpretations of experiences and projected forward on possible changes towards a growth mindset. Students understood that growth mindset "was not an all or nothing switch to be flipped."
[10]	Mixed. Four-part intervention. Videos with discussion, reading with written answers to questions.	In week 1, students watched Carol Dweck explaining growth mindsets on TedTalk and Khan Academy videos, followed by class discussion. In weeks 4, 9 and 13 students read an article on growth mindsets and wrote answers to questions.	Students already had growth mindsets to begin with. Greater shifts to growth mindsets were noticed in (non-traditional) students 10+ years out of high school.
[11]	Mixed. Three-part intervention for belonging, part 2 on mindsets. Work in progress. Video and discussion.	A first-day collaborative activity to establish classroom norms; a midquarter activity on growth mindset and metacognition; and a one-to-one instructor/student meeting. For mindset intervention, students watched the Ted Talk video by Eduardo Briceño, then discussed in groups “What kind of situations trigger your fixed mindset.” Students shared strategies they believed would develop growth mindsets and the class worked together to identify what classroom situations might trigger fixed mindsets and how classmates, teaching assistants, and/or instructors can work together to encourage growth mindsets.	Work-in-progress. Students rated how the growth mindset intervention (amongst other course components) influenced their sense of belonging. Sense of belonging was measured by survey responses. "Researchers anticipate that the three interventions will improve student sense of belonging and will look to use the survey response data to evaluate the relative effectiveness of the interventions as perceived by the students."
[12]	Quantitative. Reading and reflective writing.	Online, students read a short scientific article explaining that the brain, "similar to other muscles", gets stronger with regular practice, then answered reflective questions, including giving examples of the use of growth mindsets in their lives, and giving advice to future first year students. In the social belonging intervention, students read stories about adjusting to university from the perspectives of senior students at the university, and answered reflective questions. The stories were based on focus group interviews with senior students. The first story was selected to be from a student that matched the reader's race and gender.	Latino/a students who received the growth mindset intervention had significantly higher first-semester grade point averages (GPAs) than did their peers in the control group (3.13 vs 2.73) but African American students in the growth mindset intervention did not achieve higher GPAs than their peers in the control group. The growth mindset intervention may be less effective for (1) students with higher high school GPAs (2) students with higher ACT scores and (3) students with higher baseline growth mindset beliefs.

[13]	Quantitative. Single intervention. Work in progress. Reading and reflective writing.	Students were assigned to a control, growth mindset or belonging group. The growth mindset group read an article comparing the brain to a muscle that gets stronger with regular practice and wrote a reflective essay; the belonging group read excerpts from fictional seniors of various ethnicities and genders describing their integration into the university and wrote a reflective essay in one of thirteen course assignments.	Before the interventions, under-represented minorities (URMs) had higher growth mindset scores than non-URMs and women had higher feelings of belonging than men. After 1 year in this 6 year project, among women, the growth mindset intervention resulted in lower course performance compared to the control and belongingness groups. Among men, the belongingness intervention resulted in higher course performance than in the growth and control. The interventions did not differentially affect course performance among URMs. Among non-URMs, the belongingness intervention led to improved course performance compared to the growth mindset and control conditions.
[14]	Mixed, two-part intervention in weeks 1 and 2. Lecture, students write advice to other students.	Lecture on growth mindset mid-way through computer science course. One week later, students were given one page reminder of lecture and asked to write advice for new students, describing a time when they learnt something new other than programming, being specific about the kinds of mistakes they made and how they overcame them, and giving advice to a beginning programmer, emphasizing how they can grow their programming intelligence through dealing with programming challenges.	Few statistically significant differences both from pre-survey to post-survey and between control and intervention groups. Statistically significant changes were evident across institutions, some increasing growth mindset, some decreasing. In a follow up course, students did recall the intervention but didn't think it changed their mindsets.
[15]	Quantitative, three-part intervention over one semester. Lecture and reflection; crib-sheet; feedback sheet.	(1) Four 10-15 minute tutor talks about an aspect of growth mindsets and then taking students through a reflective exercise focusing on their own learning experience and relating it to mindsets. (2) Crib-sheet of 35 things to try if your programme fails, to encourage using different strategies rather than the fixed mindset trait of repeatedly trying the same inappropriate strategy. Half a lecture spent explaining the purpose of the sheet. (3) Adding this text to feedback sheet on fortnightly assignments, "Remember, learning to program can take a surprising amount of time & effort – students may get there at different rates, but almost all students who put in the time & effort get there eventually. Making good use of the feedback on this sheet is an essential part of this process."	In the first week, 19 (21%) of the students displayed a fixed mindset and 38 (43%) a growth mindset. The crib-sheet intervention did not affect mindset and test scores. Teaching about mindsets shifted students towards growth mindsets but did not impact class test scores. The students' mindset showed a two-way interaction between the time interval from weeks 1 and 7 and the mindset training intervention. There were two-way interactions with mindset training and rubric interventions on both the first class test and final exam.

[16]	Quantitative, single intervention over one semester. Open-ended design project.	Open-ended design project in an Introduction to Engineering course.	Students had a very slight drift toward fixed mindset and away from growth mindset over the course of their first year. Results were not statistically significant but did show a small effect size (fixed: p=0.265, |d|=0.135: growth: p=0.282, |d|=0.113). In the semester after the intervention students had a shift toward growth mindsets.
[17]	Mixed, four-part intervention over one semester. Open-ended creative assignments.	Four open-ended creative assignments given to students in an engineering statistics course, e.g. make your own exam questions.	Fixed mindset was negatively related to performance on the real-world probability assignment, and positively related to performance in the statistical independence assignment. Creative self-efficacy was negatively related to performance on Assignment 3, which was designed to test students' motivation and ability to search for different solutions to a well- posed problem. Results should be interpreted with caution, as they were examined in only half of the sample, and there was sizable uncertainty in the posterior regression coefficient distribution. There were modest relationships between perceived creativity and actual creativity.

The dominant methodology was quantitative or mixed methods, using existing mindset and belongingness scales, analysis of reflective answers, and focus group discussions to assess students' mindsets. The only qualitative study [9] used thematic analysis of students' written responses to reading group discussions of Dweck's book *Mindset: The new psychology of success*. It could be argued that this study should be excluded since it didn't use a scale to assess students' mindsets. However, it was included because the themes that resulted from analysis of the reading group sessions suggested that students had developed growth mindsets due to the intervention. This was the only included record with a qualitative assessment of mindset.

The results from these nine studies do not provide strong evidence of shifts towards growth mindsets as a result of the interventions aimed at engineering students. Where mindsets were compared to course marks, there was no correlation between growth mindsets and higher academic performance, which agrees with [4]. The thematic analysis in [9] concluded that the growth mindset framework was useful for students' reflections on past experiences and allowed them to project possible changes they would make to strengthen their growth mindsets.

We offer some reasons for why the growth mindset interventions with engineering students did not produce big changes towards growth mindsets. Firstly, engineering students may already start with growth mindsets, as was the case in [10]. A second reason is that shifting beliefs is often a slow process and most of the included studies reported on results gathered over a semester or a year. Follow-up studies, as planned in [13], may show that growth mindset interventions are effective over longer time spans than a year. A third reason is that there may be a trend for engineering students to develop a fixed mindset in their first year, as observed in [7], particularly in students taking computer science. Interventions may be off-setting the trend towards stronger fixed mindsets.

Finally, interventions that increase growth mindsets have been shown to be most beneficial for students from lower socio-economic backgrounds and minority students [8]. If the trend of increasing diversity in engineering courses continues, growth mindsets interventions may show stronger results from a more diverse population.

SUMMARY AND ACKNOWLEDGMENTS

Developing growth mindsets appears to help in the development of creativity in students even if this does not result in a short-term increase in academic performance. This systematic literature review of growth mindset interventions for engineering students points to a research field that is still developing. Further research, including studies on the same students over more than one year, can help us to understand the complexities of how to develop and assess growth mindsets in engineering students, particularly for engineering classes with a high level of diversity among students. The range of interventions used in the reported studies provide inspiration for new interventions suited to engineering students.

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STEM4GirlsUC3M: reducing gender gap in engineering

C. Campo[1], D. Segovia-Vargas, E.M. Ruiz-Navas
EPS Polytechnic School – Carlos III University of Madrid
Leganés (Madrid), Spain

Conference Key Areas: Diversity in Engineering Education; Gender, Inclusion and Ethics.

Keywords: engineering vocations in women; mentoring programs; workshops

ABSTRACT

In the last years, the number of engineering vocations has been reduced. In Spain, according to the competent Ministry, the variation rate in the last 10 years is -28.7%. This decrease is even greater in the case of women. In Engineering and Architecture studies, only the 25.6% are women.

Since 2016, in the EPS Polytechnic School of the Carlos III University of Madrid we have been working on several initiatives to reduce this problem, which have been unified in 2018 under the global project STEM4GirlsUC3M. The target audience is high-school girls between 12 and 18 years old. The action lines are (1) mentoring programs; (2) scenic arts to raise awareness about the problem; (3) technological workshops and experiences, named Tech-Fridays, given by university teachers and researchers, (4) technological contests and, finally (5) sessions with relatives.

Regarding mentoring programs, we have selected the Technovation Challenge international program from Iridescent (non-profit organization) and the STEMTalentGirl program from ASTI Talent and Technology Foundation. Furthermore, we also developed our own technological workshops and experiences, in which the high-school girls can experiment with technology and improve their knowledge about it.

The global project will be evaluated through surveys and interviews to the participants.

[1] Corresponding Author
C. Campo
celeste.campo@uc3m.es

1 INTRODUCTION

In 2010, the UNESCO published the "Engineering: Issues, Challenges, and opportunities for Development" report [1] produced in conjunction with the World Federation of Engineering Organizations (WFEO), the International Council of Academies of Engineering and Technological Sciences (CAETS), and the International Federation of Consulting Engineers (FIDIC). This report shows the value of engineering to transform the world we live in, and to improve our quality of life. Only in sub-Saharan Africa, it is estimated that 2.5 million new engineers and technicians will be needed, to be able to guarantee the access to drinking water and sanitation of infrastructures. The report warns that despite this, in many regions of the world there was a reduction in the interest of young people, especially young women, in engineering, science and technology studies. Without engineers, there is no engineering; without engineering, the sustainable development of our planet will stop. Therefore, it is fundamental to break this trend and get more young people want to be engineers. For this, it is necessary to transform the education, both in the curriculum and in the methodologies. We must also address the important gender gap that clearly is one reason that aggravates the problem.

Despite the many initiatives that have been developed in recent years, they have not been able to reduce this lack of vocations in most countries and the gender gap in STEM (Science, Technology, Engineering and Mathematics) studies has been aggravating. In 2017, the UNESCO once again published the report "Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM)" [2] with the aim of trying to understand the reasons that lead to this situation and, above all, to give recommendations on what should be done. The report emphasizes that the "*research on biological factors, including brain structure and development, genetics, neuroscience and hormones, shows that the gender gap in STEM is not the result of sex differences in these factors or in innate ability*". Studies [3] suggest that girls, although they seem to freely choose not to study these subjects, do so more because of self-selection biases that result from the explicit and implicit stereotypes that have been instilled into them since childhood. Many times even in their closest family environment. The representation of women made by the media and the state of society in terms of gender equality also exert a very important influence.

There is clear evidence [4] that working with girls at an early age, these tendencies can be reversed so that this selection is truly vocational and not conditioned by biases. Among the lines of action that are recommended, one is to work with girls by doing practical activities in laboratories, relating what is done in these practices with their real application and with the social impact that they entail. Another one is to involve girls in mentoring programs, because they encourage their confidence, motivation and improve their understanding of STEM careers. Several works in recent years also speak about the importance of visualizing female referents in STEM areas, to be "role models" for them. Some studies [5][6] also suggest that women, in general, prefer to develop their professional job in areas with a strong content of social commitment, hence their predilection for studies in the fields of Health and Education. However, as we have said, if there is anything that has changed the world for the better in recent years, it is the advances in the STEM disciplines. In fact, the 2030 Sustainable Development Agenda considers that STEM fields will have a fundamental role in the transformation that will allow compliance with this Agenda.

In 2018, SEFI published a Position Paper [7] in which it states that "*diversity, equality and inclusiveness are essential to enriching engineering education experiences and generating innovations that can drive the development of creative solutions to address the world's challenges*". It encourages the institutions to work on improving the educational environment to allow, achieve and consolidate this diversity. While this task is fundamental, in the case of gender diversity, it is also necessary to carry out specific actions that facilitate the number of women who access our higher engineering education institutions increase. Only in this way, we can achieve gender diversity in our own classrooms. In addition, our institutions, as generators of engineering knowledge, are the best places to carry them out.

In the EPS Polytechnic School of the UC3M we studied how this problem affects us. We also wanted to provide solutions, working with high-school girls of our environment. In 2016, we started with some activities, but in this course 2018/19 we have grouped and expanded them into a global project called STEM4GirlsUC3M which has five lines of action: (1) mentoring programs, (2) scenic arts and technology, (3) workshops and technological experiences, (4) contests and (5) sessions with relatives.

The paper is organized as follows. In section 2, we will contextualize this problem in our country (Spain) and in our university (UC3M). In section 3, we will talk about some of the most important programs that try to solve this problem. In section 4, we will describe the project that we have implemented. In section 5, we will provide some preliminary data on the impact of the actions already carried out. We will finish with the conclusions and future work in section 6.

2 SITUATION IN OUR NEAR ENVIRONMENT

According to the CRUE (Conference of Rectors of Spanish Universities), in the latest report, "The Spanish University in Figures 2016/2017" [8], the number of undergraduate female students represents 54% of all undergraduate university students. However, in recent years, it has been observed that its distribution in the different fields of knowledge is very unequal. The women students concentrate their preferences in Health and Welfare and in Education, and are reluctant to study Engineering and Architecture and, above all, Information and Communication Technologies. In the period 2008-2016 there has been a decrease in enrollment in the number of women in engineering education by 36.5%, which has led to a reduction of 2.7 points in their relative presence in the total of these teachings

(28.3% to 25.6%). This behavior is not something unique in our educational system, but it is a clear trend in many educational systems worldwide.

In the EPS of the UC3M, several degrees are offered in various engineering specialties, specifically, bioengineering, aerospace, industrial, telecommunications, computer science, and computer science and business administration. Only since the 2014/15 academic year, we have data disaggregated by gender that can be seen in Fig. 1.

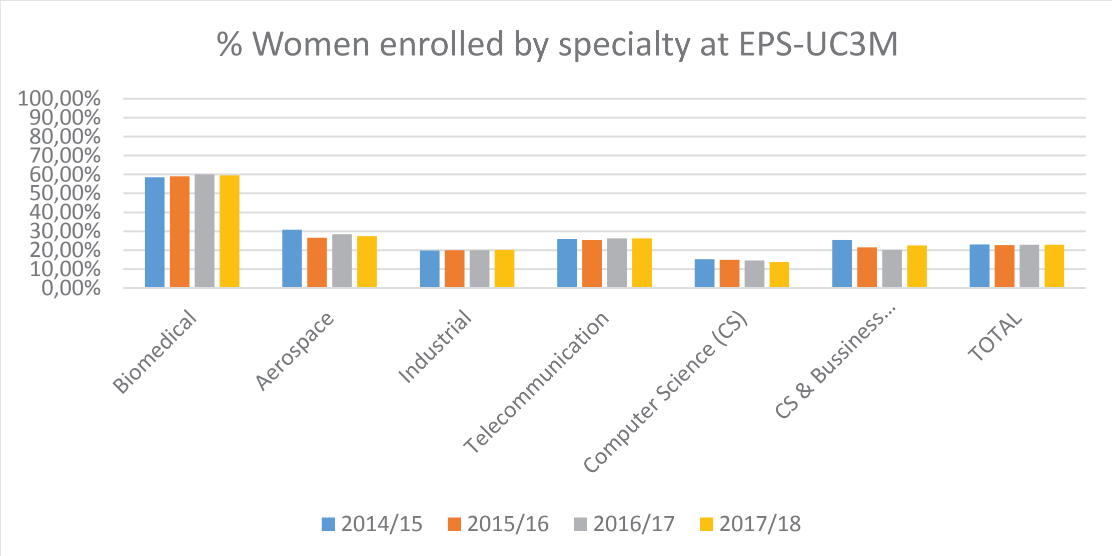

Fig. 1. Distribution of women enrolled per specialties at EPS UC3M

As you can see, the specialty in Biomedical Engineering is the one that attracts the greatest number of women (around 60%), while Computer Science has the lowest percentage (around 14%). This degree experiments a slight, continuous decline in the last academic years. The global values at EPS-UC3M are below 23%, a figure that is far from the parity objective of 40%.

3 PROGRAMS TO PROMOTE STEM VOCATIONS IN GIRLS

In recent years, there have been numerous programs that try to stop the gender gap in STEM vocations and understand it better. Of course, they do it by working directly with girls. These initiatives have been promoted and funded by both public and private entities. Due to the limited extension of this article, it is not possible to review all of them in detail; we highlight those that have been implemented in Spain.

HypatiaProject (http://www.expecteverything.eu/hypatia/) is a project funded by the European Union whose main objective is that a large number of girls, between 13 and 18 years old, choose to study STEM disciplines. The project works in two lines. The first one is to bring these disciplines closer to the girls, so that they know them in the first person and see their many applications. The second one is to promote the participation of educational centers, museums, research institutions and industry in the promotion of the STEM model from a gender perspective. The project, completed in 2018, has developed a digital collection of modules with different types of practices, scientific content workshops, informal discussions and meetings with professionals from the STEM disciplines aimed at adolescents, and which is ready to be used by teachers and schools. Finally, more than 69,000 teachers and 110,000 teenagers from Europe and Israel participated in the project.

InspiringGirls (https://www.inspiring-girls.es/) is an initiative created in the United Kingdom and deployed in Spain since 2017. Its strategy is to connect women's professions with girls, between 11 and 16 years old, through different formats: talks in their own schools; events called “speed networking” in which they offer 80-100 girls to meet 8-10 volunteers through short 10-minute meetings; finally sectoral thematic events so that they know the uniqueness of some STEM disciplines.

For Women in Science, L’Oreal-UNESCO (http://bit.ly/2cKwOuG), in addition to the well-known prizes to young women scientists and to support them in their trajectories so to be considered “role models”, this program also has an initiative for girls based on meetings called “Science Dating” that connects researchers and/or professionals with young girls between 13 and 16 years old.

STEMTalentGirl (https://talent-girl.com/en/) is a program of the Spanish Foundation ASTI that focuses on the talent and promotion of STEM vocations in girls through several initiatives. It offers “masterclasses” of relevant women of the STEM world and organizes “shadowing” sessions for girls of 14 and 15 years old. In these sessions, the girls accompany the women scientists and professionals in their place of work for two hours, so they can live with them how their job is.

Technovation Challenge (https://technovationchallenge.org/) is an annual entrepreneurship and technology competition that aims to inspire girls and young women, between 10 and 18 years old, to become leaders and innovators. This program started in 2009 in the US from the NGO Iridescent and since then, more than 15,000 girls from 100 countries have been part of it. The girls work in teams of up to 5 members, for 12 weeks (usually between January and April), to propose an entrepreneurial solution that addresses a nearby, social problem (health, education, peace, poverty, equality, environment ...). This solution is based on the development of a mobile app and a business model. The teams work supported by one or two mentors who help them throughout the process.

Women and Engineering of the Spanish Royal Academy of Engineers (http://www.raing.es/es/content/acciones-mujer-e-ingenier) is a project that aims to address the gender gap, both for young women engineers, through a mentoring program, as the problem of lack of vocations in girls. In this second line, it stands up its competition for teams of boys and girls between 12 and 16 years old, called TECHMI, where teams must build an engineering solution using a robotic kit. Girls must be at least half of the team and must led it. This year is the second edition.

In brief, all these programs have two main lines of action. The first one is to connect women scientists and STEM professionals with girls, to act as “role models”. This contact allows girls to better understand the work that these women do and to break with acquired gender stereotypes. The second line is to encourage girls to work on STEM projects that solve social problems. This idea allows to understand what STEM fields are and what consist of, and to know the important social value that they have.

4 STEM4GIRLSUC3M PROJECT DESCRIPTION

Our project includes five actions that aim to provide high-school girls with the necessary information to choose, without gender stereotypes, their studies in the medium and long term. The participating girls are recruited advertising the project among high-schools in the region at Madrid. The following sections describe the different actions that are carried out.

4.1 Mentoring programs

In this action we have decided to integrate into some existing mentoring programs. In the first place, we have selected the international initiative Technovation Challenge. We train a team of mentors, made up of students from different disciplines, mostly women. The fact that mentors have an age close to the girls, leads to very valuable relationships and in many cases, they transcend much beyond the program itself. Our mentors also have the support of teachers who accompany them in their work, establishing mentoring relationships on two levels, university professor with university students, and university students with girls. In this program we participate since 2018.

Secondly, we have selected the STEMTalentGirl program, in which our women researchers carry out shadowing sessions at UC3M. Groups of girls accompany a woman researcher one afternoon, for two hours, to see her in her daily work environment and share their concerns with her. This activity has begun this year.

4.2 Scenic arts and technology

This action proposes the representation of a performance to raise, through the scenic arts, awareness among high school students about the problem of lack of STEM vocations in girls. It also wants to do a reflection about how the conscious and unconscious stereotypes may be influencing this problem.

Working jointly with the theater company “T*he Cross Border Project*”, we have created a theater play entitled “*The girl who dreamed of Maxwell's equations*” which was represented on February 11, 2019 (International Day of Women and Girls in Science). After the play, several works of female researchers of the UC3M were presented in order to visualize their research activity. Unlike other actions, this one is aimed at girls and boys, so all together can reflect on the importance of women in science and technology, and contribute to the normalization of women's participation in these branches of knowledge.

4.3 Tech-Fridays: technological workshops and experiences

In this action, workshops are taught by professors and researchers from the EPS-UC3M, mostly women. Girls can choose between workshops on 3D bio-printing, materials technology, aircraft construction, micro-robotics, cybersecurity, smart cities design, chatbots development, web accessibility, mobile communication networks, and internet of things. These activities are planned, as the previous one, within the celebration on February 11.

In the technological experiences, some relevant woman researchers, committed to equality in the STEM field, give talks to discover girls, in an entertaining way adapted to their age, what their research consists of and what practical applications it has. After these talks, the girls participate in various workshops organized by companies collaborating in our project.

4.4 Technovation Challenge regional contest

The Technovation Challenge program encourages to do regional contests in areas of the world where there are more than 10 teams competing. The EPS-UC3M has hosted the regional final at Madrid in 2018 and will also do it in 2019, on May 18. The final has a welcome session, then the teams of girls present their projects to a group of judges, while in parallel a technological fair is held, in which the teams can present their idea of entrepreneurship to the rest of the attendees. The event ends with an awards ceremony, in which the award-winning teams present their work to all the attendees.

4.5 Sessions for relatives

In most previous actions, welcome sessions and guided tours of the EPS' labs also take place. In this case, the target audience is mainly the relatives who accompany the girls to the activities. In this way, we also involve families in solving the problem and we can also answer their doubts and concerns, which are often shared and transmitted to their daughters.

5 FIRST RESULTS AND IMPACT OF THE PROGRAM

Although the program exists since this 2018/19 academic course, all the previous actions have been developed at least once. We believe that the success achieved with all of them, measured in terms of participation, have been very high.

In the mentoring program, Technovation Challenge, 3 coordinating teachers, 20 mentors and 30 mentees, who are girls from various high-schools, have participated. All our teams have delivered their projects. In the STEMTalentGirl program, 4 researchers participate, who have carried out shadowing sessions with 20 girls (5 girls each of them).

In the representation of the play performed on February 11, 2019, a total of 6 high-school centers participated, with 313 students.

Regarding technological workshops, in this academic course, 74 girls attended to a total of 7 workshops (the next course will be increased to 10 workshops). In the surveys we carried out, they valued the activity with 4.43 out of 5, highlighting as the most important the practical application of them, and as an improvement they asked us to carry out more workshops. Their families have also highlighted the value of guidance that these workshops bring to the participants.

Regarding technological experiences, this course they involved 45 girls. At the date of delivery of this article, we still do not have results of surveys because the activity took place on April 5. The researchers who accompanied us on this occasion were Professor Karin Verspoor of the University of Melbourne in Australia and Professor Patricia Arias of the University of Mannheim in Germany.

Regarding the Technovation Challenge regional contest, in 2018 almost 400 girls participated in 94 teams. This year it will be held on May 18 and this time we have almost 600 girls confirmed to participate in it.

5.1 Activities just for girls

Most of our activities are just for girls. This condition raised us a lot of doubts when we launched the project. Several studies indicate that at early ages, girls have less leadership capacity than boys, due to their insecurities, so they do not work under equal conditions, and this makes that in teamwork they acquire a secondary role. Encouraged by these studies we have done it this way, having in mind to assess this point with our own studies.

The technological workshops, which we have offered just for girls, have been also offered for boys and girls during the rest of the academic year. A maximum of 15 people can attend the workshops and the selection criterion is the registration order. In Fig. 2 we can see the percentage of girls and boys who participated in these mixed workshops by specialty. Some specialties seem very little demanded by girls.

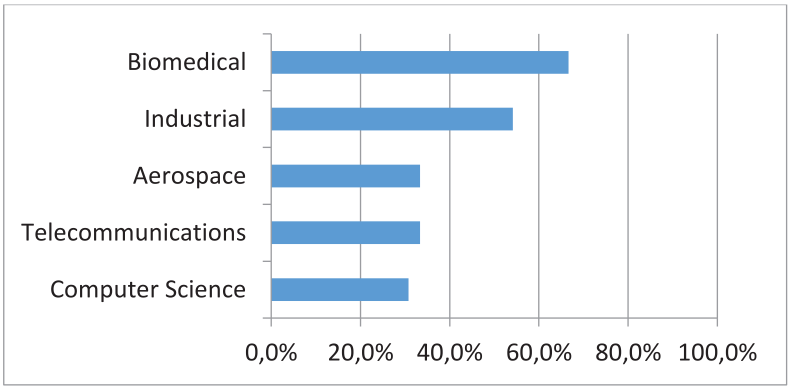

Fig. 2. Percentage of women in gender-mixed Tech-Friday

However, when we offered workshops for girls, we saw how some of them, at the beginning, did not seem to have a demand, but as the date of their completion approached they were filling up. And finally all of them were complete. Many of the girls told us in the workshops that they finally signed up because their parents encouraged them to do so and thinking that they had nothing better to do. However, most of them finished the workshops saying that they had learned a lot and that they did not imagine that these disciplines were so useful and fun. In Fig. 3 we see how the workshop records evolved by specialty during the registration period.

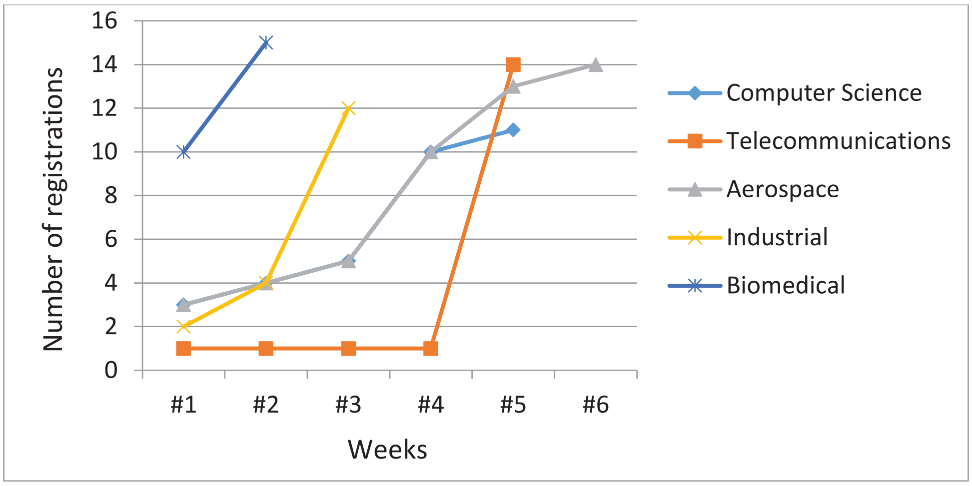

Fig. 3. Progress of registrations in Tech-Friday for girls

6 CONCLUSIONS AND FUTURE WORK

The lack of vocations in engineering in general, and in particular in women, seems to be a trend that has been consolidated in recent years. This is a very serious problem for society in general, due to the importance of engineering and STEM disciplines in the sustainable development of the world. The higher education institutions that teach STEM studies must get involved in this problem, working with girls from an early age, otherwise these students will not reach our classrooms.

In this paper we describe the initiative that we are carrying out to alleviate the lack of STEM vocations in girls. We have created a program in which we involve our academic staff and our own students to help us. The program is being very supported within our university and very well received by the girls who participate in it.

We are aware that the real impact measure of these programs should include a monitoring, up to the university stage, of the girls who participate in them. This task is always complicated and difficult to automate without the direct cooperation of public education managers. However, our intention is to conduct surveys from time to time to participating girls to try to know the academic trajectory they are following and how the participation in our program has influenced them. It is a follow-up task that requires several years.

7 ACKNOWLEDGMENTS

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Enhancing Interdisciplinary Skills in Engineering with the Cognitive Tools of Storytelling

P. Caratozzolo[1]
School of Engineering and Sciences, Tecnologico de Monterrey
Campus Santa Fe 01389, Mexico City, Mexico

A. Alvarez-Delgado
School of Social Sciences, Tecnologico de Monterrey
Campus Santa Fe 01389, Mexico City, Mexico

Z. Gonzalez-Pineda
School of Social Sciences, Tecnologico de Monterrey
Campus Santa Fe 01389, Mexico City, Mexico

S. Hosseini
School of Engineering and Sciences , Tecnologico de Monterrey, Writing Lab,
TecLabs, Vice rectory of Research y Technology Transfer,
Monterrey 64849, NL, Mexico

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ABSTRACT

The studies carried out so far on how digital native students learn and think make researchers reevaluate the importance of the development of interdisciplinarity in higher education. In the case of engineering programs, the issue of strengthening interdisciplinarity is often hampered by the modality of logical-scientific thinking that predominates in all its courses and disciplines. The present work was based on the importance of the development of the narrative-artistic modality of thinking and the way to enhance creative experiences in the educational field. The cognitive tools of storytelling were adapted for the design of non-engineering, co-curricular activities related to fine arts and literature and were included in different programs of engineering. The methodology used was quantitative-experimental with a Solomon 4-group design and involved 183 engineering students. The measurement of results was carried out using different VALUE rubrics to evaluate the development of interdisciplinary skills and competencies of students, including critical thinking, creative thinking, and intercultural knowledge. The results showed that the selected cognitive tools of storytelling were highly useful for the development of interdisciplinary skills in engineering students.

[1] Corresponding Author
P. Caratozzolo
pcaratozzolo@tec.mx

1 INTRODUCTION

The report, *Towards a Reskilling Revolution,* was released in January 2019 by the World Economic Forum, and it introduced a comparison of today's skills with those demanded of future professionals to face the challenges of the so-called "Fourth Industrial Revolution." Table 1 shows the skills expected to be trending or declining by 2022. Soft skills such as creativity, originality, and critical thinking are on the rise.

TABLE 1. World Economic Forum Report

	Comparing skills demand	
	Today, 2018	*Increasing, 2022*
1	Analytical thinking and innovation	Analytical thinking and innovation
2	Complex problem-solving	Active learning and learning strategies
3	Critical thinking and analysis	Creativity, originality, and initiative
4	Active learning and learning strategies	Technology design and programming
5	Creativity, originality, and initiative	Critical thinking and analysis
6	Attention to detail, trustworthiness	Complex problem-solving
7	Emotional intelligence	Leadership and social influence
8	Reasoning, problem-solving and ideation	Emotional intelligence
9	Leadership and social influence	Reasoning, problem-solving and ideation
10	Coordination and time management	System analysis and evaluation

Source: Towards the Reskilling Revolution report

The Occupational Information Network (O * NET) defines *critical thinking* as the ability to use logic or reasoning to identify the strengths and weaknesses of alternative solutions, conclusions, or approaches to problems. Likewise, *creative thinking* is defined as the metacognitive process that allows not only complex problem solving but also promotes a high degree of innovation. In this sense, it is essential to strengthen these two soft skills in the training of future engineers, with the objective of enabling them to perform disruptive tasks successfully and to confront problems for which they have not learned solutions.

The importance of soft skills in engineering, especially critical thinking and creativity, has been studied for many years by academic researchers. However, it has not been until very recently (since today's freshmen, the digital natives, belong almost 100% to *Generation Z*) that the need has been seen to introduce innovative, effective ways to develop critical thinking and creativity among the Generation Z students, considering their particular characteristics. The year 2015 was the watershed for reports on the necessity to include new cognitive and metacognitive tools for full development of soft skills that would be needed by Generation Z students, due to two fundamental causes: first, the strong consolidation of social networks meant an unanticipated difference in the way recent graduates see the world, think about private and public matters, and become aware of themselves; and second, the exponential development of technological platforms became accessible to them [1].

Some exciting studies referring to the use of Storytelling as a cognitive tool for enhancing soft skills while fostering student engagement can be highlighted:

Hiromi Nishioka proposed in 2016 the use of digital storytelling as a collaborative tool to develop the construction of knowledge through the exercise of coherent discourses and lexical enhancing. The strength of this study was the clear and in-depth formulation of the cognitive theories that underpin collaborative learning based on storytelling [2].

Artur Lugmayr introduced in 2017 the term, “Serious-Storytelling,” as a powerful coherent speech construction tool in the current era of media digitization. The strength of this study was the depth in the categorization of the components of storytelling, the definition of a solid framework for it, and the foundation with respect to theories of cognitive processes [3].

Amreen Mistry proposed in 2017 the storytelling technique to acquire conceptual information in an effective way, perform critical analyses of texts, and impact the emotional commitment of students. The strength of this study was the establishment of relationships between the didactic technique and the affective domain of learning along with the capacity for student commitment that it can generate [4].

Helmut Hlavacs proposed in 2018 the technique of storytelling to insert learning content in narrative discourses and counteract the tendency of Generation Z students to be distracted by technology. The strength of this study was that it presented a complete state of the art on the technique and based its methodology on different instruments such as observations, questionnaires, and interviews with students [5].

The weaknesses of some of the previous studies were that in some cases, there were no data collection or evaluation of results, and in other cases, there was a lack of evaluation instruments to measure the impact of content retention and emotional commitment.

Our project consisted of an interdisciplinary approach that incorporated those storytelling tools that effectively trigger the cognitive and metacognitive processes of learning in a mixed infusion/immersion environment [6] and had the objective of developing, in future engineers, the soft skills required by employers. This study also proposed the solution to the various pending problems mentioned above; it had the following characteristics: (i) the work was carried out using a methodology and instruments previously tested in different authors’ works [7]; (ii) the instruction was applied to a large sample of students in a quantitative experimental research design; and (iii) the impact and findings were evaluated with tools specially designed for the educational field [8].

2 GENERATION Z AND HIGHER EDUCATION

Although Generation Z differs in many ways from Generation Y, especially in regard to learning styles, it is currently considered that the methods associated with the strengthening of skills and competencies related to critical and creative thinking can be designed by taking advantage of the numerous studies and works carried out in the past twenty years [9]. Furthermore, Generation Z students arrive at college, having varying levels of cognitive development and abilities in creativity and criticism. In our work, we have especially considered the level of cognitive development of the students and have adapted the procedure design to the unique characteristics of Generation Z.

Texting is a prominent mode of communication that is widely popular among Generation Z. One in three digital native students reports sending over one hundred messages a day [1]. This fact presents new challenges in the sense that students have almost created their own language in texting. Shortening words and using abbreviations have been at the core of texting from the beginning. Emoji, or emotion icons, add another layer to the text messaging language in which students are fluent. They can, in fact, carry on an entire conversation with these tiny pictures alone. However, this “language” cannot be considered a real narrative of Serious-Storytelling. One way to enrich the lexical experience has always been the practice of reading and writing. However, today's digital natives do their academic work by copying and pasting documents, relying on automatic word processors to correct spelling and even grammar, and using digital social platforms such as YouTube, Instagram, and Snapchat to "tell" stories. All these narrative habits weaken the force of their argumentations, hinder their vocabulary acquisition, and fail to contribute to the development of their critical and creative skills.

3 COGNITIVE THEORIES AND CONCEPTUAL FRAMEWORK

The present work, with a methodology and instruments specially adapted for engineering students of Generation Z, was based on two long-established cognitive theories. First, Jerome Bruner's *theory of cognitive functioning* was revised to strengthen the students' skills in criticism through the narrative-artistic modality. This theory deals with the ability of students to find meaning in works of art and to develop new technological products by converting imaginative concepts into a believable reality. Secondly, John Dewey's *theory of the development of the mind* was revisited to achieve a higher degree of commitment of the students by increasing their creative thinking skills. This theory deals with the need to create active learning experiences in all academic courses through the exercise of aesthetic activities and their assessments.

Jerome Bruner points out that there are two modalities of cognitive functioning of thought, and each of them offers characteristic ways of constructing reality and ordering experience: The *logical-scientific modality* tries to fulfill the ideal of a mathematical, formal system of description and explanation. It uses categorization or conceptualization and the operations by which the categories are established, represented, idealized, and related to each other in order to build a system. The *narrative-artistic modality*, on the other hand, looks for connections between two events and uses procedures to establish the likelihood, not the truth. This thinking modality is concerned with how we perceive meaning for experience and deals with human intentions and actions, the vicissitudes and consequences that mark its course, and the events of experience in time and space.

Until now, educational theories have tried to avoid incorporating the narrative-artistic modality in engineering programs so as not to lose the rigor of the search for empirical truth. However, during our research, we have found that attempts to ignore one of the modalities at the expense of the other inevitably lose the possibility of developing flexible critical thinking and creativity. Critical thinking and creativity do not occur automatically but are processes that depend not only on the cognitive effort but also on the metacognitive processing, which in turn depends on the developmental stage of the student. Because in the same classroom, students with different levels of cognitive development coexist, we considered two fundamental concepts derived from Vygotsky's work, *Scaffolding and Zone of Proximal Development (ZPD)*. The "scaffolding" refers to the observed fact that when a teacher interacts with students with the intention of teaching, they tend to adapt the degree of help to the level of competence they perceive in themselves. The ZPD is the gap between the real development level of the students and the level of potential development that could occur with the teacher's guidance or the support of the classmates.

4 SERIOUS-STORYTELLING

Serious-Storytelling conveys a perspective in serious application contexts and uses the narratives with a purpose beyond the entertainment. Given that stories are a fundamental component of human memory and the basis for the most fundamental cognitive events, it is understandable that emotions and reflection are two of the fundamental aspects of storytelling. The addition of storytelling activities to the learning process creates a personal relationship between the instructor and the audience and is also a powerful tool to engage students and form emotional connections to the topics under study.

Storytelling is also an ideal cognitive tool to include in Vygotsky's approach because it is based on active and collaborative learning and is produced through the knowledge and previous experience of students. The process of storytelling can be considered *mimesis* -artistic imitation- or visualization of real-world happenings, in a way that an engaged audience interacts with the narrative flow of a story and perceives the narrative as an emotional experience, in Dewey's theory style. The essential components of storytelling can be divided into four elements:

- *Perspective*. It is a subjective point of view and includes story features such as cognition and emotion.
- *Narrative*. It is the actual content of the story and includes features such as mimesis and digenesis.
- *Interactivity*. It is the essential interaction between the speaker and the audience and includes features such as engagement and decision.
- *Medium*. It is the message and includes features such as content and forms.

With respect to the academic framework, it is essential to understand that serious stories can be entertaining and fun, but their primary purpose is knowledge and value creation for a serious context matter [10]. In the case of Serious-Storytelling, the four components must be understood in such a way that the following features are achieved:

- Provision of real-world understanding.
- Self-reflective and introspective context.
- Intrinsic motivation.
- Relation to a matter of importance, experience, knowledge, and understanding.
- Self-empowerment and personal advancement.

In storytelling systems for entertainment, the notion of story progression entails a progression of events in time and space. Clear examples of this are films based on mythology, very trendy today. In Serious-Storytelling systems, which are intended to be used as cognitive tools in the academic field, the notion of progression of a story is much more complex, and it can be said that it is an abstract artifact that makes the story progress, instead of the characters, events, or a cause-effect relationship.

5 METHODOLOGY

Participants. The participants were 183 undergraduate students in engineering programs. They joined the study voluntarily, and 116 of them underwent metacognitive instruction for five semesters (the experimental group), while 67 students remained untrained (the control group).

Instruments. Two different types of instruments were used in this study. The first type had vocabulary tests, with multiple-choice and true or false questions designed to establish the approximate lexicon of each student, compared to the Corpus of Contemporary American English (COCA). Second, to assess how well students performed each outcome and considering that assessing the evidence for competencies like critical thinking and creativity typically involves subjective judgments concerning products or behaviors, we also used a second type of instrument, which we adapted from an already-existing rubric, the VALUE Rubrics, which had been developed for the Essential Learning Outcomes of the Association of American Colleges and Universities (AAC&U) [8].

The instruments for the data collection and the group criteria were the following:

PreTest: Vocabulary tests regarding COCA.
Treatment: Dialogue seminars and online discussion boards.
PostTest: Vocabulary test regarding COCA and Value Rubrics by AAC&U.
EG-PreT-T: Experimental Group with PreTest and Treatment (60 students)
EG-T: Experimental Group without PreTest, only Treatment (56 students)
CG-PreT: Control Group with PreTest (33 students)
CG: Control Group without PreTest (34 students)

Procedure. The research methodology of the study was quantitative-experimental to establish a correlation between groups of variables. The independent variable was our experimental variable or treatment, and the dependent variable was our result or criterion, with which we achieved the effects observed in the study. The research hypothesis was that interdisciplinary incorporation of Serious-Storytelling-based activities for the development of critical thinking and creativity leads to the enhancement of the engineering students' intellectual engagement and intercultural knowledge. The methodological design is schematically illustrated in Figure 1.

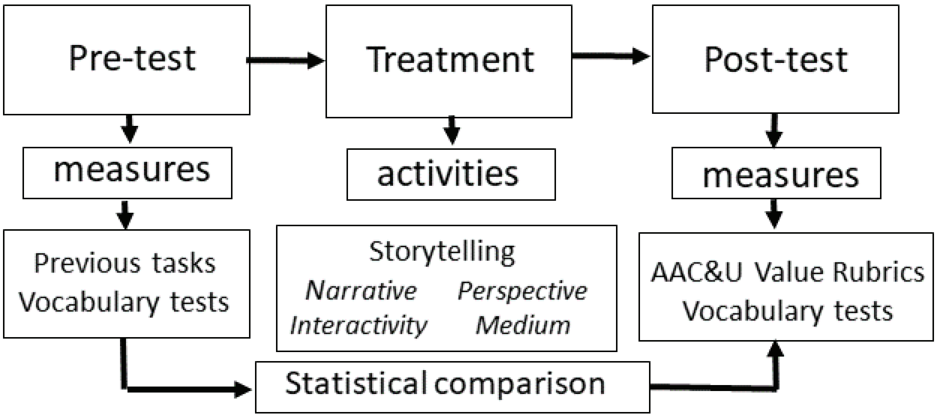

Figure 1. Procedure design.

6 AN EXAMPLE OF STORYTELLING ACTIVITY

Title of the Series of Activities: *Narratives with and without words: from a photograph to the story and vice versa*.

The fifteen different storytelling activities carried out during our study were designed relying on existing scholarship in the field around the world, including experiences from North America, Latin America, Europe, and Asia. The activities were based on the successful initiative that the MuseWeb Foundation, *Be Here: Main Street*, carries out together with the Smithsonian Institution, which consists of traveling exhibitions that are taken to small towns in the United States. The program bases their project on the conviction that everyone has a story that is worth sharing. These rarely heard narratives capture a “story” of the small towns of the United States based on experience, knowledge, and memory instead of historical data and dates. In this way, the stories published offer people a personal and authentic vision of the traditions and culture of a community.

For the proper development of the activities in the Serious-Storytelling framework, the *Text-Photography Binomials* were selected in a way that allows observing whether students effectively develop creative thinking through the verification of compliance with four performance criteria that were included in the VALUE Rubric of Table 3; namely, a) Attentiveness towards different situations; b) Competencies acquisition (reflect, create, adapt or model); c) Perspective-taking and, d) Knowledge of cultural worldview frameworks.

Example of activity: *Mexican Binomial*

Learning Objectives. The activity allowed the students to know the work of Mexican writer Juan Rulfo and to write their own stories and anecdotes of their childhood and home cities using Rulfo's style.

Background of the work. Juan Rulfo was one of the great literary innovators of the twentieth century. His 1953 work, *The Plain in Flames*, is considered one of the foundational classics of magical realism. Lesser known are his poignant photographs of Mexico, which exhibit remarkable parallels to his prose; his photo book, *Juan Rulfo's Mexico,* contains 175 pictures mainly taken between 1945 and 1955. Rulfo extracts unique moments through his photographs; his images of desolate, abandoned buildings and landscapes are expressions of the loneliness and anguish experienced by the artists of his time.

Preliminary Activity (infusion-immersion approach). Students were asked to read the stories that are part of *The Plain in Flames*; also, a brief virtual tour was provided so that they would know more about the artistic and social concerns of the time and the country in which the author lived.

Divergent Thinking Activity. Students were asked to search the internet for information about the author and his photographic work. The photo book, *Juan Rulfo's Mexico,* was introduced to the students. A discussion session was held where the students established a personal relationship with some of the stories and some of the photographs. The group was divided into teams of 4 participants, and there was a role-play activity in which each member of the team was characterized as a friend or colleague of the author. The students recorded with their cell phones short interviews of the type that would be included in a documentary program about Rulfo and his photographic work.

Convergent Thinking Activity. Each student chose a landscape photograph that he/she would have taken in the hometown and then wrote a short story (using Rulfo's style) based on the picture. The students told these in a final session where each storyteller shared his/her life while projecting the chosen picture.

The *Mexican Binomial* was selected because the stories told present a vision of Mexican society - at that time, mostly rural - after two significant social conflicts, the Mexican Revolution and the *Guerra Cristera.*

Another activity was the *American Binomial,* comprised of the book, *The Grapes of Wrath* (1939), by John Steinbeck and the photographs of *An American Exodus: A Record of Human Erosion (1939)* by Dorothea Lange and Paul Taylor, where the stories presented the rural poverty of a country and the Depression-era exodus that brought thousands of migrants to California in search of farm work.

Observations. Evidence was taken in the classroom to analyze the interactions and processes between the speaker and the audience. The four components of the narrative technique (perspective, narrative, interactivity, and medium) along with the Serious-Storytelling features already discussed in previous sections were verified in each session to encode / decode contextual knowledge and the way in which the narrative could be a vehicle to trigger emotional and cognitive responses in the audience.

7 RESULTS AND DISCUSSIONS

In order to verify that the students of the experimental group and the control group had similar initial conditions of the lexicon, the results of the vocabulary PreTest in both groups were compared. The initial comparison between 183 students (116 students of the EG-PreT-T and 67 of the CG-PreT) where the PreTests were applied revealed no significant differences in their vocabulary background. However, the PostTest comparison of the vocabulary scores revealed that the EG-PreT-T group showed significantly higher improvement than the CG-PreT.

The PostTests on critical thinking, creative thinking and Intercultural Knowledge using AAC&U rubrics showed that the experimental group attained 66% improvement in comparison with the students of the control group in the upper "Capstone" level and a 25% decrement in the number of students who remained at the lowest "Benchmark" level of the rubric. These results are shown in Table 2. Additionally, an example of a rubric adapted from the AAC&U VALUE Rubrics is shown in Table 3.

TABLE 2. AAC&U Rubrics distribution for EG and CG

	Value Rubrics			
Groups	Capstone 4	Milestones 3	2	Benchmark 1
EG	30 %	35 %	23 %	12 %
CG	18 %	31 %	35 %	16 %
	+ 66 %	+ 13 %	- 34 %	**- 25 %**

Findings. The convergent stage of the activity present in the technique of Serious-Storytelling is the one that allows the assessment of the different performance criteria of the rubric; they were chosen based on the employers' requirements. It is noteworthy that it would not have been possible to apply a VALUE Rubric or obtain a correlation between the results of the PreTest and the PostTest if the activity had been limited only to entertainment storytelling.

Discussion on the creative thinking assessment: The rubrics were used with the intention of evaluating and discussing learning related to the students' interdisciplinary skills, not the grading. These rubrics allowed positioning the learning within a basic framework of expectations [10].

Discussion on the inclusion of Serious-Storytelling in engineering courses: The incorporation of artistic activities, such as those presented in this study, to develop soft skills in engineering courses is a proposal of educational innovation in response to compliance with the requirements of employers and accreditation agencies. This concept responds to the growing need to achieve integrated thinking in engineers. It is suggested that the incorporation of storytelling activities into the curricular courses be carried out by trained instructors and follow a sequential taxonomy of the type: creating, inventing, innovating, engineering, and controlling [11]. It is precisely in the first two stages of the process (creating and inventing) where the development of artistic activities could help to free the modality of narrative-artistic thinking explained in previous sections.

TABLE 3. Example of the Rubric used as PostTest. (*This rubric was created using the Association of American Colleges and Universities (AAC&U) VALUE Rubrics) [8].*

	Capstone	Milestones		Benchmark
	4	3	2	1
Attentiveness towards different situations	Interprets intercultural experience from the perspectives of self and more than one worldview and demonstrates the ability to act in a supportive manner that recognizes the feelings of another cultural group.	Recognizes intellectual and emotional dimensions of more than one worldview and sometimes uses more than one worldview in interactions.	Identifies components of other cultural perspectives but responds in all situations with own worldview.	Views the experience of others but does so through their own cultural worldview.
Acquiring competencies	Reflect: Evaluates creative process and product using domain-appropriate criteria.	Create: Creates an entirely new object, solution or idea that is appropriate to the domain.	Adapt: Successfully adapts an appropriate exemplar to his/her own specifications.	Model: Successfully reproduces an appropriate exemplar.
Perspective-taking	Evaluates and applies diverse perspectives to complex subjects within natural and human systems in the face of multiple and even conflicting cultural positions.	Synthesizes other perspectives (such as cultural, disciplinary, and ethical) when investigating subjects within natural and human systems.	Identifies and explains multiple perspectives (such as cultural, disciplinary, and ethical) when exploring subjects within natural and human systems.	Identifies multiple perspectives while maintaining a value preference for their own cultural positioning.
Knowledge of cultural worldview frameworks	Demonstrates sophisticated understanding of the complexity of elements important to members of another culture in relation to its history, values, or beliefs.	Demonstrates adequate understanding of the complexity of elements important to members of another culture in relation to its history, values, or beliefs.	Demonstrates partial understanding of the complexity of elements important to members of another culture in relation to its history, values, or beliefs.	Demonstrates surface understanding of the complexity of elements important to members of another culture in relation to its history, values, or beliefs.

8. Conclusions

The 21st-century engineers must be creative and critical enough to build values and judgments and even solve ill-defined problems to understand and remember conceptual information. The results of our study showed that Serious-Storytelling could be an effective cognitive tool to enhance specific dispositions of particular soft skills, such as perspective-taking (critical thinking) and acquiring competencies (creative thinking), that foster the abilities and dispositions of temperament that are required by employers. Additionally, we could verify that our method propitiated the development of specific personal attitudes necessary for the future engineers of Generation Z: attentiveness towards different situations (empathy) and knowledge of global cultural frameworks (intercultural competence).

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A Comparison and Classification of Grading Approaches used in Engineering Education

A. R. Carberry[1]
Arizona State University
Mesa, Arizona, USA
https://orcid.org/0000-0003-0041-7060

S. A. Atwood
Elizabethtown College
Elizabethtown, Pennsylvania, USA
https://orcid.org/0000-0001-9759-9328

M. T. Siniawski
Loyola Marymount University
Los Angeles, CA, USA
https://orcid.org/0000-0001-5999-9988

H. A. Diefes-Dux
University of Nebraska
Lincoln, NE, USA
https://orcid.org/0000-0003-3635-1825

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[1] A. R. Carberry, adam.carberry@asu.edu

ABSTRACT

Grades are intended to communicate achievement associated with a learning experience. Engineering educators in higher education often default to a particular grading approach without considering how the approach impacts student achievement. This work proposes a model for comparing and classifying commonly used grading systems in engineering higher education. Examples from the engineering education literature revealed five general categories of grading: 1) normative, score-based grading, 2) summative grading, 3) standards-based grading, 4) mastery-based grading, and 5) adaptive grading. (Note: variations in naming conventions were observed.)

Each grading system was examined to determine key characteristics of the system and how student performance was ultimately assessed. A continuum of grading approaches was created after discovering that each system ranged in its intention to select and/or develop talent. The most widely adopted approaches to grading in engineering higher education, norm-based grading, were classified using purely selective processes (e.g., letter grades). Alternative, learning outcomes-based grading approaches differentiate themselves by the level in which they attempt to develop talent. This was determined by examining differences in how the grading system impacted sequencing of content, course pace, number of attempts to demonstrate achievement, scale and weight of performance, feedback provided, and basis for a final grade. The resulting continuum provides a tool for engineering educators to compare and discuss grading approaches in order to select an appropriate system for their course or program. Informed decisions on grading can have a critical impact in student retention and program improvement.

1 INTRODUCTION

Assessment of student achievement using a grading system is a major task asked of educators since the late 1700s (Postman, 1992). Engineering instructors are faced with the constant challenge of selecting appropriate assessment measures and grading systems for the courses they teach. Take for example Dr. Smith.

> *Dr. Smith is an engineering instructor with a clear idea of and confidence in her ability to teach the course's topics. Her approach to assessing her students is the same way she used to be assessed as a student herself. This involves summing scores on a variety of assignments - homework, quizzes, projects, and exams - and calculating a final grade. The process, grading scale, and learning outcomes associated with the course are outlined on her syllabus. Dr. Smith's reflection on her grade distributions at the end of the course cause her to question whether the assignments and grading system accurately represent how well the students have learned the course material. She is interested in making some changes, but is unaware of who to ask or where to go to learn about alternatives beyond what is familiar.*

This paper provides engineering instructors like Dr. Smith and engineering programs with the information needed to make an informed decision about how student learning will be assessed in their classrooms.

Grades are intended to communicate how well students have achieved the learning outcomes established for a course of study by: 1) communicating achievement to other interested parties, 2) selecting, identifying, or grouping students for certain educational pathways or programs, 3) providing information to students for self-evaluation/assessment, 4) providing incentives for students to learn, and 5) documenting student performance for the purpose of evaluating the effectiveness of instructional programs (Guskey & Pollio, 2012; Muñoz & Guskey, 2015). The wide variation in motivations for and uses of grades leads to confusion over their primary purpose in higher education. Should grades be used for ***selecting*** talent by differentiating student performance for outside parties or internal programs or for ***developing*** talent by improving performance through instructor feedback and student self-assessment?

This paper compares and classifies the variety of grading approaches used in engineering education to provide a continuum for engineering educators and programs to differentiate systems and make an informed decision on what approach to use in their course(s).

2 BROAD CATEGORIES OF GRADING SYSTEMS

2.1 Norm-based Grading

The most widely used systems in higher education are normative, score-based approaches (norm-based) that aim to differentiate and ***select*** talent (Freeman & Lewis, 1998; Walvoord & Anderson, 1998; Huba & Freed, 2000; Morgan, Dunn, Parry, & O'Reilly, 2004; Muñoz & Guskey, 2015; Stevens & Levi, 2004; Suskie, 2004). Such grading systems efficiently maximize differences between student achievement by measuring student performance on a number of discrete and disparate tasks throughout the semester. This approach makes it difficult for students to clearly understand what constitutes success. Conflicting evidence about student achievement and progress is often lost in the process of weighting or combining grades on separate assignments (Cross & Frary, 1999). The resulting end-of-semester grade ultimately communicates a student's performance on separate tasks relative to other students rather than individual achievement referenced directly to the stated course learning outcomes (Muñoz & Guskey, 2015, Angelo & Cross, 1993; Broad, 2000; Sadler, 1987, 2005 & 2009; Shay, 2005). The learning outcomes referred to are defined as explicit statements of what students should be able to do if they have learned what their instructor has attempted to teach them (Diamond, 2008; Felder & Brent, 2016). This *selection* approach fosters negative competition among students and a belief by instructors that not all students *should* achieve mastery (Krumboltz & Yeh, 1996).

Little variation exists among norm-based grading approaches. All systems use a summation of scores or summative approach. Some include a norming process that allows for direct comparison and "curving" of grades based on the class performance as a whole.

2.2 Learning Outcomes-based Grading

Outcomes-based, objectives-based, or criterion-referenced approaches (heretofore referred to as learning outcomes-based) are alternatives that shift the goal of assessment more toward student talent development. This is accomplished through direct measures of student proficiency on well-defined course learning outcomes (Heywood, 2014; McIntyre-Hite, 2016; Sadler, 2005). The focus is on the detailed descriptions of what a student must be able to do at the conclusion of a course, which is different from course goals - broad definitions of student competence - and course learning objectives - content an instructor will cover in a course (Diamond, 2008).

These learning outcomes-based (LO-based) approaches, developed in the 1970's (Burke, 1989; Heywood, 2016; Spady, 1977), allow instructors to support students' mastery of clearly articulated course learning outcomes by aligning course activities and assessments (Heywood, 2014; Sadler, 2005). The outcomes are supplemented by specific and targeted feedback. Feedback is a critical mechanism used to increase transparency of the criteria for success and to guide students in their efforts to succeed (Butler, 1988; Guskey, 1997; Wiggins & Tighe, 1998; Post, 2014). Multiple assessment opportunities of learning outcomes offer students the ability to improve their learning. Alignment of assessment with the identified course learning outcomes increases the overall validity, reliability, transparency, and fairness of the grading process (Muñoz & Guskey, 2015; Wiggins & McTighe, 1998).

Numerous variations of LO-based grading have been found in the literature and are used in practice, including standards-based, mastery-based, competency-based, and adaptive grading. Each of these are distinguished by implementation features including point scale, pace, and opportunities to demonstrate mastery. The variation in LO-based approaches seen in the literature demonstrates an instructor's ability to select the structure that best fits their course content, teaching style, and students.

3 THE NEED FOR A TOOL TO CLASSIFY GRADING SYSTEMS

Norm-based grading systems are still highly used in engineering higher education, but the use of LO-based grading systems is on the rise as demonstrated by many examples discussed in the recent engineering education literature. For example, Henri et al. (2017) conducted a review of competency-based learning tools assessments and recommendations. Additionally, the authors of this paper have extensively examined the use and implementation of standards-based grading in various contexts (Atwood et al., 2014; Carberry et al, 2012; Sinawski et al., 2012; Hylton & Diefes-Dux, 2016) to reveal best practices (Lee et al., 2018) and student use of feedback (Diefes-Dux, 2018).

There is little confusion as to what classifies as norm-based grading. The same cannot be said for LO-based grading efforts, which have been quite scattered and bogged down by inconsistencies in nomenclature. For example, Post (2014 & 2017) highlights the use of what he refers to as standards-based grading in fluid mechanics (2014) and thermodynamics (2017) courses. The use of standards-based grading in these examples highlights an approach that leverages a two-point, pass/fail scale for nine and eleven course objectives, respectively. This binary approach to grading and multiple opportunities to achieve a score of 'pass' is inconsistent with our use of standards-based grading.

Bekki, Dalrymple & Butler (2012) also use a two-point, pass/fail scale as described in their implementation of mastery-based grading in an undergraduate engineering curriculum. Students are provided with two chances to demonstrate mastery of well-defined learning objectives, which roughly aligns with Post's description of standards-based grading. Another example labelled as mastery or competency-based grading is provided by DeGoede (2018) within an engineering dynamics course. Students must demonstrate mastery on eleven skills, but are assessed using a 5-point scale. Each skill is assessed individually using a test question and students are provided with multiple opportunities to display such mastery. This approach appears to overlap or mix with what was previously described as standards-based and mastery-based.

These examples do not introduce forms of computer assistance, but instructors are beginning to add such technology either in class or online (e.g.,Padhye & Blumenstein, 2017). This added level of complexity further muddies the water in terms of being able to compare and classify these emerging grading systems in engineering education. The continual emergence of learning outcomes-based grading system variations suggests a clear need to examine what has/is being done to help engineering instructors and programs navigate the growing grading landscape.

4 USING PRINCIPLES TO DIFFERENTIATE GRADING SYSTEMS

All grading systems are designed to assess student performance within a learning environment. A set of principles, suggested by Heywood (2016), can be used as a first level of filtration to differentiating grading systems used in engineering education. Fig. 1 presents these principles mapped directly to norm and learning outcomes-based systems introduced in the previous sections. A clear dividing line can be made separating principles and grading systems that focus on selecting and developing talent.

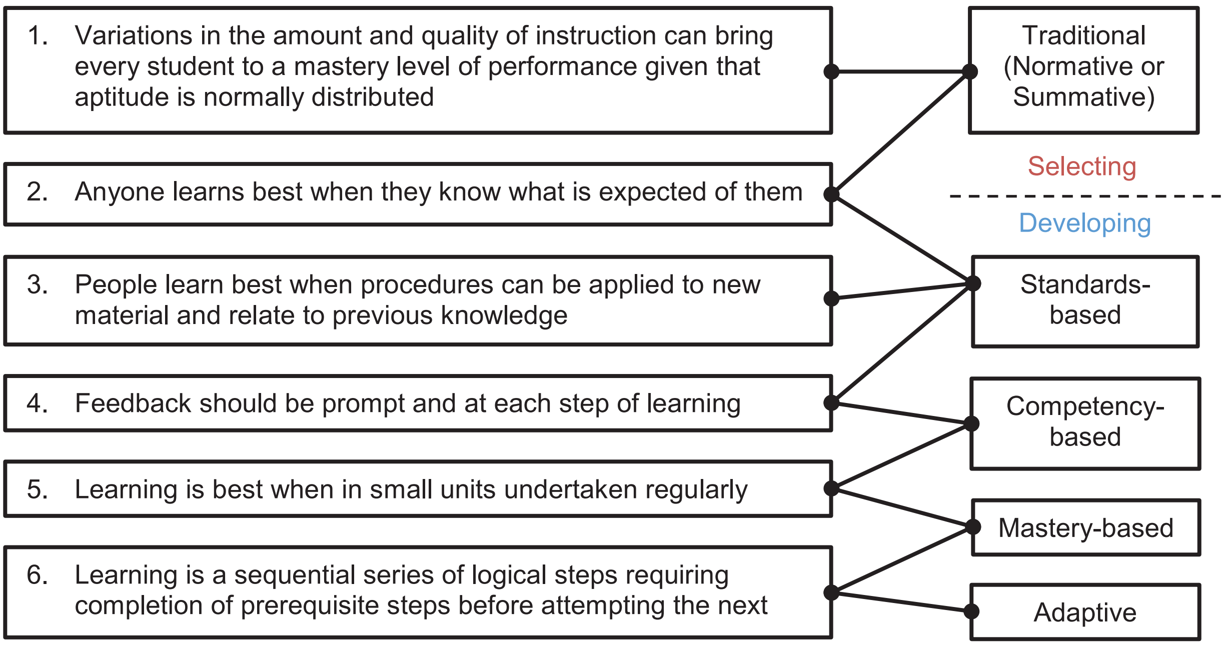

Fig. 1. Mapping of criterion-referenced principles (from Heywood, 2016) and assessment methods found in the literature.

5 A GRADING SYSTEM CONTINUUM

The defining principles of grading systems can be further expounded upon to better understand the degree in which each system attends to these principles and differentiates itself from other grading systems. Fig. 2 places each grading system on a continuum from developing to selecting talent by examining differences in how the grading system impacts sequencing of content, course pace, number of attempts to demonstrate achievement, scale and weight of performance, types of feedback provided, and basis for a final grade.

There is little need to further elaborate on traditional, norm-based grading approaches. The continuum captures the previous discussion, including the primary action of adding up a number of discrete and disparate tasks throughout the semester to determine a student's performance using a 100-point scale or letter grade. LO-based grading approaches have clearly demonstrated variation that has led to subsequent confusion and inconsistent labelling of these systems across instructors and programs. The presented continuum defines each grading system in an effort to alleviate confusions that have emerged due to a lack of a tool to help guide the use and description of these systems.

Adaptive	Mastery-based	Standards-based	Summative Grading	Normative Grading
- Mastery-based + - Entirely self-paced - Unlimited attempts - Entirely sequential - Computer-assisted - Electronically adapts for individual - Immediate feedback	- Based on explicit Learning Outcome (LOs) - Binary performance - Self- or semi-self paced - Multiple attempts on each assessment - Mostly sequential - 1 LO assessed at a time - Yes/no prompt feedback - Course grade based on how many/which outcomes are passed (best/last attempt)	- Based on explicit Learning Outcomes (LOs) and rubrics - Continuum of performance (coarse) - Structured pace - Single attempt on each task - Criterion repeated assessed on increasingly complex tasks - Multiple LOs assessed together - Detailed rubric feedback - Course grade determined by performance on outcome (may be weighted and averaged)	- Based on explicit assignments - Continuum of performance (fine) - Structured pace - Single attempt on each task - Not sequential – moves on - Many LOs assessed together - Points achieved are feedback - Course grade determined by performance on assignments (usually weighted and averaged)	- Summative Grading + - Student performance directly compared to determine grade (i.e., grading on a curve)
100% correct for mastery	Typically 80-90% correct is "mastery"	Performance scale (typically 3-5 point scale)	Typically 100% scale of performance	Letter grade performance

Fig. 2. Continuum of various assessment methods used in engineering higher education.

6 GRADING SYSTEM REFORM

The primary intent of the grading system continuum is to clarify what has become a confusing landscape of grading systems. A secondary goal is to drive grading system reform as a necessity for the future (R.A. Voorhees, 2001). It was estimated in 2015 that over 600 colleges have or are attempting to implement some form of

LO-based grading (Fain, 2015), but it's unclear what has been the basis for such change and how efforts are being benchmarked. An example of a large systematic attempt at grading system reform that can be referenced occurred in primary and secondary education within the United states (US) back in the 1990s. The effort was in response to increasing legislative involvement to set content and performance standards in public education to improve and increase accountability toward monitoring student learning (Marzano, 2011; Reeves, 2002). The primary challenge associated with such a movement is the difficulty overcoming the pervasive mindset that the primary function of grading is differentiating between students rather than assessing a particular student's achievement or competency (Kendall & Marzano, 1996; Guskey, 2011); yet calls for alternative grading approaches in K-12 have risen again with recent concern for accountability in the public education system and online learning (Spencer, 2017).

Adopting a similar approach in higher education should consider the challenges faced in US K-12 education; however, Marzano (2011) and Kendall & Marzano (1996) note that one size does not fit all and that tailoring approaches is difficult to balance against the broadly sweeping standardized criteria set by a state or national panel. These considerations are noted within the context that K-12 and higher education have inherently different structures. Much of the pushback at the K-12 level has arisen from standards that are too exhaustive and do not allow for individual instructors to determine how best to teach the material. Such angst may be inherently ameliorated in higher education because equivalent course-level standards across institutions do not exist. Instructors maintain much more autonomy over their classroom structure and assessment even when designing a course to fit within accreditation standards or institutional goals (Eaton, 2016). This presents an interesting opportunity for courses designed to be "tailor-made to individual schools" (p. 13), which is described as a must for successful implementation (Kendall & Marzano, 1996).

The challenge associated with changing a grading system in such a fashion is that course changes are rarely accompanied by institutional changes, i.e., grades still need to be converted. Additional challenges include a lack of consensus on how to structure courses, what assessment techniques are best, and what actually constitutes a full conversion to an LO-based grading system (Witt et al, 2006). Establishing a consensus and differentiating the variations used by engineering educators will help provide guidelines for those wishing to convert and a standard upon which to compare different systems (JEE).

7 SUMMARY

Higher education engineering instructors have a variety of grading systems to choose from when assessing their students. Traditional, norm-based approaches are still widely used, but alternative LO-based approaches are starting to see greater use in engineering classrooms. The initial overhead to change current practices can be seen as quite large, but the benefits in the long run are worthwhile for students, instructors, and programs (Lee et al., 2018). The presented continuum is a tool that instructors and programs can use to understand the options and help make an informed decision for an individual course or curriculum. It is our role as researchers to help educate our colleagues about grading options using tools like the continuum presented in this paper in order to address greater institutional accountability (A.B. Voorhees, 2001).

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Reconceptualising studies of engineering professional skills: Moving the field on

Darren Carthy
PhD Researcher
TU Dublin
Dublin, Ireland
E-mail: darren.carthy@dit.ie

Kevin Gaughan
Assistant head of school,
Multidisciplinary Technologies
TU Dublin
Dublin, Ireland
E-mail: kevin.gaughan@dit.ie

Prof. Brian Bowe
Head of academic affairs & assistant registrar
TU Dublin
Dublin, Ireland
E-mail: brian.bowe@dit.ie

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ABSTRACT
The authors make use of methodological criticism to criticise the methods used in empirical studies of professional skills and the treatment of skills as objectively real and discreetly measurable. Accordingly, a systematic review of the literature pertaining to engineering professional skills was undertaken to identify positivist papers. After appliying the screening criteria, 36 papers remained and were included in the review. The main findings include: issues with definition of the skills under examinations, issues with the interpetation of Likert scale data and issues with the abuse of parametric statistics. Finally the authors make recommendations for a more interpetive approach to the study of engineering professional skills with the aim of moving the field away from the use of particular methods and practices in this research area.

1. Introduction
When one looks to the study of engineering professional skills there is a great deal of activity at both an European and at an international level, with the European Commission publishing numerous reports on professional skills and the importance of their development for the labour market [1]. Skills are generally defined as the ability to perform a task and can be nuanced depending on the type of task to be completed,

engineering professional skills can be defined as those skills which are valued by an employer [2]. Engineering professional skills are generally studied quantitatively in one of two ways. The first type of study are those regarding *the level* of these skills among students, usually before and after an intervention. The second type are those who wish to know *to what degree* each of a list of skills are important to various stakeholders, for particular engineering disciplines. In this paper, the authors highlight concerns about the methodological approaches to empirical studies in this field and call for a reconceptualization of how one approaches engineering professional skills research; in the hope that this research area can be delineated.

2. Methodology

We assert that these skills are measureable as behaviours that are developed through social interaction. These skills are multidimensional constructs that cannot be understood outside of a particular socio-cultural context [3]. The authors reject deterministic views of social reality that do not consider the effects of social, political, educational and economic processes on the development of professional skills and take into consideration the living processes in which the various stakeholders including industry experts, HR professionals, educators and engineering students themselves are situated, these contextual specificities interfere with a researchers' ability to generalise about *what* skills are important without consideration for *who*, *when* and *where* they may play a role. Skills do not exist independently and can be understood in multiple contexts. There is never a definitive or final comprehension of a skill. The authors acknowledge that individuals can attach different meaning to the same word and in doing so acknowledge the complexity of the research conducted in this area [4]

The authors make use of methodological criticism to highlight concerns over the methods used in empirical studies of professional skills and the treatment of skills as objectively real and discreetly measurable. Methodological criticism is most often attributed to the works of Karl Popper, one of the most prolific philosophers of the 20th century, in particular this paper relies on his work on the nature of scientific inquiry and the falsifiability of scientific methods [5]. The authors would like to make clear that this is not an anti-positivist position paper. Instead, it presents a case for an interpretive approach and highlights the limitations of the quantitative methods currently employed in the literature. Positivism certainly has its' place in education research, however it is the authors' view that the current over emphasis on quantitative data collection has resulted in stagnation of the research conducted on engineering professional skills. A flurry of literature published by the European Commission in this area in the past decade is evidence that the study of engineering professional skills is an integral part of being successful in the labour market [6]. With this vested interest in professional skills comes the responsibility of being rigorous in the approach to studies which seek to investigate these skills.

3. Methods

A systematic literature review was carried out in order to identify articles relating to engineering professional skills. The databases of Wiley, Taylor & Francis, SEFI, IEEE Xplore and ASEE peer were searched with the terms "engineering skills" and “engineering competence” anywhere in the text, this lead to 162,814 papers being identified in the Wiley library alone. The search terms were again implemented to search the article titles. This lead to the identification 1064 journal, conference or magazine publications across the 5 databases. The search criteria were then narrowed to the terms “engineering professional skills”, “engineering professional competence”, ”engineering soft skills”, “engineering graduate skills” & “engineering graduate competence” in the title, leading to the identification of 187 papers with overlap.

Search term	Wiley	Taylor & Francis	ASEE	IEEE	SEFI
Engineering professional skills	6	12	36	31	0
Engineering professional competence	1	3	9	11	1
Engineering soft skills	1	1	7	28	1
Engineering graduate competences	0	0	2	2	0
Engineering graduate skills	3	0	21	11	0

Table 1. Results of systematic literature review

When overlapping papers were removed 27 journals & 151 conference articles remained. Magazine articles were excluded due to lack of a peer review process. Papers reporting on interpretive studies were excluded. Papers were categorised based on the type of study carried out, whether definitions for competences were provided and contextualised and the type of statistical analysis that was carried out. Papers published before 2000 were also excluded. This resulted in 48 papers being screened for this study. Following screening, 37 papers were analysed; 21 regarding assessment of professional skills [7–28] and 16 regarding their importance to a variety of stakeholders [12,23,37–41,29–36]. The main drawback of this review method was the volume of literature that was initially identified on the topic which falls outside the scope of the search criteria, resulting in seminal research in the area being excluded from the screening process.

4. Results

4.1 Issues with definition

One of the issues with the approach of a great many studies into engineering skills is the use of strict definitions of skills which are seldom contextualised for the purpose of the investigation. Participants attach meaning to these skills based on their own lived experience, the definitions provided are therefore subjective and result in a multiplicity of meanings being attached to each definition. In some instances researchers do not provide any such definition. The issue in both instances is that when a participant is asked to indicate *how important* or *how much they have mastered* a particular skill, they are attributing that to experiences which are qualitatively different from those of another participant. It is the authors’ view that the best skills definitions, if they are to be defined at all, are those which can be defined in terms of demonstrable behaviour. In this way, they may be studied in a scientific fashion. Of the 37 papers analysed, 19 did not define the competences they listed. Of the remaining papers, 2 papers defined and contextualised the definitions for the purposes of the study. This lack of definition and of contextualizing the definitions for the purposes of the study raises two issues. If one paper says “Teamwork” is the most important professional skill for an engineer to have and another paper finds the same thing they do not necessarily *mean* the same thing, as the definition of Teamwork is highly contextual and conceptually dense. Teamwork could be stratified into more nuanced skills, such as an ability to negotiate effectively, possessing a positive critical attitude and having the capacity to empathize and listen effectively, for example. These substrata can be further nuanced when one considers the actors which are engaged in these processes. For example, are you negotiating with a client, a teammate or a supervisor? These are the subtleties which are lacking from the body of literature examined in this paper that we would argue makes it difficult to aggregate data collected about skills that are not sufficiently nuanced.

4.2 Issues with statistical analysis

Another observation about the literature which is currently in circulation is the use of parametric statistics on ordinal data. In theory this practice is acceptable, provided the data can be shown to be normally distributed by Shapiro-Wilk or another equivalent test of normality [42]. Little evidence that this has taken place is presented in the current body of literature. Of 18 papers which utilised statistics, 16 utilised parametric statistics, 0 papers reported a test of normality. It is also important that authors making use of parametric statistics acknowledge the theoretical assumptions of such a decision. The biggest assumption being that a Likert scale is an equal measures scale (the distance between a 1 and a 2 is the same as the distance between a 3 and 4, etc) and that the numbers being collected and interpreted are objectively *real*. It is rare that Likert scale data can follow a normal distribution and those which do usually have skewness values outside of an acceptable range [43]. Two papers utilised a non-parametric approach to the analysis of post intervention self-assessments, which highlights a broader issue around what exactly it *means* to have statistically significant differences in self-reported “measures” of skill.

5. Discussion

It is clear that a more interpretive approach to these studies is required. The authors believe that one starting point for a study of this nature is to define skills in terms of measurable behaviours. This opens the door to scientific measurement through behavioural psychology. Such measurements can be made in a behavioral assessment such as a Situational Judgement Test (SJT) [44]. Situational judgement testing can be attributed to the work of Motowidlo, Dunnette & Carter [45] who discussed the use of what they called a low fidelity simulation of behaviours for predicting job success. The authors used the critical incident technique to collect lived experiences from managers in 7 companies around the topics of problem solving, interpersonal and communication skills resulting in the development of a 58 situation and a 30 situation test. Then, they met with 150 managers and asked them to write a few short sentences about how they would react to those situations, these formed the 4 possible responses to each item. Forty-two managers were then asked to select the relative appropriateness of each response before the pilot study took place. The authors found poor correlation between test scores and the Grade Point Average (GPA) of participants but relatively strong correlation with interpersonal skills, negotiation and communication skills which were evaluated in interviews with test participants. We believe that this methodology is consistent with the authors view that skills are multidimensional constructs which are developed through social interaction. There are of course limitations to this method in that a single test item is construct heterogeneous and repeated observations would be required to build a complete picture of a skill and its' interrelated factors. Responses to such tests can be mediated by culture and experience and can therefore be extremely useful instruments in candidate selection. The second potential means of making a measurement of skill is to use the high fidelity scenario, which is observation of behaviour in a group setting. Such research comes with the limitation that observing group behavior may change alter the groups' *true* behaviour. The benefit is a direct measurement of professional skills. Both methods have proven popular in Human Resources for candidate selection, with both methods providing a greater sense of an individual's skill level than a self-assessment.

6. Conclusions

There is a flagrant abuse of statistics occurring in research in this area. The level of abstraction from a self-assessment as measuring skill to interpreting that data as being composed of real numbers is far too great an assumption and so the use of statistics in such studies - should at minimum - come with a section which acknowledges the rather large assumptions made to carry out the analysis and the appropriate statistical tests and their outcomes published to verify that the data are in fact normally distributable and suitable for a parametric approach. More fundamentally the treatment of skills as objectively real and discretely measurable has resulted in the aggregation of rating scale data without due regard for the contextual nature of the definitions of these skills, this pursuit of certainly in the field has resulted in a loss of a sense of meaning in the papers which report such data, what does it *mean* that Problem solving, for example, is rated 1 point higher than teamwork by a stakeholder? And what does it *mean* that students' self-assess their skills after an intervention with higher or lower ratings following an intervention? We believe that there are certainly more interesting questions to be answered in professional skills research that address the context in which these skills are important to a variety of stakeholders that present fresh avenues of inquiry for the engineering education research community to explore.

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Exploring the relationship between spatial ability, individual characteristics and academic performance of first-year students in a French engineering school

S. Charles[1]
Laboratoire BONHEURS, EA 7517
Université de Paris-Seine
Gennevilliers, France
Laboratoire Quartz, SUPMECA EA 7393
Supméca
Saint-Ouen, France

A. Jaillet
Laboratoire BONHEURS, EA 7517
Université de Paris-Seine
Gennevilliers, France

N. Peyret
Laboratoire Quartz, SUPMECA EA 7393
Supméca
Saint-Ouen, France

L. Jeannin
Laboratoire BONHEURS, EA 7517
Université de Paris-Seine
Gennevilliers, France

A. Rivière
Laboratoire Quartz, SUPMECA EA 7393
Supméca
Saint-Ouen, France

Conference Key Areas: Diversity in Engineering Education, Gender, Inclusion and Ethics

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ABSTRACT:

This study is concerned with spatial visualisation and its possible inferences as a necessary ability in French engineering education. It is completed as part of a French

[1] Corresponding Author
S. Charles
sophie.charles@supmeca.fr

research programme, which aims at better understanding how multi-purpose 3-D modelling software is used by learners at different levels of schooling. Spatial ability may be measured thanks to paper tests and predicts choices and success in science, technology, engineering, and mathematics education and professions. It is often described as an ability composed of two factors, namely spatial orientation and spatial visualisation. The latter can be further developed into mental rotation and mental transformation. In order to evaluate the spatial visualisation skills of first-year students in a French engineering school specialised in mechanics, the Revised Purdue Spatial Visualization Tests: Visualization of Rotations, the Mental Rotation Test, which both aim at measuring mental rotation, and the Mental Cutting Test, which aims at measuring mental transformation, were administered to 137 engineering freshmen in September 2018. This data collection was completed with a selection of demographics and academic assessment scores. The purpose of this article is to explore, by carrying out an analysis of variance, how these students' spatial visualisation skills can be related to individual characteristics and how they contribute to academic performance.

1 INTRODUCTION

Spatial visualisation is a component of spatial ability, which predicts success in engineering courses and professions [1]. Although, numerous studies addressing this issue have been carried out in engineering education around the world [2, 3], no similar research has been led in France to our knowledge. In 2016, the French government decided to investigate the impact of the current transformations education is experiencing through the increasing role played by digital tools, by sponsoring research programmes addressing this issue [2]. EXAPP_3D, an e-FRAN projects, aims at better understanding how multi-purpose 3-D modelling software is used by learners at different levels of schooling. This project provides the opportunity to investigate spatial visualisation and its possible inferences as a necessary ability in French engineering education. More specifically, this work aims at studying whether spatial visualisation, as measured by pen-and-paper tests, can predict academic success for first-year students in an engineering school specialised in mechanics. A secondary objective is to explore whether pre-engineering school specialisations and gender are linked to spatial visualisation scores.

2 RESEARCH CONTEXT

Science, Technology, Engineering and Mathematics (STEM) require students to visualise, manipulate and understand two-dimensional (2-D) and three-dimensional (3-D) shapes. Chemistry students analyse the spatial structure of molecules, medicine students learn anatomy, and engineering students model 3-D objects from 2-D representations and analyse mechanisms from 2-D and 3-D representations. Wai, Lubinski and Benbow's longitudinal study highlighted how high school students' spatial ability predicts choices and success in STEM education and careers [1]. The authors studied the evolution of 306,665 subjects from Project Talent [4], who were assessed on their verbal, mathematical and spatial skills while in high school in 1960. The analysis of the eleven-year follow-up after high school graduation established that the likelihood of obtaining an advanced qualification in STEM disciplines, i.e. a master's degree or a doctorate, increased with the spatial ability demonstrated in high-school. It also showed that the individuals who held positions in STEM domains had obtained higher spatial ability scores while in high school.

2.1 Spatial ability

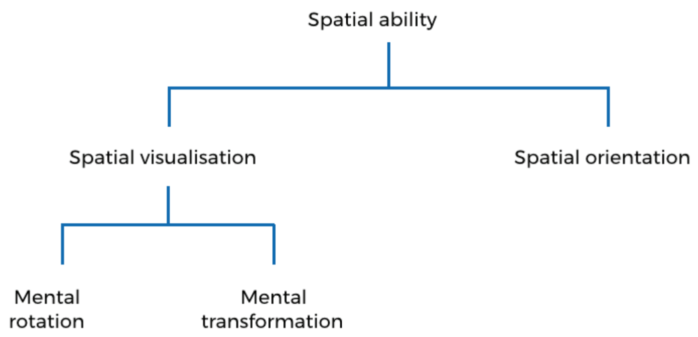
Often described as a set of skills, spatial ability is rarely defined as a single concept [5]. Its most frequently quoted components are spatial visualisation and spatial orientation [6, 7, 8]. This study focuses on spatial visualisation, therefore, spatial orientation will not be detailed.

2.2 Spatial visualisation

Spatial visualisation, as defined by McGee, implies "*the ability to mentally rotate, manipulate, and twist two- and three-dimensional stimulus objects*" [7, p. 896]. This skill is characterised by the mental manipulation of objects. Kersh and Cook [9, cited by 8] further decompose this skill in two sub-skills, namely mental rotation and mental transformation, as illustrated in *Figure 1*. The authors justify this distinction by the size of the transformation: mental rotation concerns the total transformation of an object, whereas mental transformation concerns the partial transformation of an object.

[2] Espace de formation, de recherche et d'animation numérique (e-FRAN) projects are supported by the Ministère de l'enseignement supérieur, de la recherche et de l'innovation.

Fig. 1. Spatial skills classification [Adapted from 8, Figure 3.1]



2.2.1 Mental rotation

Mental rotation "*describes the mental movement of an entire object to a different position*" [8, p. 30]. This term was coined by Shepard and Metzler in 1971, after carrying out an experiment requiring eight subjects to decide whether two perspective drawings of 3-D objects, presented before and following a rotation, were similar [10]. The authors noticed the response time rose with the increase of the angular discrepancy between the two representations of the object.

2.2.2 Mental transformation

This capacity implies "*different operations on separate parts of the mental image*" [9, p. 8, cited by 8, p. 31]. Tartre distinguishes four categories:

- the transformation of a 2-D representation to a 2-D representation, as in mental tangrams;
- the transformation of a 2-D representation to a 3-D representation, as when one mentally folds a pattern to form an object;
- the transformation of a 3-D representation to a 3-D representation, as when one mentally builds a complex object from simple objects;
- the transformation of a 3-D representation to a 2-D representation, as when one mentally unfolds an object.

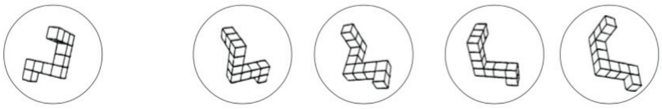
2.3 Measuring spatial visualisation

Numerous pen-and-paper tests exist to assess spatial ability. The most frequently quoted tests are the Mental Rotation Test [11], the Special Aptitude - Spatial Relations, better known as the Mental Cutting Test [12], and the Purdue Spatial Visualization Test: Visualization of Rotations [13].

2.3.1 Pen-and-taper tests measuring mental rotation

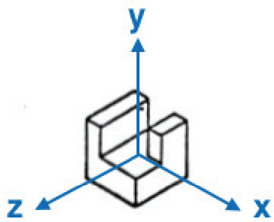
The Mental Rotation Test (MRT) is a pen-and-paper test designed by Vandenberg and Kuse consisting of twenty questions [11]. For each question, a shape is presented and must be identified, once rotated, among four choices. The rotations are carried out according to a central symmetry. Each stimulus corresponds to the isometric drawing of a 3-D object. Half the questions present distractors in the shape of rotated mirror images of the stimulus, and the other half present distractors in the shape of rotated images of one or two of the answer choices. Respondents need to select the two correct answers to score a point. This marking scheme aims at preventing guessing. There are two parts to the test, which are separated by a pause. The time limit for the questions and the pause depend on the test battery and the respondents' experience (A.R. Kuse, personal communication, 25 June, 2018). Albaret and Aubert provide a French version of the test [14].

Fig. 2. Sample question from the MRT



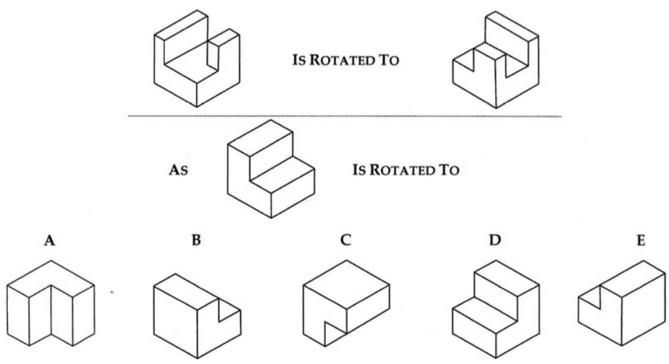
The Purdue Spatial Visualization Test: Visualization of Rotations (PSVT:R) is a 20-minute multiple-choice pen-and-paper test consisting of thirty questions. Each presents a 3-D object represented in two positions. The respondent needs to identity the sequence of rotations required to move the object from the first position to the second, and apply it to a second object, to find the corresponding position it has reached out of four possible answers. The rotations are in 90° multiples, and follow the directions of the object using the right-hand rule. The test displays objects with plane, curved and inclined surfaces. It is designed to restrict analytical processing and "*to measure a specific type of spatial visualizing ability that requires imagining movement according to explicit directions*" [15, p. 9].

Fig. 3. Stimulus from the PSVT:R presented in a 3-D Cartesian coordinate system



The Revised Purdue Spatial Visualization Tests: Visualization of Rotations (R PSVT:R) [17] results from Yoon's revision work, with Guay's permission. In this version of the test, a single problem is displayed per page and the questions are presented in an increasing order of difficulty. There is no time limit to this test.

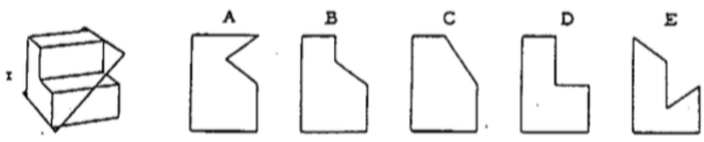
Fig. 4. Sample question from the R PSVT:R



2.3.2 Pen-and-taper test measuring mental transformation

The Special Aptitude test in Spatial Relations, better known as the Mental Cutting Test (MCT), is a 20-minute pen-and-paper multiple-choice questions which contains twenty-five questions [12]. Each problem presents a 3-D object cut by a plane. The respondent must choose the correct resulting cross section out of five possible answers. Some of the questions can be solved by selecting the shape of the cross section, and some further require to take the measure of the sides and of the angles into consideration [16]. Steinhauer [3] studied the correlation between students' performance on the MCT and their 3-D modelling ability. She concluded that a significant relationship existed between the two abilities. She suggested that the efficient use of 3-D modellers and the solving of the MCT problems both require "*the ability to discern the correct 2-D profiles associated with a solid model*" (p. 48).

Fig. 5. Sample question from the MCT



2.4 Research question

Spatial ability predicts student choices and success in engineering [1]. It is linked to the ability to use 3-D modellers [3] and gender [2, 6, 7, 14, 18], and can be measured thanks to pen-and-paper tests. One of spatial ability components, spatial visualisation, enables the total or partial manipulation of 2-D and 3-D objects. This study is aimed at determining whether spatial visualisation, as measured by the MCT, the MRT and the R PSVT:R, can predict engineering students' performance in academic assessments. A secondary objective is to explore whether performance on spatial visualisation tests can be linked to undergrad specialisation and gender. Previous studies [2, 3] allow us to the formulate the hypothesis that spatial scores will predict student performance in assessments which require the mental manipulation of 2-D and 3-D representations, and that male students will outperform female students on the spatial tests. We also predict that students who received training in complex system analysis and modelling will outperform students who did not benefit from such experience.

3 RESEARCH DESIGN

3.1 Participants

Students join Supméca, a French engineering school specialised in mechanics, upon successful qualification through several recruiting processes : they need to pass competitive entry exams, after completing intensive preparatory courses, the first two years of a university degree or obtaining a vocational qualification (DUT). Students coming from intensive preparatory courses are specialised in Mathematics and Physics (MP), Physics and Chemistry (PC), Physics and Engineering (PE), Physics and Technology (PT), or Technology and Industrial Science (TIS). PT, PE and TIS students are taught about complex systems form 4 to 8.5 hours a week, whereas this course is optional for MP students and not part of the PC students' curriculum.

Table 1. Hourly volumes of subjects in the MP, PC, PE, PT and TIS courses

	Mathematics	Physics	Chemistry	Industrial science
MP	12	7	2	(2)
PC	9	9	5.5	-
PE	10	7.5	2.5	4
PT	9	6	2	8.5
TIS	10	6	2	7

Note: Industrial science courses cover complex mechanism analysis and modelling.
() indicates these lessons are optional.

The students were aged between 18 and 23, mean 20.35. 137 students (N_F = 37 [27%] women and N_H = 100 [73%] men) took the MCT and the MRT. 131 students (N_F = 36 [27.48%] women and N_H = 95 [69.34%] men) took the R PSVT:R.

3.2 Instruments and procedure

3.3.1 Spatial tests

In September 2018, 137 freshmen took the MRT and the MCT and 131 freshmen took the R PSVT:R:

- MRT: the students were given three minutes to complete the first part and three minutes to complete the second part of the test. They benefited from a two-minute break. Such timing was deemed appropriate for our sample by one of the authors (A.R. Kuse, personal communication, 25 June, 2018). We used the French version of the test [14].
- MCT: the students were given twenty minutes to complete the test, as prescribed on the test paper. We used our own translation.
- R PSVT:R: the students were given a time limit of one hour, for timetabling reasons and based on the author's indication that most students complete the test in thirty minutes (S.Y. Yoon, personal communication, 16 May 2018). We used our own translation, which was approved by the author (S.Y. Yoon, personal communication, 18 October 2018).

We decided to translate the tests for which a French translation was not available so that English ability would not affect student performance. We used the pen-and-paper versions of the tests. The students answered directly on separate answers sheets for the MCT and the R PSVT:R, but answered on the question papers and reported their answers on the answer sheets during the break and after the test for the MRT. The students were instructed to not guess the answers. The order of the tests was chosen depending on the time slots. Some groups took the MRT and the MCT during the same session, and the R PSVT:R at a different time on the same day. Other groups took the MRT and the MCT during the same session, and the R PSVT:R on a different day.

3.3.2 Academic assessment

Individual assessment scores and assessment descriptions for the first term were collected from the student office and teachers. They were part of the following courses: Applied Mathematics (APMA), Mechanism Analysis (MEAN), and Algorithmic and Programming (ALPR). All the data were anonymised.

APMA addresses distributions of real variables and the Laplace transform. The assessment focused on distributions, convolutions, the Laplace transform and the Fourier transform.

MEAN aims at teaching students how to analyse an industrial mechanism to sketch its kinematics schematic representation, identify the necessary technological conditions for its efficient operation, check its performances using calculations, and propose a manufacturing method for some of its components. The assessment included 2-D representations of a 3-D object from different perspectives, horizontal and vertical cross sections (*Figure 6*), and an exploded view. Students had access to a digital model in CATIA [19], with which they could generate different representations of the system they were analysing, as illustrated in *Figure 7*.

Fig. 6. Examples of perspectives and cross sections presented in the MEAN assessment

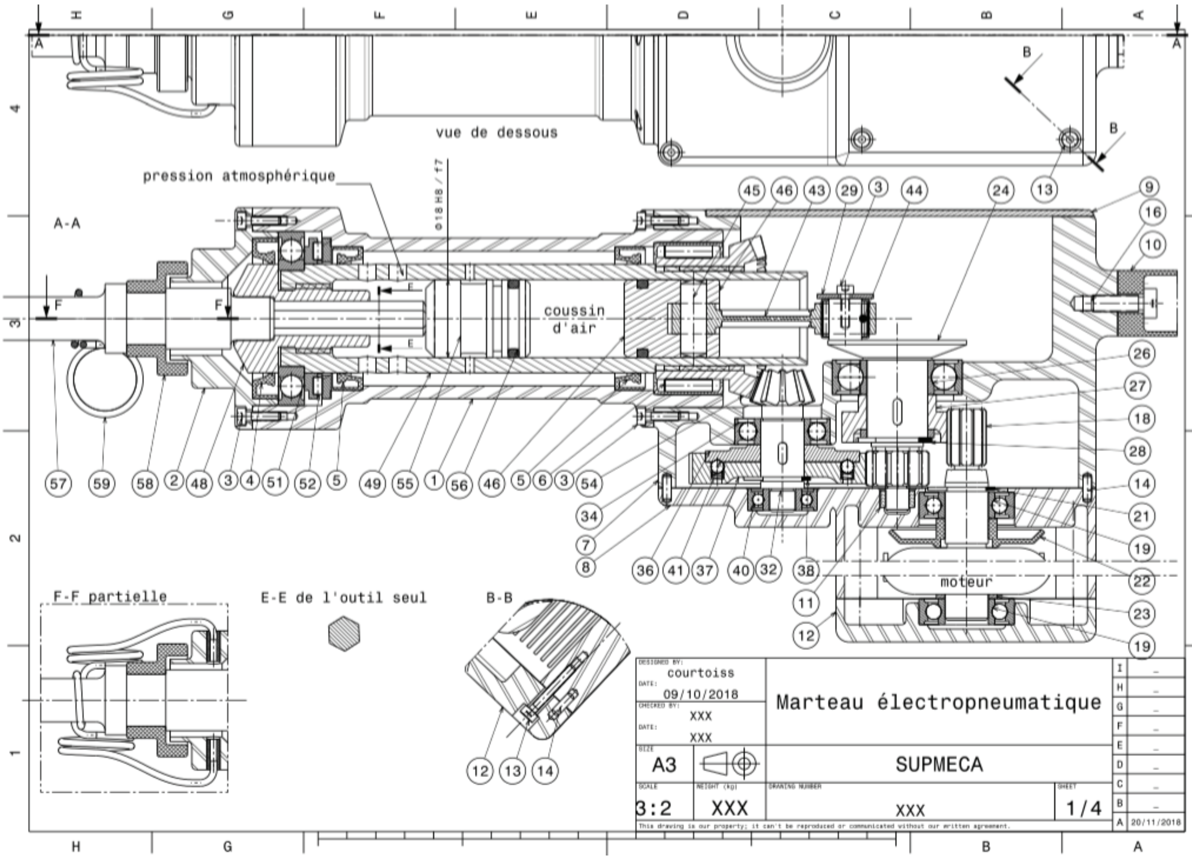
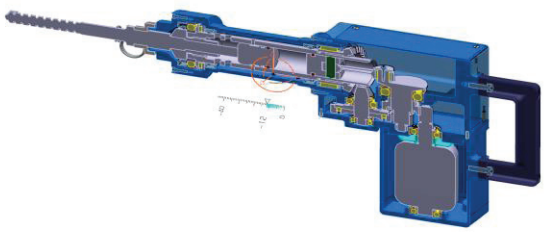


Fig. 7. Example of a perspective representation of a cross section generated in CATIA



ALPR deals with the acquisition of basics in algorithmic, fundamental data structures, and C programming language. Assessment ALPR1 focused on the understanding of code and the writing of simple functions. ALPR2 focused on algorithmic and C programming language.

3.3.3 Data analysis

An analysis of variance (ANOVA) was performed to explore the link between student performance on spatial tests and academic assessments, using SPSS. For each analysis, the spatial test score was used as the independent variable and the academic result was used as the dependent variable.

Means and standard deviations for each group, i.e. males, females, undergrad specialisations, were calculated to compare performance on the spatial tests.

4 RESULTS

Students' spatial scores are presented in *Table 2* and results for APMA, MEAN, and ALPR in *Table 3* respectively.

Table 2. Spatial scores

Spatial test	Highest score possible	Mean	Standard deviation	N
MCT	25	15.14	5.60	137
R PSVT:R	30	24.12	4.25	131
MRT	20	12.24	4.23	137

Table 3. Academic results

Course	Highest score possible	Mean	Standard deviation	N
APMA	20	11.40	3.68	140
MEAN	20	13.02	2.53	138
ALPR1	20	15.12	3.23	138
ALPR2	20	12.65	4.35	134

The significant results following the ANOVA are presented in *Table 4*.

Table 4. Analysis of variance

Dependent variable	Predictor	P-value	Coefficient	Constant
ALPR1	MCT	0.007 **	0.139	13.050
ALPR1	R PSVT:R	0.041 *	0.140	11.847
ALPR1	MRT	0.012 *	0.171	13.060
ALPR2	MCT	0.036 *	0.145	10.420
APMA	MCT	0.038 *	- 0.116	13.127
APMA	R PSVT:R	0.049 *	- 0.145	15.024
MEAN	MCT	0.001 **	0.241	9.394
MEAN	MRT	0.016 *	0.240	10.277

Note : ** $p \leq 0.01$
* $0.01 < p \leq 0.05$

The ANOVA revealed a low significant prediction capacity of the R PSVT:R ($p = 0.041$) and the MRT ($p = 0.012$) for performance on ALPR1, and of the MCT ($p = 0.036$) for performance on ALPR2. It also showed a highly significant prediction capacity ($p = 0.007$) of the MCT for performance on ALPR1. It indicated a low significant prediction capacity of the MCT (0.038) and the R PSVT:R (0 = 0.49) for performance on APMA. Finally, this analysis brought to light a highly significant prediction capacity ($p = 0.001$) of the MCT and a low significant prediction capacity ($p = 0.016$) of the MRT for performance on MEAN.

The mean scores for undergrad specialisations are presented in *Table 5*. Those for men and women are presented in *Table 6*.

Table 5. Spatial scores according to undergrad specialisation

	MCT		R PSVT:R		MRT	
DUT	Mean	17.4 (SD= 5.16, N= 5)	Mean	26 (SD= 2.19, N= 5)	Mean	13.2 (SD= 4.87, N= 5)
	Mean %	69.6	Mean %	86.66	Mean %	66
MP	Mean	13.5 (SD= 5.46, N= 44)	Mean	24.35 (SD= 3.93, N= 44)	Mean	11.47 (SD= 4.42, N= 44)
	Mean %	54	Mean %	81.19	Mean %	57.38
PC	Mean	14.10 (SD= 5.39, N= 19)	Mean	24.36 (SD= 4.45, N= 19)	Mean	12.31 (SD= 3.74, N= 19)
	Mean %	56.41	Mean %	81.22	Mean %	61.57
PE	Mean	15.91 (SD= 4.88, N= 45)	Mean	23.64 (SD= 4.01, N= 42)	Mean	12.33 (SD= 4.09, N= 45)
	Mean %	63.64	Mean %	78.80	Mean %	61.66
PT	Mean	20.45 (SD= 4.05, N= 11)	Mean	25.5 (SD= 3.44, N= 10)	Mean	15.72 (SD= 3.13, N= 11)
	Mean %	81,81	Mean %	85	Mean %	78.63
TIS	Mean	22 (SD= 2.16, N= 3)	Mean	28.33 (SD= 1.69, N= 3)	Mean	14.33 (SD= 2.62, N= 3)
	Mean %	88	Mean %	94.44	Mean %	71.66

Table 6. Spatial scores for men and women

	MCT		R PSVT:R		MRT	
Men	Mean	14.86 (SD=5.42, N=100)	Mean	24.26 (SD= 3.75, N= 95)	Mean	12.19 (SD= 4.16, N= 100)
	Mean %	65.12	Mean %	82.94	Mean %	66.10
Women	Mean	12.08 (SD= 4.81, N= 37)	Mean	22,11 (SD= 4.75, N= 36)	Mean	9.62 (SD= 3.06, N= 37)
	Mean %	48.32	Mean %	70.70	Mean %	48.10

Men outperformed women in all tests. Students with technical backgrounds, i.e. DUT, PT, PE and TIS, outperformed students with other backgrounds, i.e. PC and MP, in the MCT and MRT, although the limited size of the samples of students with technical backgrounds does not enable us to draw conclusive comparisons.

5 DISCUSSION

The ANOVA showed there is a weak to strong significant relationship between the spatial tests used in this study and the academic assessments for ALPR. Although these did not contain spatial elements, correlations between spatial ability and computer science have been established: Wai et al.'s study showed that Project Talent's subjects who gained masters or doctorates and held positions in computer science demonstrated higher spatial ability in high school [1].

The analysis revealed a weak significance of the capacity of the MCT and the R PSVT:R to predict performance in APMA. This assessment did not contain visual elements, but the negative correlation indicates that high scores on the spatial tests predict failure in this subject, whereas low scores predict success. According to the assessment's author, solving the problems presented in this assessment requires abstraction (S. Dugowson, personal communication, 3 April 2019). Does this mean that individuals with high spatial skills lack this ability? Inversely, does this mean that individuals who possess it are characterised with low spatial skills? There is a notable difference between the ANOVA results for the MRT and the R PSVT:R, which both claim to measure mental rotation, but whose administration procedures are different.

The MRT is time-limited, as time restriction discourages analytical processing [6]. Analytical processing, which allows subjects to decompose objects in smaller elements to enable comparison, does not make use of mental rotation [6], which involves the mental manipulation of visual objects. Post-test consultation of respondents' solving strategies shows that the MRT allows for a variety of strategies [14, 15]. On the contrary, the R PSVT:R is not limited in time to avoid female underperformance, as women tend to get lower scores when they take time-limited tests [18]. As far as we know, no study has described the use of analytical processing in solving the R PSVT:R items. The difference in the ANOVA results for the MRT and the R PSVT:R could be explained by the fact that the R PSVT:R is a more reliable instrument to measure mental rotaion.

Using visual information presented in perspectives and cross sections implies the ability to understand and interpret different means of representation of the same information. The significant correlations between the MCT and the MRT scores and the MEAN results can lead to several interpretations: the spatially weak students could not interpret and use the visual information provided in the assessment, use the 3-D modeller successfully [3], nor benefit from the information available in the modeller because their weak internal representations did not allow them to access external representations [20]. The absence of a correlation between the R PSVT:R and the MEAN results, whereas there is one with the MRT, could be explained by the fact that the MEAN assessment does not make use of mental rotation.

The well-documented lower performance of women on spatial tests [2, 6, 7, 14, 18] is confirmed in our study, which also highlights a difference in performance according to the undergrad specialisation. Students with more technical backgrounds, i.e. DUT, PT, PE and TIS, outperformed other students in the MCT and the MRT, although this conclusion must take into consideration the small size of the samples of students with TIS, PT and DUT backgrounds. Interestingly, the PT, PE and IST students are taught about complex systems form 4 to 8.5 hours a week, whereas it is optional MP students and absent from PC students' curriculum. The very close scores of PE and PC students on the MRT and the R PSVT:R seem to indicate that this course has a greater impact on performance on the MCT.

4.4 Limits and perspectives

The students were not asked which strategies they adopted while taking the spatial tests. It is therefore difficult to assert which spatial skill, if any, was made use of during the tests. Further experiments including the collection and the encoding of these data are necessary to clarify this variable.

The MEAN assessment allowed students to access CATIA, where they could create richer isometric views – the views are in colours and shadows represent depth - and 2-D representations: e.g., possibility to hide and reveal parts and to choose a point of view or a cross section. The students' activity on the software was not recorded. A complementary study is necessary to explore how student use, or lack of use, of the software is related to their spatial skills and performance on the assessment.

6 CONCLUSIONS

The spatial visualisation skills of French first-year engineering students, who joined the school after a two-year undergrad course, were measured with the MCT, which aims at measuring mental transformation, the MRT and the R PSVT:R, which aim at measuring mental rotation. The students took the tests at the beginning of the academic year. An analysis of variance of these scores and their performance on assessments focusing on applied mathematics, system analysis, algorithmic and C language programming revealed a highly significant capacity of the MCT to predict performance on mechanism analysis and C language understanding and programming. It also highlighted a low significant capacity of spatial visualisation skills to predict performance on the ability to understand codes and write simple functions in C language, as well as a low significant capacity of the MRT to predict performance on mechanism analysis. Finally, it brought out a fairly significant negative correlation between spatial visualisation and the ability to solve problems focusing on distributions, convolutions, the Laplace transform and the Fourier transform. Our hypothesis that spatial visualisation and performance in assessments including 2-D and 3-D representations has been validated. Our study revealed a link between spatial visualisation and the ability to understand codes and write simple functions in C language, confirming previous research that spatial ability and performance in computer science are related [1]. A negative correlation was also found between spatial visualisation and performance in applied mathematics. The well-documented underperformance of female students, compared to male students, was confirmed in our study and a better performance for students coming from undergrad technical backgrounds was observed. The capacity of spatial tests to predict performance in engineering courses [1] and the malleability of spatial skills have been established [5]. These findings open the possibility to design and implement remedial courses, prior to the beginning of the academic year, to support French engineering student learning and performance [2], and give students access to a larger choice of specialisations in their academic career.

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Startup Garage: The Way to Apply Knowledge

Check your idea. Get involved. Be inspired

M. Citraro, S. Cometta, C. Carcano, L. Sommaruga, A. Righetti, T. Cataldo
University of Applied Sciences and Arts of Southern Switzerland (SUPSI)
Lugano - Switzerland

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Keywords: Entrepreneurial Education, Idea Management, Idea Scouting, Startup, Web Application

ABSTRACT

Based on the vocational model - which made Switzerland one of the best places for young people to start working - DTI *Startup Garage's* mission is to go further in developing individual skills, such as entrepreneurial attitude. At the end of October students are called to register their own business ideas. These will then be processed through an innovative web application (*PingelApp*), used to match proposal ideas with the most suited teacher and researcher, who have initially accepted to be *Standby Mentor*. Once associated with the student (*Idea Owner*), *Standby Mentors* assess the idea and, together with a larger evaluation committee, choose which student can be called *Idea Startupper*. *Standby Mentors* can voluntarily endorse the students' idea to be actively further supported. At the end of every academic year, *Idea Startuppers* who want to remain in the *Startup Garage* must pass through a tailor-made training program. The *Startupper* is responsible to develop her/his roadmap of technical and entrepreneurial knowledge. Room 177, aka *Startup Garage*, is organized exclusively to let students work at their ideas in a free area, now generally considered an enjoyable and creative place to be in.

1 INTRODUCTION

Based on the dual education system - which made Switzerland leader in Innovation (*Table 1*) and an outstanding country enhancing "Human capital" (see World Economic Forum: https://www.weforum.org/reports/the-global-human-capital-report-2017, consulted 2019/06/25) - DTI *Startup Garage's* mission is to go further in developing individual skills, such as entrepreneurial attitude, as the basis for students to possibly become entrepreneurs. To that effect, a method was developed to scout entrepreneurial ideas among all students who attend academic courses in different branches of the Department of Innovative Technologies (DTI) of the University of Applied Sciences and Arts of Southern Switzerland.
In order to contribute to keeping up the Swiss innovation ecosystem, a new concept has been developed in a Swiss university where experience is *leitmotiv* of the educational framework. "*Startup Garage Concept*" must be thought as a method-based search for applying knowledge aiming at discovering practical solutions. Problems are identified by students and, thanks to their creativity, bound to be solved in some way. In so doing, principles for promoting innovation are experienced by students attending courses at our university.
Startup Garage offers all students opportunities to turn knowledge into promising business ideas. Along those lines our motto is "The way to apply knowledge". The

way leading to *Startup Garage* is easier to engineering students, who are typically provided with natural talent useful to develop entrepreneurial skills. This kind of students have ideas and can turn them into action developing entrepreneurial spirit at the same time. In a way to discover ideas the team of *Startup Garage* carries out a horizontal approach and cross curricular scouting throughout all engineering bachelors.

Table 1. Bloomberg Innovation index, 2018 (from https://www.bloomberg.com/news/articles/2019-01-22/germany-nearly-catches-korea-as-innovation-champ-u-s-rebounds, consulted 2019/04/16)

2018 rank	2017 rank	YoY change	Economy	Total score	R&D intensity	Manufacturing value-added	Productivity	High-tech density	Tertiary efficiency	Researcher concentration	Patent activity
1	1	0	S. Korea	**89.28**	2	2	21	4	3	4	1
2	2	0	Sweden	**84.70**	4	11	5	7	18	5	8
3	6	+3	Singapore	**83.05**	15	5	12	21	1	7	12
4	3	-1	Germany	**82.53**	9	4	17	3	28	19	7
5	4	-1	Switzerland	**82.34**	7	7	8	9	11	17	17
6	7	+1	Japan	**81.91**	3	6	24	8	34	10	3
7	5	-2	Finland	**81.46**	8	16	10	13	19	6	4
8	8	0	Denmark	**81.28**	6	15	11	15	26	2	10
9	11	+2	France	**80.75**	12	35	14	2	10	21	9
10	10	0	Israel	**80.64**	1	27	9	5	41	1	19
11	9	-2	U.S.	**80.42**	10	23	6	1	42	20	2
12	12	0	Austria	**79.12**	5	8	15	26	12	12	5
13	16	+3	Ireland	**77.87**	22	1	1	18	20	14	33
14	13	-1	Belgium	**77.12**	11	22	13	10	37	13	21
15	14	-1	Norway	**76.76**	19	37	19	11	23	8	14

A dynamic environment enables innovation to be promoted. Space and support to succeed are provided to innovative projects. A new kind of teaching method can identify good ideas among students with outstanding pioneering potential.

The main goal is to transfer knowledge gained by students at school and apply it by working at their own entrepreneurial ideas. The expectation is that the chances to set up and develop science-based companies will increase and science-based innovation will be encouraged. In promoting science-based entrepreneurial initiatives, connections between higher education institutions, the private sector, and society will be strengthened, and accelerated also through the use of digital tools [1].

2 GENERAL DESCRIPTION OF THE DTI STARTUP GARAGE

The main details of how it is working are:

- Students attend courses for a variety of bachelor studies, thus enabling useful cross-fertilization
- Active Standby Mentors are available to help students to develop their Startup ideas
- A webapp, PingelApp, associates the idea with the competent Standby Mentors
- Idea Startuppers can ask for financial support to develop their MVP (Minimum Viable Product) and obtain refunds for costs incurred in developing business ideas
- The Startup Garage Team is always available whenever students ask for assistance

- Lunch Seminars are organized to achieve milestones which mark progress in developing Startup Ideas and, if achieved, enable students to remain in the Startup Garage
- Business Cake Events with teachers and students are enjoyable moments to deepen discussions
- Assignment of vocational credits from courses teaching entrepreneurial soft skills, in order to integrate part of the courses taught by Standby Mentors
- Students can prepare their work in order to participate in competitions for the most prestigious startup accelerator
- Students promote their entrepreneurial ideas among secondary school pupils in order to foster innovation and creativity
- The Startup Garage offers entrepreneurship-related courses to students on an on-going basis

3 STARTUP GARAGE: A THREEFOLD CONCEPT

3.1 Startup Garage: the space where ideas can be worked on

Like an “island of freedom” (the name of the app comes from a Micronesia island: Pingelap) Room 177 at SUPSI, is a physical location of the *DTI Startup Garage*. Here, students can put classical theoretical-scientific instruments and knowledge, which they gradually obtain during their curricula, at work into a stimulating practical adventure. In fact, students are enabled to develop their own entrepreneurial ideas without taking the risks of real entrepreneurs, but growing into dynamic people enabled to become real entrepreneurs at the end of their academic path.
Startup Garage is an enjoyable and creative place set up recently inside a Department (DTI) that is focusing on the applied engineering sciences, in general within the industrial sector, and with technology and information services for both training and research.
In developing the “*Startup Garage Concept*”, a physical area had to be laid out, in order to make an impacting space useful to reach the main goals of the course. In the traditional conceptual framework, academic rooms are still thought as an orderly learning space where students can develop their ideas [2]. However, in Room 177, a new space has been created in which rules of freedom and openness help ideas to become useful products or services.
Only enrolled and motivated students, with good entrepreneurial ideas, obtain exclusive access to the *Startup Garage* and to its benefits. In the Garage students can put classical theoretical-scientific instruments and knowledge, which they gradually obtain during their curricula, into a stimulating practical adventure. But no credits are awarded yet, no award-winning contest is directly promoted, nevertheless Idea *Startuppers* are helped to take part in national and international related competition. Startup Garage is a methodological way to back vocational education and training as developed in Switzerland, in order to be much oriented towards entrepreneurship and self-consciousness of own business ideas.

3.2 An entrepreneurial approach to teaching: Teachers and Technology as supporters and facilitators

In a responsible way, engineering students, as motor and genius, are able to switch on a renewable digital economy boosted by freedom and creativity (*Fig. 1*). Leonardo Da Vinci, genius but “*omo senza lettere*”, put the **Man at the centre of the earth and**

universe. Accordingly, we should nowadays find next generation innovators, who put their good ideas at mankind's disposal.

Academic education, as delivery of learning, surely contributes to form and reshape breeding ideas, but it fails to promote entrepreneurial attitude, especially at the very beginning of the academic curricula.

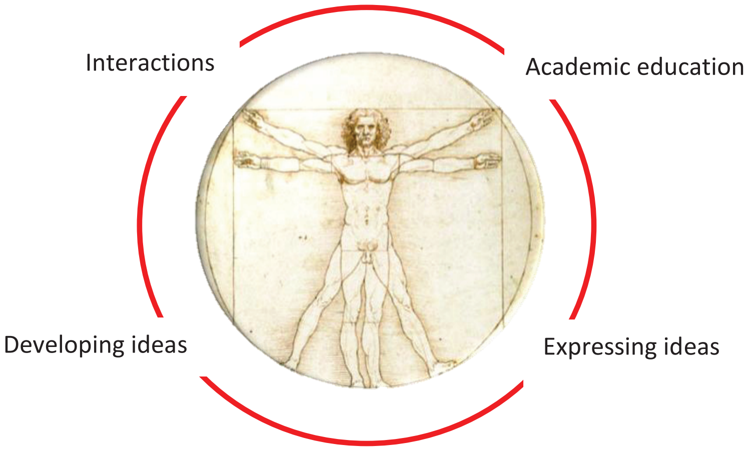

Fig. 1. Student-centered approach - Personal elaboration

Beyond formal learning objectives, the management team of the *Startup Garage* is helping students to develop entrepreneurial ideas and go further into business aspects. Inside the Garage, students can find an openness and free access to functional knowledge to be tapped into in order to spread the entrepreneurial spirit among students.

This approach fosters collaborative creativity, sustainable adaptive learning, new credentialing, peer learning, and the understanding of assessing business opportunities on a continuous basis.

Management mission

The Startup Garage Team is made up of persons with different backgrounds but united by the same goal: helping students to succeed in their entrepreneurial initiatives as a good way to keep on studying in a stimulated academic environment.

In developing a particular entrepreneurial teaching approach (see "on a renewed EU agenda for higher education" https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52017DC0247), the Team believes in human relationship as well as human capability to learn by doing, which has shown to be very useful to motivated students.

PingelApp

At *Startup Garage*, in order to support the entrepreneurial teaching aims, a collaboration started with ICT colleagues to exploit digital technologies for developing student business ideas and facilitating the management process. The initial approach was to develop a web application, *PingelApp,* that provided on one hand the capture, collection, and management of young students' ideas in a rationale and homogeneous way, and, on the other hand, it allowed a gathering of skills of potential teachers and researchers who could act as Standby Mentors. In this way students' idea needs and mentors' expertise are collected. A further step in this innovative platform for the management of ideas and of the ideation process was completed by

an algorithm that associates an idea with a potential mentor, based on the needs expressed in the idea description and the competences declared by the mentors.
The PingelApp project was developed in two phases: in the first phase, as a result of a semester project of the SUPSI Bachelor course in Computer Engineering [3], a first robust platform was created for the collection of ideas and skills, with a basic automatic matching mechanism mentor-idea; in a second phase, through a diploma thesis [4], the system was improved focusing on the graphical and algorithmic aspects of the application, in order to further facilitate the process of collecting and managing ideas thanks to a more usable and attractive layout, and at the same time, to find a better matching between mentors and ideas.
The heart of the webapp, i.e. the matching algorithm, was also enhanced thanks to the semantic relatedness similarity [5] between words of the WS4J library [6] based on WordNet [7]. Using the Wu/Palmer [8], Lin [9] and Lesk [10] algorithms, and the WordNet lexical database, the application currently calculates the correlation between ideas and Standby Mentor.
The development of this web application is still in progress both for what concerns the introduction of new functionalities and for the code cleaning and refactoring.

PingelApp Roles and Actors

The main features of the *PingelApp* can be summarized by describing the roles of the main actors involved.
Unauthenticated users can access all the published public information about ideas and calls on the web application. In addition, there are four main authenticated roles of users within the webapp: the *student*, the *standby-mentor*, the *manager*, and the *admin*.
Users with *manager* role can create, open and manage new calls for ideas, mainly by setting a title, a start and an end date. The manager can also define some visibility criteria to let other users access the presentation of ideas.
Standby-mentors can enter the system and, after having filled in their list of core-competencies to describe their expertise, find any associated idea, which matches the offered competences.
Users with *student* role act as idea owners, they can insert a new idea related to an open call for ideas, edit or view her/his inserted ideas, where the associated mentors are also displayed when available.
An ad*min* user is also present in order to manage *PingelApp,* i.e. the creation, updating and deletion of all its elements.
Ideas are inserted according to a precise structure defined also on the basis of previous work carried out at SUPSI about a web application for managing the breeding of ideas [11].
The idea structure is a core concept at the base of *PingelApp* and is exploited to capture the essence of an idea through a number of fields: a title, a description, a representative image, an optional short video (such as a pitch), a story about the birth of the idea, differentiation, motivation, application fields, and required competencies.
An example (*Fig. 2*) in which an idea (left column) called SMARS — Screwless Modular Robotic System — has been associated by the *PingelApp* to a *Standby Mentor* who wanted to be active (self-candidates, right column), although the matching system recognized other possible *Standby Mentors* (suitable mentors proposed by the matching algorithm, central column).
Independently from the automatic *PingelApp* matching suggestion, *Idea Startuppers* do choose their favourite “Active Standby Mentor”. Throughout the entire matching

process the *Startup Garage Management* acts as supervisor and checks the consistency between the business idea and the Standby Mentor selected.

Fig. 2. WebApp' s partial view of the matching between Ideas and Standby Mentors.

Idea Featuring

Business ideas are classified according to typical industry sector definitions as appeared in "Industry Classification Benchmark" published by the FTSE (https://www.ftserussell.com/data/industry-classification-benchmark-icb) and their *Supersector*, *Sector* and *Subsector,* where possible.

Assessment Process

Members of the *Startup Garage Management*, and *Standby Mentors* build-up the "Evaluation Committee" in charge of assessing entrepreneurial ideas to be eventually elected as *Startup Ideas*. Quantitative results are generated automatically in order to make this important task easier. Each *Standby Mentor* associated by the *PingelApp* to a particular idea receives the following "Assessment Sheet" (*Fig. 3*) to be filled out on the idea associated with him or her.

Name of the Startup Idea: **@ Coffee**

Evaluation criteria for admission to the DTI Startup Garage

Meaning of numerical evaluation:

1 = No Relevance
2 = Unforeseen Evaluation
3 = Some Chances If
4 = Good Opportunities
5 = Brilliant Future Applications

Put your numeral evaluation as defined above for each criteria listed in the table below

Innovation items	Technology Feasibility/Implementation	Potential Breakthroughs	Points

Name of the Standby Mentors assessing the Startup Idea: ______________________________

NB: Admission is not granted if the results is below 6 points

Fig. 3. Idea's Assessment Sheet.

Once the presumably best ideas have been selected, "Idea Owners" will become "Idea Startuppers". They get a *Startuppers kit*, made up of a T-shirt, a badge for 24h free access to the Startup Garage space and the opportunity to be assisted by an "Active Standby Mentor" who endorses the idea he or she has reviewed and considered viable. As a result, *Active Standby Mentor*s are ready to assist *Idea Startuppers* in progressing with their business ideas during their academic and vocational path, well beyond a particular semester period.

At the end of the academic year, the "Evaluation Committee", based on *an add-on endorsement* by the *Active Standby Mentor*, decides if the project deserves to be further supported and if the team can maintain their status as Idea Startuppers.

3.3 Vocational Training Education

Entrepreneurship education is underpinned by the model depicted in *Fig. 4*. In order to carry out updating assessments, three milestones have been set to enable the evaluation progress on a regular basis. According to the contents of the milestones shown below, *Idea Startuppers* are invited to show what they have done in the previous 3 months and to explain the current status of their *Startup Idea,* inside an entrepreneurship education framework and training opportunities.

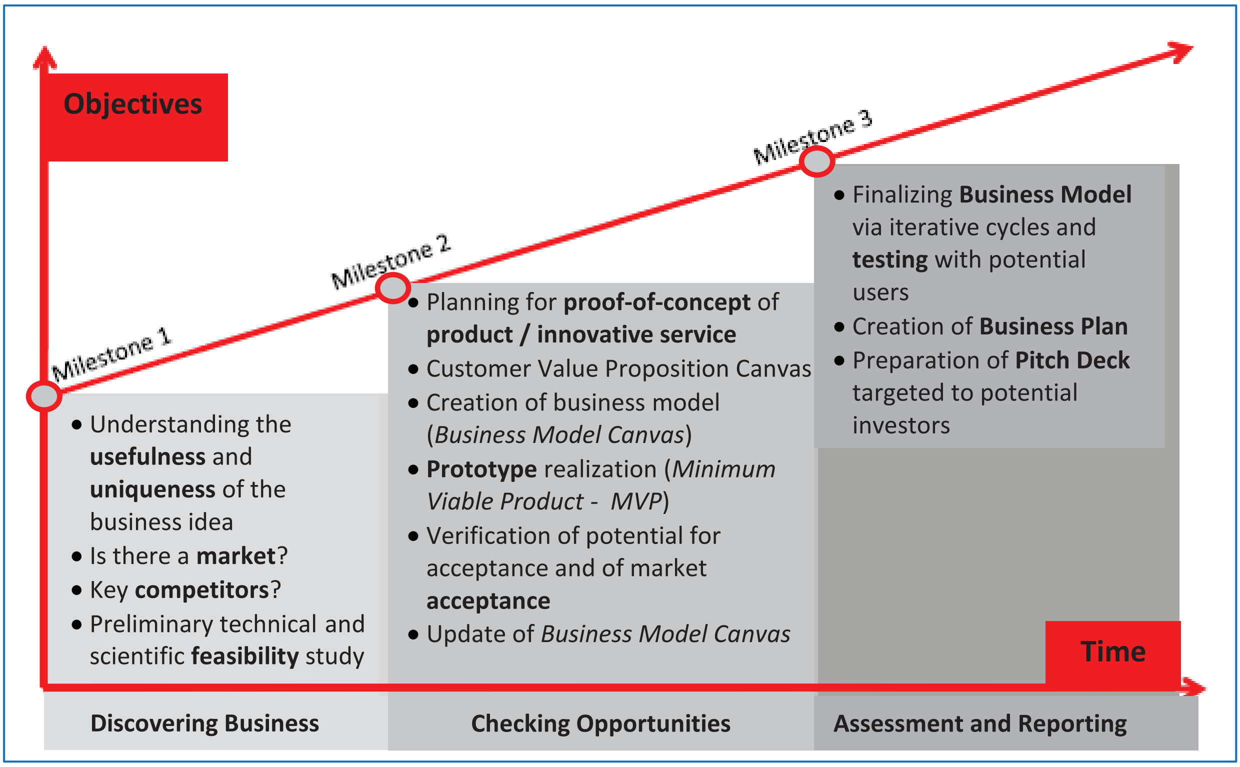

Fig. 4. Business Idea Management.

Functional Events

The Startup Garage Team organizes training units on general interest topics for entrepreneurial, personal and managerial skills with guest speaker or case studies.
Business cake events are organized every first Thursday of each month, special courses (often as lunch seminars) are offered to the *Idea Staruppers* comprising subjects such as "Teamwork", "Business model, Business plan, Accounting and Financial sheets", "Private funds from banks and business angels", "Marketing", "Intellectual property ", "Reports and presentations", "Crowdfunding" bringing into focus Pitching tailored to enable the Startupppers to participate at important Swiss startup competitions.
Whilst the topics related to the technical, scientific and productive aspects linked to the idea are developed with the support of the *Standby Mentors* and with experts and entrepreneurs.

Soft Skills

The Startup Garage Team takes care of the application of soft skills [12] that allow Idea *Startuppers* to improve their own personal skills. The Startup Garage Team supports and motivates *Idea Startuppers* to overcome difficult times and situations with the aim of giving the skills so that the *Idea Startuppers* learn to support each other. In this sense, a focal point is the “Cross functionality”. Functional team members serve not only as the team’s conscience in their particular area of expertise, but also as enthusiastic ambassadors.”

4 STARTUPGARAGE, A USEFUL TOOL TO BUSINESS COMMUNITY

Startup Garage Team wants to foster willingness among students to put themselves into the foreground [13], to give some chances to their entrepreneurial ideas, and trim them to possibly go further in developing a real startup. We want to nourish Accelerators in a way to limit failures – not the right team, wrong business model, product not a hit, no market need, … [14] and to increase the chances for achieving success. Most of the startups growing inside the academic environment have more chance to survive three years after being set up [15]. That is why we want to make the “culture of failure”, as promoted in the Silicon Valley, less traumatic than the virtue of becoming an entrepreneur.
We want to transform weaknesses into strengths in terms of spreading the word, continuing to look for students with good ideas so our “base” of entrepreneurial students becomes bigger. This will obviously increase the odds of having a real working company in the future.

5 FACT AND FIGURES

The balance of the first two years (*Table 2*) is certainly positive, all numbers are growing.

Table 2. Results 2018 and 2019

	1st Edition **2017-2018**	2nd Edition **2018-2019**	**Increase**
Ideas presented	11	17	+ 55%
Ideas accepted	7	13	+ 54%
Idea Startuppers	13	20	+ 77%
Standby Mentors	13	39	+300%

The *Idea Startuppers* transmit their positive experience to schoolmates; this “cross-fertilization” does not only involve young people, but also extends to teachers and researchers, companies, partners and experts.

6 FUTURE DEVELOPMENT

- Starting in 2021, the new Campus opens to all SUPSI Departments and to USI (one of the 12 certified public universities in Switzerland: https://www.usi.ch/en). The Startup Garage will then be transferred to the new Campus.
- Create and improve contacts with other Universities in Switzerland, in Europe and in China.
- Offer internships to Idea Startuppers in Departments that could offer added value to the development of the "working" business idea.

- Establish contacts with local companies that relate to the ideas of *Idea Startuppers* to offer summer work experience.
- Allow students of each Department for the possibility of being part of an Idea Startuppers Team by offering their scientific and technical knowledge.
- Provide ECTS credits for the skills acquired in the implementation phases expected to go further in developing Startup ideas.
- Let *Idea Startuppers* who finished their vocational experience in the Garage to become acquainted to the newly established Association “Friends of Startup Garage”.
- Making PingelApp available to other communities and improving the quality of the code for an open-source release.

7 CONCLUSION

The Startup Garage Concept it to be understood as a means to connect students to the entrepreneurship reality, despite the fact that they should remain on the path to their main goal: graduation.
A new educational space focused on the interaction between students, teachers and researchers who together create a multidisciplinary and tailor-made training laboratory to develop entrepreneurial ideas aimed at growing the local economy.
Startup Garage Method seeks to motivate students to look for a better future. Standby Mentors are involved in understanding entrepreneurship by helping Idea Startuppers and stimulated on finding new inspiring teaching and, why not, developing their own entrepreneurship attitude thank to dynamic students. Entrepreneurial student education therefore fits into a broader engineering curriculum and helps to manage the students career path, possibly the best way to match today’s needs of the job market.
In doing things real, a particular importance is given to partnerships with the business community, which is sharing their experience with students enabling them to put good ideas and entrepreneurial skills into practice.
Globalization speeds up the race to a common market in which a greater inclusion of diversity has to be ruled by a creative thinking and idea scouting, which in turn are sustained and strengthened by cross fertilization. Inter- and multidisciplinary is promoted by applying the “Startup Garage Concept” hence making room for an entrepreneurial approach to teaching.

Connecting the dots… to ensure that step by step
Idea Startuppers develop entrepreneurial and personal skills.

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Integrating industry seminars into a professional practice module to prepare students for future engineering challenges

Graham Collins
Senior Teaching Fellow
University College London
London, United Kingdom
E-mail: g.collins@ucl.ac.uk

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ABSTRACT

The postgraduate professional practice module at University College London (UCL) has been designed with a range of guest speakers to equip research students for the challenges of the 4th industrial revolution ("Industry 4.0"). This module supports the teaching of software engineering research students within the Department of Computer Science.

The focus of the academic lectures are project management skills; providing an understanding of teamwork and leadership, and an appreciation of the importance of ethics, inclusion and diversity. The teaching is aligned with the aims of Responsible Research and Innovation (RRI) to foster inclusion and sustainability.

The industry guest speakers cover a range of topics including: IoT, cloud computing, microservice architecture, security, and cognitive computing. The module currently integrates guest talks from Fujitsu and HSBC covering quantum technologies; microservice architecture and cloud-native development, HPC cloud provision, GDPR, and sustainability from RedHat, Form3, NGINX, and Verne Global. Detailed coverage of: distributed ledger technologies (DLTs) from Digital Asset; team organisation from ThoughtWorks; and cognitive computing, data architectures, and engineering trends from Instana, NetApp, and IBM.

It was a considerable challenge to integrate these guest speaker talks with academic lectures, so that the module was delivered in a logical sequence. Without student-generated material and surveys to gauge the extent of understanding before each topic is covered, it would have been far more difficult to deliver this short module. Student feedback indicates that guest lectures help prepare them for their research projects and discussions following talks provide a valuable opportunity for professional-instrumental networking.

1 INTRODUCTION

The accelerating technological change brought on by the 4th industrial revolution is having a major impact on the labour market, and creating an "annual shortfall of 59,000 engineering graduates and technicians to fill core engineering roles" in the UK [1]. The CIO 2018 survey [2] highlights that particular skills shortages are in areas such as data analytics, AI, technical and enterprise architecture, and project management. In these areas, many organisations have difficulty hiring; the concern is exemplified by Coindesk in their coverage of difficulty in attracting developers for blockchain technologies [3].

It is also recognised that there is a shortage of engineers across Europe. Metz has outlined that as organisations adopt new technologies, they are finding it harder to recruit qualified engineers and researchers [4]. Telukdarie & Sishi [5] describe the 4th industrial revolution of smart industrial environments as, "systems, smart devices, and products communicate and share information in real-time"; a framework of integrated layers creating a value chain for industry. They outline that, data analytics, IoT, cloud, and Cyber-Physical Systems (CPS) are enablers for Industry 4.0. Xu et al. [6] go further in encompassing in their discussion of Industry 4.0, enabling technologies such as blockchain and emergent technologies which will integrate industrial manufacturing systems and change the world of work. Klaus Swab, the executive chairman of the World Economic Forum in his book, the 4th Industrial Revolution [7], considers that all disciplines, economies, industries will be affected.

The Royal Academy of Engineering (RAEng) recommend there should be a "radical increase in the involvement of industry in university education", including in the design of university engineering courses [8]. The RAEng also cite examples of good practice where business school staff are involved in the teaching of engineering courses to widen their understanding, and students are involved in addressing real-world challenges [9]. The RAEng consider that guest lectures by industry leaders should be incorporated into engineering modules. Additionally, this provides real-world contexts for the application of theory, and allows students to appreciate alternative perspectives, both of which potentially increase student engagement.

Fung argues that there should not be a conflict between the needs of industry and research in universities [10]. Both need the skills of critical thinking, and the analysis of new technologies and their impact on society. The Humboltian philosophy, that teaching and research should be inexorably linked, and that students learn more effectively via research-based teaching forms the basis of the Connected Curriculum at UCL [11]. The core principle of this curriculum initiative is that students learn through research and enquiry. One of the six dimensions of this curriculum is that students connect academic learning with workplace skills, which can partly be addressed by industry guest lectures.

2 BACKGROUND

This paper outlines the ongoing development of an MSc professional practice module within the faculty of Engineering Sciences at UCL. It covers the opportunities and challenges in combining a series of industry talks with academic lectures. Two cohorts of students take this module; one class majoring in Financial Software Engineering and the other majoring in Software Systems Engineering. The guest speaker talks, which take up 20 hours, are closely aligned to 10 hours of project management teaching, which includes application development and enterprise delivery.

This module is designed to widen students' knowledge of engineering, alongside their specialism of software engineering. In effect, it is helping to create, what some call "T-shaped engineers" [12]. The module includes topics that all genders have declared an interest in, creating a more inclusive environment [13].

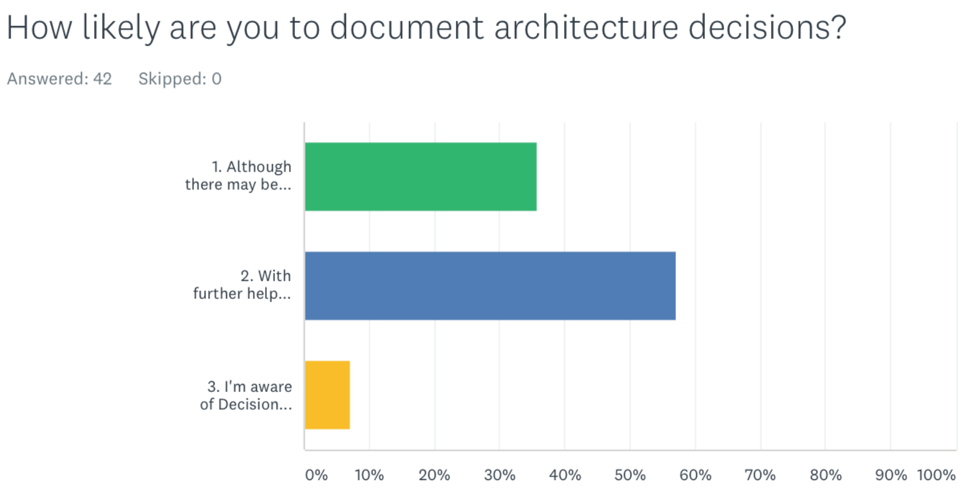
The module aims are to also provide industry perspectives alongside project management theory, and to help students prepare for their research projects with industry partners, and their professional careers. There has also been a shift in focus for this module, from primarily academic report writing to increase the coverage of business reports and presentations emphasising the economic and humanitarian value of student research.

At the core of this postgraduate module is the Engineering and Physical Research Council's (EPRSC's) approach to Responsible Research and Innovation (RRI) [14]. RRI is also embedded in the European Commission's Horizon 2020 programme which aims to "foster the design of inclusive and sustainable research and innovation" [15]. The module teaching includes the EPRSC's Anticipate, Reflect, Engage and Act (AREA) framework [16], to ensure that students continuously evaluate their projects. The analysis of this framework is in the form of process, product, purpose, and people [17], so that all facets are considered ethically and responsibly for the benefit of society.

3 DESIGN AND DELIVERY OF THE MODULE

Examples from previous student research projects are outlined at the start of this module. These are currently based on machine learning research, to provide pedestrians and cyclists lower air pollution routes in cities [18]. These are included to show how previous students have structured their work and the impact their research has made. These examples provide relevant material, and show a clear relationship to both the EPSRC's Responsible Research and Innovation framework and the UN's sustainability goals [19]. This creates an atmosphere of shared endeavour to research-led teaching and solving humanitarian problems. This also provides an opportunity to highlight engineering topics such as health and sustainability, which female students, in particular, have indicated they would like in to study [13]. It is also a useful mechanism to show the different approaches student teams have taken for their research projects; highlighting the value of considering other stakeholders' perspectives.

The theme of acknowledging the value of everyone's contribution and inclusion also runs throughout the course. This is emphasised in the lecture focusing on teamwork, inclusion and diversity, and that optimal solutions come from a diverse team with a range of experiences. Encouraging different perspectives and understanding of bias also helps support the concept of neurodiversity: that differences in communication, such as with autism, should be supported and appreciated [20].



ANSWER CHOICES	RESPONSES	
1. Although there may be some industry approaches regarding architecture decisions I would not necessarily look at these, but would at least document the problem, a solution and an alternative.	35.71%	15
2. With further help or working as a team I feel confident I could adapt an appropriate method, document a solution, outline an alternative and describe why our chosen solution was adopted.	57.14%	24
3. I'm aware of Decision Centric Architecture Reviews (DCAR) or an alternative method and may reference this and adapt this method so that the time involved in using this is not an overhead to the project. As well as the solution and alternative I may also include forces in favour of our solution as well as those against.	7.14%	3
TOTAL		42

Fig. 1. Choices provided by students attending the Professional Practice module academic year 2017-18. Several students from the School of Management also attend selected lectures. N=42.

Providing feedback is essential to improve learning, however, some students may take constructive comments on their work personally. Goldsmith [21] suggests that if the lecturer discusses with the class something that will be taught, it avoids any potential criticism of students and creates a more positive learning atmosphere. Feedback requires the student to have some knowledge of the topic, whereas “feedforward just requires considering the question and having innovative ideas to solve the task or think about it in different ways” [21]. In addition, the answers they provide will be naturally aligned to their way of thinking. Discussing the results of an anonymous questionnaire in class and considering suggestions is one way to inspire ideas and connect concepts.

Prior to topics being covered students are asked about their level of understanding via electronic surveys using the open-source web application SurveyMonkey. *Fig.1* illustrates an example of the answers, to questions asked before the software architecture topic. In this question, students are asked how they would approach their research projects and their awareness of software architecture frameworks. The answers provided, as in *Fig.1* are not meant to be right or wrong, but give different views for discussion. This gives both valuable insights for the lecturer and the industry guest speaker, to better plan the content for their forthcoming talks. This information is further enhanced by discussions within Moodle, the electronic module forum for the class.

4 CHALLENGES

Guest speakers often find the syllabus outlines are insufficient to gain an understanding of the students' background knowledge. In planning talks, industry speakers typically ask the lecturer about the students' awareness of programming languages and patterns, industry and project experience, as well as concepts and frameworks. The planning problem for this module is complicated by there being two cohorts of students. A carefully designed set questions for the class, via an electronic survey, to be completed before talks, helps ensure all students are considered when deciding the content. This has shown to help both the lecturer and industry practitioner in understanding the knowledge and experience the students are likely to have. This ensures that talks are pitched at an appropriate level, and topics that are well understood by students are not subject to extensive explanations.

It is also a challenge meeting the aspirations of both cohorts of students in the class and balancing the range of leading-edge engineering topics. As the first academic lecture was based on the project management and technology used for a humanitarian project the first guest talk covered a technology project in the financial markets. The lecturer and guest speaker co-planned a topic covering HPC quantum and Adjoint Algorithmic Differentiation (ADD). This talk included the necessity of Basel IV compliance and risk modelling, how sensitivities of financial instruments can be effectively modelled using ADD using coding examples, and how quantum annealer technologies provide an advantage. Since only two hours were allocated for this talk, it was important to ensure appropriate background coverage within the project management theory classes and that the programming languages were already covered within the software engineering modules. This material was designed to be further supported by discussions, addressing what a project manager needs to be aware of when resourcing such projects. This topic was also linked to the content of the talks covering quantum technologies from the guest speaker from Fujitsu, and HPC and sustainability from the speaker at Verne Global.

The greatest challenge is sourcing relevant and inspiring speakers. As with the findings of other academics in this area, one of the key challenges is the additional time this involves [22]. Allocating adequate time for this is activity is important, as students appreciate talks covering leading-edge technologies that are related to their research projects:

"[The lecturer] managed to secure talks from incredible industry speakers who shared up-to-date, relevant knowledge on current topics." Professional practice student academic year 2017-18

Planning the talks so they create a coherent module structure, and designing the talks with guest speakers, also takes time. This includes ensuring that guest speakers are aware of the generic module feedback, which typically shows an appreciation for real-world scenarios and live coding. One particular lecture, with student input, included a live demonstration of how the NGINX product protected a website from a denial-of-service (DoS) attack. A volunteer student in the class acted as the “hacker”, showing real-time how a website, specifically created for the talk, was protected from multiple attacks. Some students have commented that they particularly appreciate talks covering software they use within their project work:

“I especially appreciated the talks from Nginx and Chef, which are two companies with whose products I am intimately familiar with.” Professional practice student academic year 2017-18

Not only do the students have a better understanding of these technologies, there is also a benefit from more engaging teaching.

As guest speakers are typically invited during the autumn semester, after the examination questions have been set, students are not specifically examined on the content external speakers deliver. However, some students have indicated that they would like to write a report or dissertation on these leading technologies:

“I think having the lecturers from industry was both very interesting and really useful. Some of those lecturers have been the highlights of my time at UCL. Maybe have an assignment that allows students to select 3 of the visiting talks then write a short report on each say 500 words critically analysing the benefits and possible complications around the topic. That way you wouldn't need a 100% exam.” Professional practice student academic year 2017-18

Engineers need to adapt to an ever-changing environment. Johnstone argues that engineers need to take on a wider range of skills including project management, and that they need to keep learning [23]. This is also emphasised by the use of term “learning animals” [24], used by several technology organisations, and by Eric Schmidt, the executive chairman for Alphabet, the holding company for Google.

Guest speakers are selected for their technical excellence, their wish to help our students and the potential for student research projects. Managing guest speakers, requires timely communications via email and phone, to address their questions and provide background information. Talks are typically planned with guest speakers during the autumn term and the content reviewed ideally at least a month before delivery. Ensuring that their slides are ready at least a week beforehand so that students can review these if they wish sometimes requires tactful reminders, as guest speakers often have numerous priorities within their organisations.

Before guest talks, students are provided with details of the forthcoming speakers, their biography, technical papers and discussion blogs they have written. This enables students to develop a better understanding of the topics and also encourages them to exchange ideas. To facilitate this further, guest speakers are encouraged to leave at least 20 minutes available after their talks for further questions, and discussions. Guest speakers ensure they have their contact details within their slides, which are made available to students via the course Moodle site. Many guest speakers invite students to contact them if they wish to discuss technologies or arrange an industry visit. Although students often engage in social media this is not always the case for professional networking. These invitations provide a less daunting way in which students feel they can approach speakers and students often continue discussions and networking after their talks.

5 CONCLUSIONS AND FURTHER WORK

Providing technical discussion papers within the course and guest speakers providing an invitation for further discussions helps create a foundation for networking with the speakers and organisations they represent. This extends opportunities for students to develop their instrumental networks: social ties to support their professional goals. Instrumental networks are important for cooperation at work [25]; they also allow individuals to create connections to further their careers. However, Gaughan et al. have found that women's professional networks which favour advice networks, are less likely to support academic activity [26]. These findings provide support to the idea that females should be encouraged to develop instrumental networks.

Previous research by the author indicates that female students are keen to explore external industry contacts within their studies [13]. This was particularly true within areas of their interest, such as research with positive environmental and humanitarian impact. Ensuring speakers cover these areas during the module is therefore important. Integrating guest speakers within the module, may increase the students' instrumental networks, especially as guest speakers often extend invitations for industry visits or continued professional connections. This may create beneficial career effects for all students. Hopefully, this will also help address the imbalance in types of networks females are reported to have, and therefore be a positive move, in supporting female research students' careers:

"My favourite course on the degree, it had leading companies come in and talk through their process and how these processes got implemented, very insightful and super useful." Professional practice student academic year 2017-18

Even though numerous reports cite the benefit of industry involvement for students [8], in terms of both research and employment prospects, there is, however, currently limited research that covers how industry guest speakers should be effectively integrated within a programme. In addition, there is limited research particularly in the way engineering courses, covering recent advances associated with Industry 4.0, have industry speakers integrated. This is partly due to the rapid developments within the associated areas such as: cloud, IoT and edge, HPC and quantum technologies, and cognitive computing.

May-Newman and Cornwall [27] outline problems in engineering where the industry speaker may not have the pedagogic experience, or where the academic may not have specific practical experience in the topic. Providing industry experts in each of the different fields of industry can ensure that the topic is always delivered by an expert and a range of real-world research projects are included.

Research has shown sourcing speakers is time-consuming and is often left to key individuals [22]. Fung [10] points out this role should be properly resourced, and the

RAEng [8] indicate this should be more of a joint venture, between industry and universities, particularly in curriculum design and delivery of content. Research is also needed on how an optimal balance is achieved in resourcing guest speakers; between individuals versus a central resource. In leaving individuals to invite speakers, there are the risks associated with the sole point of contact. Often guest speakers deliver talks for altruistic reasons, including to give “something back” and to help future generations. However, it needs to be also recognised that guest speakers will often help simply because of the valued professional relationship they have built up with the person who has invited them.

It is important to integrate external speakers, not only for the technology insights they provide but also to help students consider different perspectives. To do this effectively, research has shown [28] that having a feedforward approach to ascertain how comfortable or what experience students have of a topic is a useful approach. Sharing this knowledge with guest speakers has not only shown that the speakers are valuable members of the teaching community but has also enabled more effective module development and alignment with the ethos of UCL’s connected curriculum initiative. Co-planning with this feedforward information has also created a logical course structure, a valuable illustration to students of industry-academic collaboration.

Research has shown that organisations need to create opportunities for instrumental networking, as the least likely to engage in this activity are the individuals that need this the most [29]. Guest speakers inviting further questions and opportunities for visits after their talks is one approach to breaking barriers down and increasing networking opportunities. These invitations may also help create an atmosphere of spontaneous networking, making it more likely that students will feel comfortable in continuing discussions with the speakers. Casciaro et al. [29] discuss that facilitating such networking contexts where the expectations are clear may not induce the feeling of being morally compromised which can be associated with instrumental networking. Further research is needed to verify this. However, these networking opportunities following guest speaker talks are one approach to help students develop their professional networks.

There need not be a conflict between preparing students for the world of work and the needs of research. Both require an openness for dialogue, and an ability to critically appraise ideas and values. Both require being able to see others’ perspectives and the ability to articulate concepts and ideas and progress society for the greater good.

If we are to expect students to engage in research that benefits industry and society, we need reciprocal arrangements from industry. With an increasingly interconnected world brought about by the advances of Industry 4.0, it is more important than ever, that students have an opportunity to learn first-hand from industry leaders driving these technologies. Integrating guest speaker talks within university research-led teaching programmes is one way to provide real-world examples, and enhance students’ critical thinking and knowledge of new technologies. Students with this industry and university research-led experience will be better able to solve humanitarian problems and create a more sustainable future.

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Python for Engineers Concept Inventory (PECI): Contextualized assessment of programming skills for engineering undergraduates

NJ Cooke[1], **KIM Hawwash, BA Smith**
University of Birmingham
Birmingham, United Kingdom

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Keywords: concept inventory, assessment reliability, computing skills, python

ABSTRACT

A key outcome of Engineering Education is computing skills for industry 4.0. The curriculum must address an increasing reliance on model-based design, simulation, and algorithmic data processing. Python is a popular, in-demand language; exhaustive online resources and tutorials exist, challenging educators to make assessment robust to online plagiarism, and to make instruction contextually relevant to engineering. How do engineering educators develop, measure, and evaluate engineering students programming skills, accelerate their learning, and improve instruction effectiveness? A Concept Inventory (CI) is a powerful standardised assessment instrument to answer this question and its development and validation is an active research topic. We present a Python for Engineers CI (PECI) which assesses concepts, and errors observed in learners through 250 Multiple Choice Questions (MCQs). It is evaluated by embedding it into an introductory undergraduate module, whose pedagogy includes contextualised learning and auto-graded interactive computing laboratory notebooks. Using a mixed-methods approach on learning data from a student cohort (n=68), we validate PECI through student learning gains, reliability analysis and qualitative feedback. Items are shown to differentiate high and low performing students, and each item contributes to assessment reliability. The work is of value to engineering educators wishing to develop standardised assessment instruments for computing skills.

1 INTRODUCTION

How can engineering students' ability and performance in programming be measured accurately and reliably, and what pedagogical practices can enhance their performance? A key part of Engineering Education is the development of computing skills. These are used for design and analytical work; electrical and computer engineers traditionally have the highest need, require design skills for programming software for desktop applications, and firmware for hardware devices using procedural

[1] Corresponding Author
NJ Cooke
n.j.cooke@bham.ac.uk

languages such as C. Other engineering disciplines such as chemical, mechanical and civil engineering have lesser need, but still make extensive use of analytical software for data and simulation that frequently requires interactive computing tools e.g. Matlab & Simulink. There is an increasing move in Engineering towards Industry 4.0 which promises a model-based design approach in all disciplines as engineering products and solutions undergo detailed simulation before production, with increasing reliance on algorithmic data processing, machine learning and automation. These trends create the requirement to increase programming in engineering curricula. According to the IEEE, Python is now the most popular and in-demand of all programming languages[2].

Online access to learning python programming skills is ubiquitous; exhaustive online resources and tutorials not specific to engineering exist of varying quality. This means that teaching programming in engineering programme is straightforward, if not particularly redundant or efficient – a programming module can be compiled from existing online materials, texts and exercises. However, this simplicity and easy-ofentry carries risks for the engineering educator: the challenge of making any programming assessments robust to online search, adding enough value to what already exists, and making the learning context entirely relevant to engineering. Furthermore, a key issue in teaching programming is assessing student output – programming is an open-ended, creative endeavour; a variety of solutions with very different coding styles and structures can produce the same result. How can assessment of this creative skill be standardised while simultaneously giving students the freedom to code how they want?

In this work we answer these questions by presenting the Python for Engineers Concept Inventory (PECI), which standardises assessment, provides engineering contextualisation, and affords analytics to measure and improve an engineer's programming skills. This article proceeds as follows. In Section 2, we describe programming pedagogies and CIs. In section 3 we describe PECI's embedding into an undergraduate module. In section 4, PECI is evaluated in terms of measured learning gain, assessment reliability, and qualitative feedback. In section 5 we discuss our findings and future work.

2 TEACHING ENGINEERING PROGRAMMING SKILLS

2.1 Pedagogical Interventions

What pedagogical practices can enhance programming skill? Programming is widely reported to be a complex cognitive skill which is difficult to master, resulting in low student engagement and drop-outs. The majority of education studies in teaching programming report case studies that investigate novice computer science cohorts. Given similar entry requirements to Higher Education degree programmes, it is reasonable to assume that CS cohorts share many similarities with early-year

[2] https://spectrum.ieee.org/at-work/innovation/the-2018-top-programming-languages

engineering cohorts and consequently their findings can be considered as valid in engineering contexts. Interventions to improve effectiveness reported include collaboration, peer support and group work, content change, preliminary courses, gamification, grade-weightings, and contextualisation [1]. The most popular foci in student-oriented education research studies is on content and measuring student ability, for teaching-oriented studies it is the tools and activities, and for assessmentoriented studies it is the theories and models [2]. Our work focuses on all three aspects, with a primary focus on measuring student ability through assessment.

2.2 Concept Inventories as a standardised assessment model.

How can engineering students' ability and performance in programming be measured accurately and reliably? To reliably measure student ability, a concept inventory (CI) is a standardised assessment tool that defines a set of key constructs and accompanying assessments used to assess a student's conceptual understanding of a subject. Identifying which concepts are key is the subject of much debate in the literature; the optimal set that minimises the volume of teaching materials while maximising student learning are known as threshold concepts. These concepts possess one more specific characteristics: they transform subject understanding irreversibly, reveal connections and relationships, define the disciplinary boundaries, and are troublesome for students [3].

One of the earliest CIs is the physics Force Concept Inventory (FCI) [4], which was demonstrated to show a reliable assessment of student understanding. Since then, Engineering Education has proposed a variety of CIs [5]. Identifying the threshold concepts within these CIs is considered important for efficiency yet difficult; much identification is done through the teacher's subject understanding with student performances highlighting the troublesome concepts. However, it is noted that troublesome concepts may be due to lack of student motivation rather than difficulty [6].

In the framework proposed by [7], a CI should be validated to ensure it measures students overall and specific understandings and propensity for misconceptions and errors. This is achieved using several techniques including classical test theory (CTT), Item Response theory (IRT), factor analyses, and hybrid approaches. CTT enables the difficulty, discriminability, reliability and coherence of the CI to be determined. IRT enables each concept item's difficulty to be evaluated against student proficiency, while factor analyses help to identify underlying hidden factors that relate elements in the CI.

2.3 Misconceptions as common programming errors

For an engineering programming CI, how are its items determined? There is a distinction between programming concept items and programming error items. Errors arise from misunderstandings of the programming concepts or misuse/understanding of programming language syntax. A good source of misconceptions comes from observing novice programmers in practice. Early work in [8] observing programmers identified three common errors relating to students: 1) parallelism, where line-by-line sequential interpretation is usurped and previous statements are incorrectly identified as active; 2) Intentionality, where sequential interpretation is mediated by goals that are inferred by the program due to other statements; 3) Egocentrism, where it is assumed the computer does and knows more than that made explicit within the code. Decades of subsequent studies have yielded comprehensive lists of misconceptions spawned from these three errors and amalgamated from all languages e.g. 162 misconceptions [9]. However, these larger lists are unwieldy and not all items can be reasonably tested or are relevant to specific languages. Specific to python, work in [10] and [11] identifies a more manageable 26 and 25 programming errors items respectively.

3 PECI STRUCTURE AND MODULE EMBEDDING

3.1 PECI Structure

The PECI structure is given in Table 1. It has 15 concept items taken from the glossaries of a standard reference python text book with each chapter constituting a specific concept item (column 1) [12]. There are 24 programming error items observed in previous work (column 2) [10][11]. 250 Multiple Choice Questions (MCQs) are devised from these items to test student's ability to understand concepts or error relating to python code written for a specific Engineering context (column 3). An example MCQ from the CI is shown in *Fig 1*.

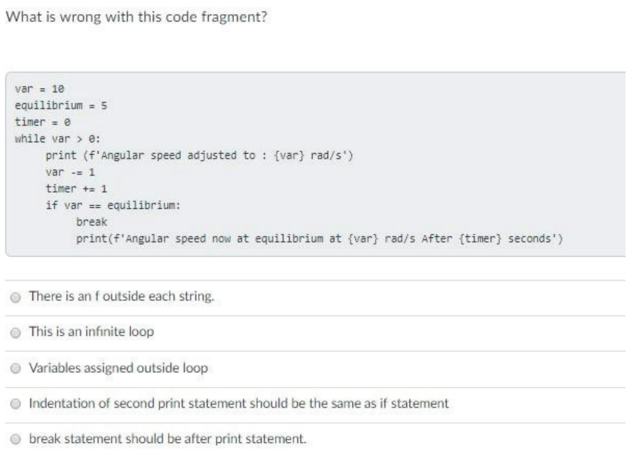

Fig. 1. Example PECI MCQ

Table 1. PECI structure. Each question in the inventory is derived from a combination of Concepts, Errors, and the Engineering context.

Programming Concepts [12]	Programming Errors [10][11]	Engineering Contextualisation
C1: The Program	A: Invalid names	Mathematics
C2: Variables	B: Left-to-right assignments	Fluid dynamics
C3: Expressions	C: Assignments in expressions	Digital Electronics
C4: Statements	D: Expressions as parameters	Analogue Electronics
C5: Functions	E: Literal values instead of variables	Structural Analysis
C6: Conditionals	F: Extra or missing spaces	Mechanical Design
C7: Recursion	G: Invalid else-statements	Materials.
C8: Fruitful functions	H: Missing or extra quotation marks	
C9: Iteration	I: Division and modulo	
C10: Strings	J: Invalid use of the and-operator.	
C11: Lists	K: Wrong or extra keyword.	
C12: Dictionaries	L: Incorrect structure.	
C13: Tuples	M: Unbalanced parentheses and brackets	
C14: Files	N: Misspelled names or keywords.	
C15: Classes	O: Using keywords as names	
	P: Using assignment instead of comparison.	
	Q: Misspelled operators.	
	R: Unterminated string literal.	
	S: Missing colon, comma or operator.	
	T: Invalid Indentation.	
	U: Code after a break statement.	
	V: Call without parentheses.	
	W: Useless computations.	
	X: Useless comparison.	

3.2 Module Embedding

PECI is designed to be independent of the teaching and learning activities. In this case-study, PECI is validated in a 10-credit module designed for 1st and 2nd year undergraduate engineering students that assumes little or no prior programming experience. *Fig. 2* shows how PECI is embedded into the module. PECI tests are administered throughout the module – an identical pre- and post-learning test, practice tests, and a final summative class test. The student performance data from pre- and post- learning test results enables learning gain to be measured for each student. Analysis and Practice improvement is afforded from this measured learning.

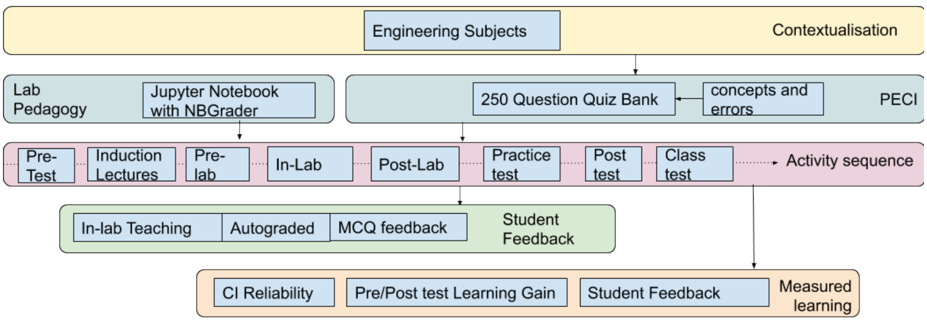

Fig. 2. Embedding PECI into the case-study Module

3.3 Lab Pedagogy

In our case study, python is learned through contextualised laboratory exercises before (pre-lab) and after (post-lab). The exercises use interactive programming notebooks[3] and automatic marking of programming code using the NB Grader plugin[4]. This means that rather than learning to program by writing source code files, students learn to code by writing snippets inline to solve problems which are automatically checked for errors by using a plugin for the notebook that can check code for correct output. The problem-solving aspects include designing digital logic schemes, signal processing and machine learning exercises. Notably, the learning materials are independent of PECI i.e. they are not directly teaching students to answer one of its MCQs.

4 EVALUATION

4.1 Student Learning Gain

Student learning gain is measured by comparing the pre-learning and post-learning student performance against PECI. 50 MCQs are pre-selected from the 250 MCQs in PECI to ensure a broad coverage of concepts and programming errors. The test is administered to the student cohort at the start and the end of the learning in timed examination conditions and is formative. For the student cohort in this study (N=68), the pre-learning PECI scores range from 12% to 53% with an average of 29% and standard deviation of 5.09. The post-learning PECI scores range from 42% to 93% with an average of 73% and standard deviation of 8.62. This demonstrates that PECI measures knowledge improvement from students undertaking learning activities where students are expected to show learning gains, with the potential for different learning gains to be compared across different cohorts and teaching methods.

To better understand the learning gain, item difficulty is calculated by dividing the mean score by the maximum possible, producing a value between 0 and 1 for each item, with 1 indicating high scores. Item discrimination is calculated by point-biserial correlation, which compares individual scores against those for the overall test, producing a value for each CI item between -1.0 and +1.0. Negative values are undesirable and indicate that high scorers are wrong. Positive values are desirable and indicate that high-scorers are scoring right, and that low scorers are scoring wrong.

Fig. 3 shows the comparison between pre- and post- learning difficulty vs discrimination. As expected, for the pre-learning test the majority of the PECI items (diamonds) prove to be difficult; no item has a discriminability greater than *0.6*. There are also several concepts with negative discriminability which suggest gaps in student knowledge regardless of ability.

The post-learning test results show a vast improvement. Most items have higher difficulty scores indicating better cohort performance, and this is positively correlated

[3] https://www.jupyter.org

[4] https://nbgrader.readthedocs.io/en/stable/#

with item discriminability indicating good separation between high and low achievers. Comparison of the pre-learning negative linear trend lines and post-learning positive linear trend line highlight this desired improvement.

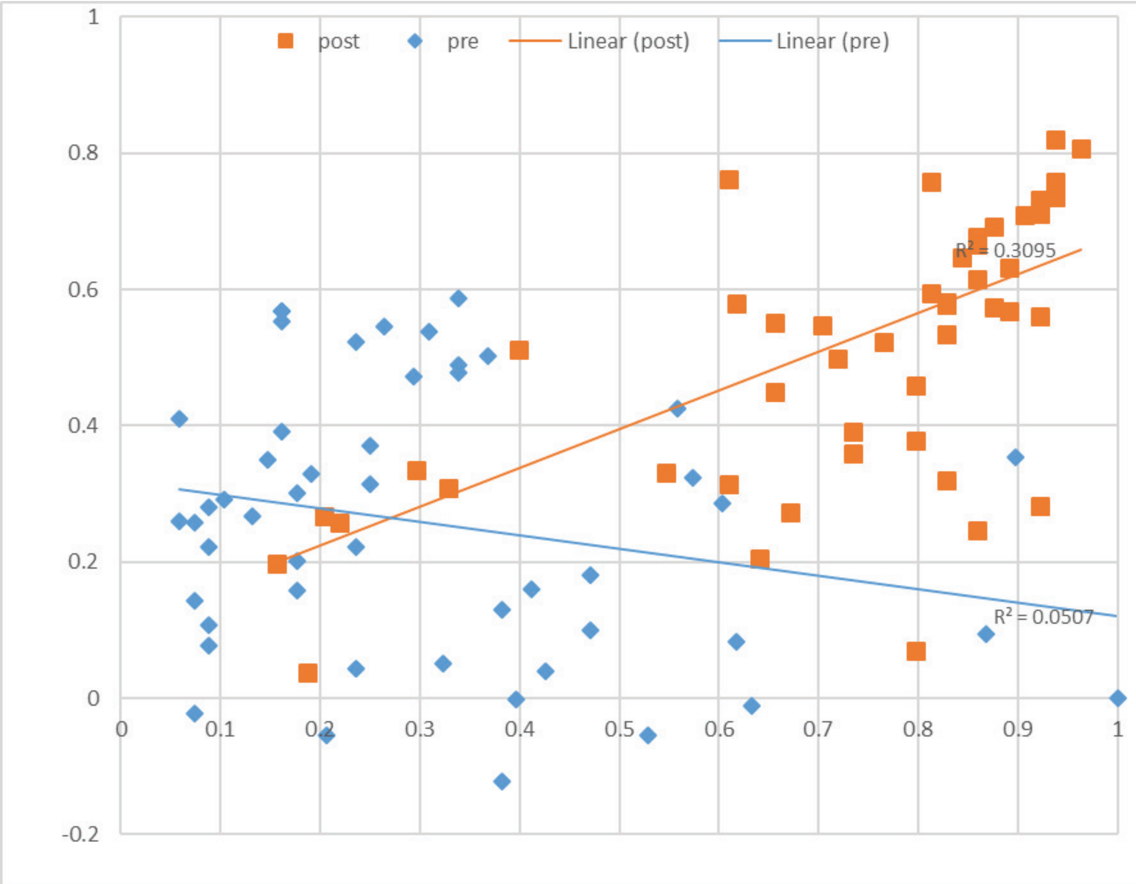

Fig. 3. Comparing Difficulty vs Discriminability of PECI between pre- and postlearning demonstrating cohort improvement.

4.2 PECI Reliability

PECI is evaluated by adopting the first stage of the framework proposed in [7] - employing Classical Test theory (CTT) to measure reliability. Test scores are analysed using SPSS software. Reliability is reported separately for PECI concept items and errors items

4.2.1 Error items

For the 24 programming errors types, Cronbach's alpha showed the test comfortably met the criteria for acceptable reliability (>0.7) at α = 0.82. There were mostly low correlations (r<0.3) between error types (*Fig. 4*), which suggests that each item is less likely to represent the same underlying concept and thus be potentially redundant.

Alpha remains high regardless of the item deleted, ranging from 0.80 to 0.82. Analysis of the mean and standard deviations for each item revealed certain errors are easily detected and corrected by students e.g. B, while others e.g. E, are not. However, all but one item results in a decrease in the alpha if deleted. The one exception - error X - would increase the alpha to α = 0.83 if not included. However, this difference is negligible.

Further evidence of the value of all programming error items in the CI comes from the inter-item correlation matrix (*Fig. 4*), which have low correlations (r<0.3) between error items. This suggests that there is no underlying single programming "error" concept could make individual items in the CI potentially redundant.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
A	1.0	0.6	0.2	0.2	0.2	0.3	0.1	0.3	0.0	-0.1	0.3	0.3	0.2	0.2	0.2	0.0	0.1	0.0	0.2	0.2	0.1	-0.1	0.0	0.0
B	0.6	1.0	0.3	0.4	0.3	0.4	0.2	0.2	0.0	-0.1	0.3	0.2	0.0	0.1	-0.1	0.1	0.0	0.1	0.0	0.0	0.2	0.0	-0.1	0.2
C	0.2	0.3	1.0	0.1	0.0	0.2	0.3	0.1	0.4	0.4	0.3	0.2	0.0	0.1	0.1	0.2	0.2	0.1	0.3	0.2	0.4	0.1	0.2	0.1
D	0.2	0.4	0.1	1.0	0.5	0.4	0.1	0.3	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0
E	0.2	0.3	0.0	0.5	1.0	0.4	-0.1	0.2	0.0	-0.1	0.2	-0.1	-0.1	-0.1	-0.1	0.1	0.0	0.1	-0.1	-0.1	0.0	-0.1	-0.1	-0.1
F	0.3	0.4	0.2	0.4	0.4	1.0	0.1	0.3	0.2	0.0	0.2	0.2	0.1	0.2	0.2	0.0	0.2	0.1	0.1	0.1	-0.1	-0.1	0.0	0.0
G	0.1	0.2	0.3	0.1	-0.1	0.1	1.0	0.1	0.4	0.6	0.0	0.0	0.1	0.1	0.3	0.3	0.1	0.1	0.2	0.1	0.2	0.2	0.1	-0.1
H	0.3	0.2	0.1	0.3	0.2	0.3	0.1	1.0	0.3	0.2	0.0	0.2	0.1	0.2	0.1	0.0	0.3	0.0	0.1	0.0	0.2	0.1	-0.1	0.0
I	0.0	0.0	0.4	0.2	0.0	0.2	0.4	0.3	1.0	0.5	0.2	0.0	0.1	0.2	0.4	0.5	0.5	0.3	0.3	0.4	0.4	0.3	0.2	0.0
J	-0.1	-0.1	0.4	0.0	-0.1	0.0	0.6	0.2	0.5	1.0	-0.1	-0.1	-0.1	-0.1	0.4	0.2	0.1	-0.1	0.1	0.1	0.2	0.3	0.3	-0.1
K	0.3	0.3	0.3	0.0	0.2	0.2	0.0	0.0	0.2	-0.1	1.0	-0.1	0.1	0.1	0.0	0.0	0.2	0.3	0.3	0.3	0.3	0.0	0.1	-0.1
L	0.3	0.2	0.2	0.1	-0.1	0.2	0.0	0.2	0.0	-0.1	-0.1	1.0	0.4	0.5	0.3	-0.1	0.1	-0.1	0.4	-0.1	0.0	0.0	-0.1	0.2
M	0.2	0.0	0.0	0.0	-0.1	0.1	0.1	0.1	0.1	-0.1	0.1	0.4	1.0	0.5	0.3	0.0	0.3	0.2	0.6	0.1	0.1	0.2	0.3	0.1
N	0.2	0.1	0.1	0.0	-0.1	0.2	0.1	0.2	0.2	-0.1	0.1	0.5	0.5	1.0	0.2	0.0	0.5	0.4	0.5	0.0	0.2	0.3	0.2	0.4
O	0.2	-0.1	0.1	0.0	-0.1	0.2	0.3	0.1	0.4	0.4	0.0	0.3	0.3	0.2	1.0	0.4	0.5	0.1	0.2	0.3	0.2	0.3	0.4	0.1
P	0.0	0.1	0.2	0.1	0.1	0.0	0.3	0.0	0.5	0.2	0.0	-0.1	0.0	0.0	0.4	1.0	0.4	0.3	0.0	0.3	0.4	0.2	0.0	0.0
Q	0.1	0.0	0.2	0.1	0.0	0.2	0.1	0.3	0.5	0.1	0.2	0.1	0.3	0.5	0.5	0.4	1.0	0.5	0.3	0.4	0.3	0.4	0.5	0.4
R	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.3	-0.1	0.3	-0.1	0.2	0.4	0.1	0.3	0.5	1.0	0.2	0.2	0.4	-0.1	0.2	-0.1
S	0.2	0.0	0.3	0.0	-0.1	0.1	0.2	0.1	0.3	0.1	0.3	0.4	0.6	0.5	0.2	0.0	0.3	0.2	1.0	0.5	0.3	0.1	0.3	-0.1
T	0.2	0.0	0.2	-0.1	-0.1	0.1	0.1	0.0	0.4	0.1	0.3	-0.1	0.1	0.0	0.3	0.3	0.4	0.2	0.5	1.0	0.4	0.2	0.5	-0.1
U	0.1	0.2	0.4	-0.1	0.0	-0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.2	0.2	0.4	0.3	0.4	0.3	0.4	1.0	0.3	0.2	0.2
V	-0.1	0.0	0.1	0.0	-0.1	-0.1	0.2	0.1	0.3	0.3	0.0	0.0	0.2	0.3	0.3	0.2	0.4	-0.1	0.1	0.2	0.3	1.0	0.5	0.7
W	0.0	-0.1	0.2	0.0	-0.1	0.0	0.1	-0.1	0.2	0.3	0.1	-0.1	0.3	0.2	0.4	0.0	0.5	0.2	0.3	0.5	0.2	0.5	1.0	0.3
X	0.0	0.2	0.1	0.0	-0.1	0.0	-0.1	0.0	0.0	-0.1	-0.1	0.2	0.1	0.4	0.1	0.0	0.4	-0.1	-0.1	-0.1	0.2	0.7	0.3	1.0

Fig. 4 Inter-item correlation matrix for PECI error items A-X. For item descriptions, see Table 1.

4.2.2 Concept items

For the 15 programming concept items in the CI, 11 are assessed via 26 questions with some concepts assessed multiple times due to their greater depth. Cronbach's alpha shows the test fall marginally short of acceptable reliability (>0.7) at α = 0.68. Removing items from the test produces a range of alphas between 0.64, 0.72. However, test reliability is easily made acceptable (>0.7) by removing one of two MCQs from either item 1 or 4.

4.3 Qualitative Student Feedback.

Students are questioned on the methods used to teaching programming in the module. Overall there is a tacit approval to using the CI MCQ to assess skills alongside developing skills using laboratory exercises. Notably, most of the comments focus on the teaching e.g. lab exercises rather than the PECI tests. A selection of the responses is shown in *Table 2*. Notably, comments validate the underlying ethos of the module, that programming is an open-ended concept learned by doing.

Table 2. Selection of qualitative feedback given by students

Question	Response
The thing I found most helpful.	*Helped to develop my programming skills, The way it was structured. Provides a very linear, easy to understand representation of how much you understand; Good for basic concepts.*
The most useful thing/skill I learned	*There is no unique answer to any program / solution; I feel like I could attempt my own work in the Python language now; Debugging ability.*
The thing that most changed the way I learned	*Learning through doing rather than listening. The incremental difficulty helped me break-down problems into smaller problems; The interactive nature of the notebook material.*
What made learning most effective for me	*Building up the difficulty. I wouldn't have understood the content nearly as well if we were thrown in the deep end right away. Being able to work through the notebooks in small stages over time. Fault-finding the basic stuff in coding.*

5 SUMMARY AND AVAILABILITY

Python for Engineering Concept Inventory (PECI) comprises 250 MCQ questions for standardised assessment. It is validated in a best-practice undergraduate module which utilises interactive notebooks to teach python in the context of solving engineering problems. Evaluation results suggest that all PECI items are reliable, and that the instrument correctly quantitatively measures the improvement in student programming skills before and after an effective learning experience.

While identifying threshold concepts i.e. those that truly transform a student understanding, is an active research topic, the work here highlights that, in practice, this worthy goal can be overstated; a manageable CI of tens of items derived from main subject concepts and observed student errors may often suffice, given an adequate validation via measuring learning gains at the item level and conducting a reliability analysis.

Future work includes further reliability analysis and employing the PECI as a pre/post learning test in other modules, cohorts, and teaching contexts. Further PECI details and sample MCQs are available to Engineering Educators via contacting the primary author.

6 ACKNOWLEDGEMENTS.

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The development of a Gold Standard Project Based Learning (GSPBL) engineering curriculum to improve Entrepreneurial Competence for success in the 4th industrial revolution

CZ Cory[1]
Senior Lecturer in Engineering & Entrepreneurship
University of Exeter
Exeter, United Kingdom
Email: c.cory@exeter.ac.uk
https://orcid.org/0000-0003-4708-9025

VI Sucala
Senior Lecturer in Engineering & Entrepreneurship
University of Exeter
Exeter, United Kingdom
Email: i.sucala@exeter.ac.uk
https://orcid.org/0000-0003-3071-5691

S Carroll
Senior Lecturer in Structural Engineering
University of Exeter
Exeter, United Kingdom
Email: s.p.carroll@exeter.ac.uk

[1] Corresponding Author CZ Cory c.cory@exeter.ac.uk

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ABSTRACT

An engineering graduate in the 4th industrial revolution must learn how to learn and unlearn, to keep up to date with rapidly changing technology and apply entrepreneurial competence to solve complex problems [1].

A pilot module facilitated action research with a methodology that combined Gold Standard Project Based Learning (GSPBL) [2] and EntreComp [3] as part of strategic curriculum development. The authentic industry-linked module began with an interactive launch that provided students with access to Light Detection and Ranging (LiDAR) and Virtual Reality (VR) equipment and lectures on Building Information Modelling (BIM) and entrepreneurship. Initial student feedback was positive and included *'you can already sense that the group projects are really going to help us collaborate and also learn about LiDAR*' and '*the transferrable skills are really useful for future projects and employment*'.

The driving question was '*How can you apply LiDAR scanning technology to create a new product, service or process?*'. PBL teams were encouraged to investigate LiDAR scanning technology to uncover and assess business opportunities using the Business Model Canvas (BMC) [4]. Students were incredibly creative, engaged and highly motivated during the mid-way storyboard checkpoint with cross-disciplinary academic and peer critique and revision. Student voice and choice is a major aspect of GSPBL

and students thrive on the independence and flexibility of the GSPBL structure that culminates in a *public product* short video pitch summative assessment.

The combination of GSPBL and EntreComp form a valuable methodology to develop the competence required for success as a professional and entrepreneurial engineer during the 4th industrial revolution.

1 INTRODUCTION

This paper describes the development of a pilot module, Entrepreneurship 1, in the 1st year of all engineering degree programmes at the University of Exeter. The pilot module tested the proposed methodology on a small scale with 1 module completed in 2018/2019 before a second module, Entrepreneurship 2, is introduced in 2019/2020. These new modules will not only test the proposed methodology but also start to build a new culture of teaching and learning with both staff and students. The authors are currently updating all engineering degree programmes with a focus on GSPBL and entrepreneurship. The lessons learned from introducing the new methodology as part of the pilot module will influence the design and delivery of the new engineering degree programmes in 2020/2021.

The integrated strategy advised by QAA in 2012 ‘to help students develop and demonstrate entrepreneurial effectiveness’ [5, pg. 24] includes a move towards teaching, learning and assessment that covers emerging situations, innovation, active learning, subjective experience, multimedia communication, authentic activities, learning from failure, self-reliance and resilience [5].

More recent higher education guidelines (2018) for enterprise and entrepreneurship education are summarised below in *Table 1* [6].

Table 1. Selected points of focus from QAA delivery methods and assessment [6].

Delivery Methods	**Assessment**
Contextualised approach	Reflection on entrepreneurial activities
Identify and solve problems	Teamwork and peer review
Enhance entrepreneurial capabilities	Realisation of failure through reflection can inform positive assessment
Action based practical activities	Assessment with pitches and business modelling are effective
Cross-disciplinary approaches	External experts are useful for inspiration
High engagement activities such as simulations for experiential learning	Portfolio style of collated work to demonstrate progression
Guest specialists and entrepreneurs	
Reflection to consolidate learning points and plan for future action	
Illustrate impact on employability as well as entrepreneurship	

There are a growing number of innovative educational establishments moving towards experiential, active learning methodologies [7, 8]. The future focus of Universities should be on complex challenges, peer-to-peer learning and lecturers as facilitators [9].

GSPBL has been developed over the last 20 years by the Buck Institute for Education (BIE) [10]. BIE have recently rebranded as PBL Works and projects are designed with 7 essential elements [2] and 21st century skills are developed during GSPBL projects including communication, collaboration, adaptability, critical thinking, problem solving, technological literacy, creative thinking and self-management [11]. PBL Works are a non-profit educational organisation with a well-established and trusted track record in GSPBL. They are part of the steering committee committed to High Quality PBL [12] with partners that include Google and High-Tech High Graduate School. They provide a range of training courses from introduction to coaching and hold an annual international PBL Works conference.

EntreComp was developed by the European Commission to create a standard framework for entrepreneurship as a competence [3]. It 'identifies the competences that make someone entrepreneurial. These can then be used to support entrepreneurial learning in different settings …' [3, pg. 13]. EntreComp complements GSPBL as the progression model [3, pg. 20] can be used to guide entrepreneurial competences from the 1st year module (foundation) to the 2nd year module (intermediate).

The authors suggest that the combination of GSPBL [2] and EntreComp [3] create a methodology that could effectively plan, deliver and assess appropriate modules within the new engineering programme.

This style of learning and teaching requires not just a change in degree programmes but also a change in students' mindset away from individual study towards the building of a learning community that encourages collaboration. Academics also have to adjust to new teaching styles to fully build the culture. Singapore University of Technology and Design (SUTD) is a 'recently-established engineering and architecture specialist university that offers a design-centred, multidisciplinary and project-based curriculum …'. Students and faculty members comment that there is a feeling of camaraderie and community spirit with 'a flat hierarchy and a start-up atmosphere'.

Changes towards a project-based curriculum can be met with initial resistance from students and staff who may find the transition from the current traditional teaching and learning challenging [7]. Thus, the rationale for this study was to utilise a new module, Entrepreneurship 1, as a pilot for the proposed teaching and learning methodology.

2 METHODOLOGY

2.1 Essential Project Based Elements

The design of GSPBL projects is an iterative process and requires regular collaboration, reflection and flexibility between the teaching team to ensure the highest quality projects are designed. Whilst undergoing the project design process, the authors continuously referred to the 7 essential project design elements [2] to ensure the project adhered to the required HQ PBL [12]. The 7 essential project design elements are shown in *Fig. 1* as these are interconnected throughout the project design steps described in section 2.2.

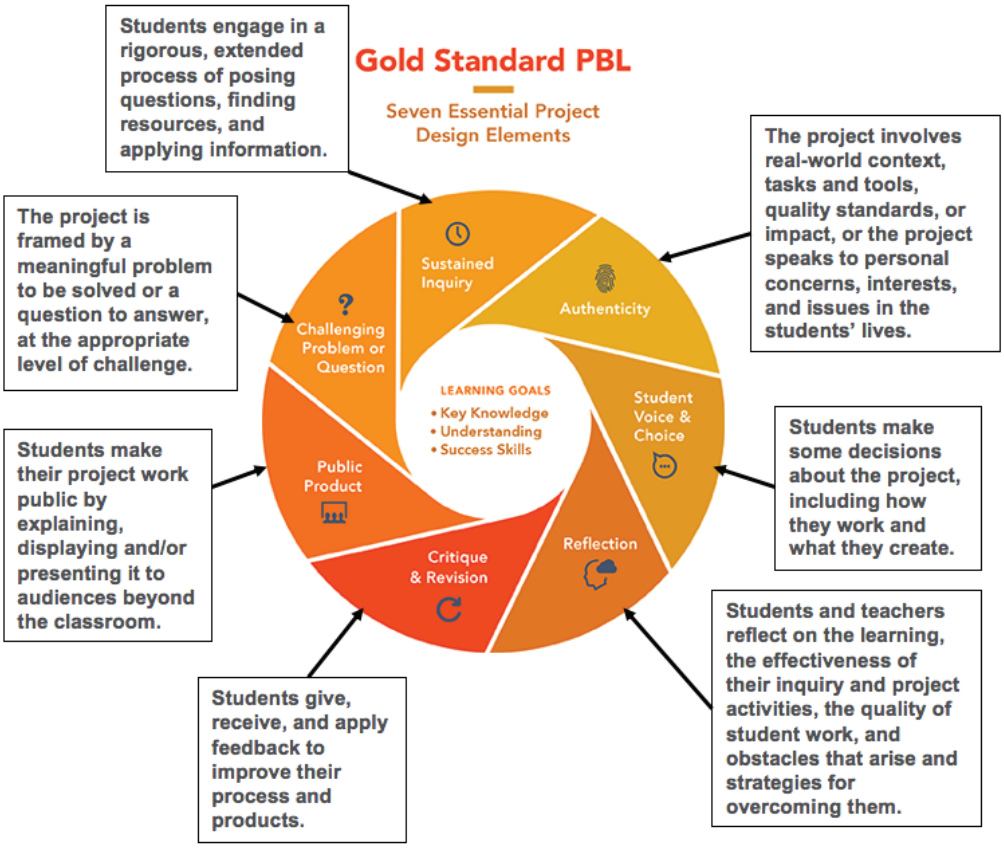

Fig. 1. Gold Standard PBL – Seven Essential Project Design Elements [2].

2.2 Designing the project

The methodology for designing this pilot module followed the '5 steps for designing a project' [13] for GSPBL.

2.2.1 Develop and idea and connect it to standards and other learning goals

Project ideas can be developed alongside competitions created by professional associations, through co-created briefs with students, community projects or global issues. The aim for this project was to create an open-ended *challenging problem or question* (*Fig. 1*) to facilitate the exploration of technology related to the 4th industrial revolution. The authors had previous industry experience and links in Light Detection and Ranging (LiDAR) and a new Virtual Reality (VR) suite had recently been commissioned within the engineering department.

The driving question was:
'How can you apply LiDAR scanning technology to create a new product, service or process?'

The driving question prompted students to find an application for the technology inside the LiDAR scanner, which widened the scope for discovery and exploration. This aligns with the foundation level in the EntreComp progression model [3].

The authors aligned the project with the requirements for the Accreditation of Higher Education Programmes (AHEP) in engineering [14] and the EntreComp framework [3] to ensure both technical and entrepreneurship learning objectives were met. The EntreComp wheel (*Fig. 2*) illustrates 3 competence areas and 15 competences and 'can be used as a guide when designing a new activity and/or a model for you to use or adapt for learning and assessment' [3, pg. 13].

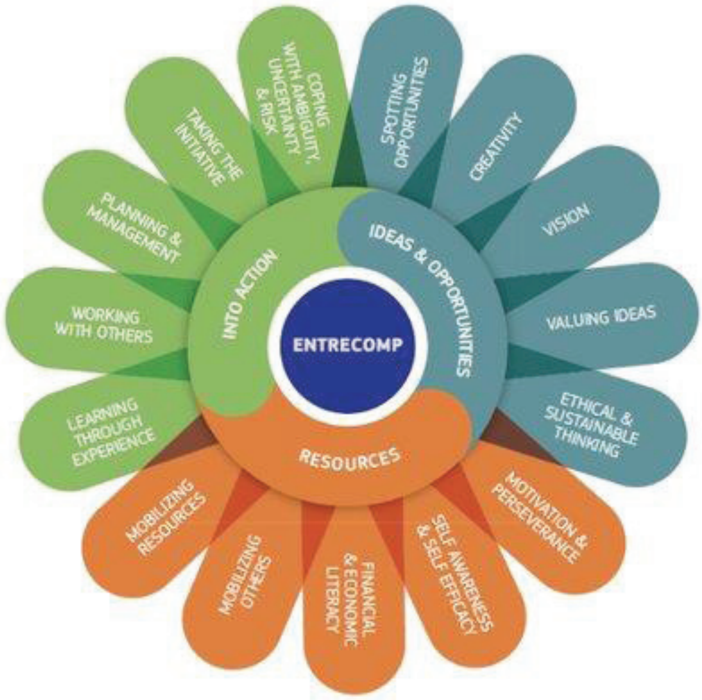

Fig. 2. The EntreComp wheel: 3 competence areas and 15 competences [3, pg. 14].

2.2.2 Decide what major products or performances students will create and how they will be made public

This step of the project design process included many parts of the 7 essential project design elements (*Fig. 1*). A formative assessment for *critique & revision*, allowed students time for *reflection* and provided two opportunities for the team to present their *public product*. *Student voice & choice* was facilitated as part of both major products and they provided opportunity for student to work towards many of the 5 competences of the EntreComp wheel under the *ideas & opportunities* competence area.

The *first major product* was a storyboard to plan out each team's final video pitch using established storyboarding techniques. This was made public through students presenting their work to Lectures in Engineering and Entrepreneurship, academic colleagues from the Business School and colleagues from Business Support. The cross-discipline formative feedback session created an exciting atmosphere with *authenticity* where students were discussing their business ideas directly with staff who had both technical and entrepreneurship experience. Feedback was provided verbally and via a highlighted formative assessment sheet to provide teams with clear critique for revision before the final summative assessment. Peer feedback was facilitated through a gallery walk where post it notes were attached to the storyboards with constructive comments related to the categories detailed in the formative assessment sheet.

The *second major product* was a 2.5-minute video pitch for the team's final product, service or process and facilitated the requirement to work towards many of the EntreComp competences. This was made public through students introducing their video, playing the video and justifying their work through a Q&A with a panel of judges.

Other teams in the allocated sessions viewed at least 8 other team presentations in their session thus expanding their knowledge of LiDAR technology and potential applications through formal peer learning.

2.2.3 Map out the steps in the project and create a timeline

This step of the project design included *sustained inquiry* and *student voice and choice* parts of the essential project design elements (*Fig. 1*).

Students were provided with an introductory lecture and deadlines for the two major products. Guidance was given to help teams to plan, agree and manage tasks using project plans, project logs and individual work packages. Teams were encouraged to follow the Stage Gate Innovation Process [15] and during Stage 2 'Build a Business Case' they made use of the business model canvas [4]. Further guidance was provided via videos, examples and templates on a VLE to facilitate blended learning.

This method follows the guidelines for HQ PBL suggesting that students need to think about what is required to complete a project and take 'an active role in planning and carrying out project activities' [12, pg. 8] and be given the 'opportunity to learn the tools and methods of project management' [12, pg. 8].

Three weeks after the completion of the second major project, teams were asked to download and complete a reflective report template to facilitate reflection on their technical skills and entrepreneurial competences, challenges faced, attempts to overcome challenges and appreciation of peer learning. Teams were also prompted to consider the impact this module had on their future ability to spot opportunities and create value for their company either as an entrepreneur or an intrapreneur. Finally, students set themselves targets for the 2nd year Entrepreneurship 2 module.

2.2.4 Plan activities and workshops and gather resources

Innovation workshops were provided by alumni entrepreneurs to inspire and motivate students by offering practical advice on how students could learn from their innovation journeys. A range of alumni attended to provide best practice examples of innovation during start-up, in a micro enterprise, in a social enterprise and within an established company.

Other practical activities included Technical Skills Workshops (TSWs) in 3D modelling, 3D printing, machine tools and electronics to equip students with specialised knowledge and skills for direct application to the main project. For example, the 3D modelling task was to model a LiDAR scanner head and during the machine tools workshop students created a plumb bob used to set up LiDAR scanners over fixed marker points. The practical electronics TSWs demonstrated aspects of the technology inside LiDAR equipment using a mini LiDAR scanner to demonstrate the control of key actions within the LiDAR scanner.

2.2.5 Plan an engaging launch for the project

This step of the project design process aimed to introduce the *challenging problem or question* and fulfil the *authenticity* part of the essential project design elements (*Fig. 1*).

The project was launched with presentations from a LiDAR scanning operator, an entrepreneur with several technology focussed companies (Teradata UK Ltd, BIM

Surveys Ltd, Snow-Forecast.com Ltd) and a Partner leading Building Information Modelling (BIM) in an engineering consultancy (Hoare Lea LLP). The LiDAR scanning operator explained the technical details of the technology inside LiDAR scanners and how short-range and long-range LiDAR scanners functioned. This created a foundation of knowledge to introduce the driving question defined in 2.2.1. The entrepreneur enthused students with his personal entrepreneurship journey and provided further details on BIM. The Partner at Hoare Lea presented BIM case studies from international projects and highlighted the importance of digital engineering to facilitate global collaboration.

The engagement with industry experts continued with LiDAR scanning demonstrations where students were able to navigate through live scan data taken on-site at the University. This connection with their local environment allowed them to inspect the data in an area familiar to them and this really helped to bring the 'real-world' connection to the project launch.

To complement the data capture aspect of LiDAR scanning demonstrations, students also had the opportunity to use HTC Vive Pro VR headsets to fly through Google Earth VR. During this demonstration students were awestruck with the level of detail and how real it felt to fly over the earth. This also allowed them to see the full technology process from LiDAR data capture to Google Earth VR output that was created using satellite imagery, LiDAR scans and photogrammetry.

3 FINDINGS AND CONCLUSIONS

The planning and implementation of this pilot module was both exciting and challenging. One of the core values at the University is that 'we relish challenge and reach for the previously unachievable' [16]. Designing and implementing new teaching and learning methodologies isn't straight forward and it requires disruptive thinking, innovation and resilience.

3.1 Module planning

Challenges encountered during design and planning included timetabling over 200 students into small group activities, finding suitable learning spaces for project-based activities, a lack of trained GSPBL facilitators and a requirement for different methods of multimedia assessment.

The authors are fortunate that the support networks at the University of Exeter are incredibly willing and able to overcome issues and have already developed some solutions. Examples include best practice timetabling strategies from previous experience with the School of Medicine, a list of all learning spaces suitable for PBL with a 360 online view, refurbishment of engineering learning spaces to facilitate project-based activities, GSPBL training for current and new staff and the development of high-quality assessment criteria for multimedia assessments.

3.2 Module delivery

3.2.1 Project Launch

There is no doubt that students were fully engaged during the project launch. It was a brilliant way to start a module and the energy generated on the day with so many industry colleagues on-site with exciting equipment. Watching students interact with the equipment and ask the experts many questions was a testament to this aspect of GSPBL and EntreComp. The key observation was that students were happy, smiling and laughing and enjoying trying out equipment with their peers and chatting with colleagues from industry in a relaxing, small group experience. Some students were interviewed following the project launch and made the following comments:

‘Project Based Learning helps communication with other people from different sections of engineering such as civil, mechanical [and] electrical and so on … Although it’s the first 3 weeks of the course, you can already sense that the group projects are really going to help us collaborate and also learn about LiDAR’.

‘By doing stuff like this it really brings it to life, whereas we're in the classroom and in lectures learning about it but when you get to put on the goggles and the VR stuff it like, really opens your eyes to what you can use it for and just, I don't know, it kind of blows your mind a little bit for the potential of what you can do with it, so yeah for me it was amazing’.

‘Hands on experience is that link between the theory and the actual application of what you have learnt, so the two combined allows you to have the necessary skills to enter the workforce’.

‘[VR can be used] for architecture and design for architects to produce designs and projects and plans and actually be able to communicate those with others’.

‘Not only do you get to learn about what other … engineers do, but you also get to apply what you do in the entrepreneurship, skills and development course and understand what you can potentially do later on.’

‘What's so great about the course and the hands-on experience is the fact you get to learn transferrable skills, I think it’s very beneficial for like future projects and future employment’.

‘I think it’s just kind of opened my mind a lot more and kind of made me realise the opportunities and the fact that technology is moving so incredibly quickly and I would quite like to be involved with that because it's very exciting’.

These comments illustrate that the methodology applied to this module helps students to appreciate the benefit of collaboration and building a learning community, authenticity, linking theory with practice, linking entrepreneurship competences with employability and it also inspires students to keep up to date with rapidly advancing technology.

3.2.2 Challenges with building the GSPBL culture

The delivery of this module generated challenges which were documented through accelerate feedback and during a feedback lecture with students. Some students found it challenging to adjust to this new type of teaching and learning after very different national and international experiences at school level. A minority of students found it difficult to form team bonds, were too shy to post on the VLE forum, struggled with the open-ended driving question, blended learning and didn’t appreciate the worth of entrepreneurship and multimedia assessment. Some international students found it difficult to manage language and cultural differences in team situations.

Most of these challenges were expected and can largely be solved by putting more emphasis on building the GSPBL culture over time. The module will be modified to provide more detail in the introductory lecture to convey the challenges they will face during the 4th industrial revolution. The new methodology combining GSPBL and EntreComp will be explained so students understand that the module is structured to facilitate the acquisition of the required entrepreneurial competences, technical skills and multimedia experience. Outdoor team building activities are planned to overcome individual barriers and build team rapport, trust and create stronger team bonds. More small group project support sessions will be timetabled to build confidence and build the GSPBL culture. A stronger link will be created between the formative and summative assessment to develop a portfolio style of collated work to demonstrate progression (*Table 1*).

3.2.3 Achievements

Although challenges were identified in accelerate feedback, the positive comments suggest that students were engaged by new methodology.

'I love … [that] … the students [had] free reign on how to approach and go forward with our idea … the course felt structured such that we had a clear objective in sight … unstructured in the sense that our path to the objective was our decision.'

'LiDAR [scanners] are really fascinating and can't wait to pursue a career in them.'

'I can't think of anything negative about this course, you could say that I had the time of my life!'

Reflection is one of the GSPBL seven essential project design elements [2] and student teams submitted a reflective report after their final summative assessment. In the EntreComp part of the questionnaire, student teams were asked to 'list the entrepreneurial skills (as shown on the EntreComp wheel) you think you have most improved as a team during this module?' The following pie chart (*Fig. 3*) shows the percentage of each competence selected. These are grouped into the 3 EntreComp areas:

- Ideas & Opportunities (Blue);
- Resources (Orange);
- Into Action (Green).

These initial results from the team reflective reports and observations by academic members of staff during the module suggest that students progressed further than the expected Foundation Level 1 (Discover) and Level 2 (Explore) [3, pg. 20] and the majority (56%) of the self-assessed and observed competences were in the action area associated with Level 3 (Experiment) and Level 4 (Dare). EntreComp state that 'Level 3 focuses on critical thinking and on experimenting with creating value, for instance through practical experiential experiences' ... 'Level 4 focusses on turning ideas into action in 'real life' and on taking responsibility for this' [3, pg. 20].

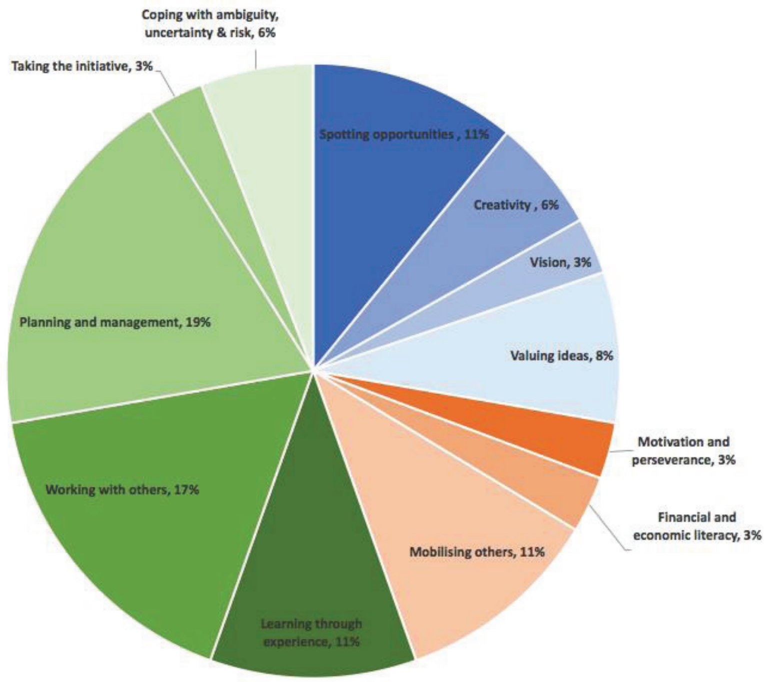

Fig. 3. Student assessed EntreComp competences gained during the project.

Initial evidence suggests that designing engineering modules to include the GSPBL seven essential project design elements facilitates students gaining competences associated with Level 3 and 4 of the EntreComp Progression Model [3, pg. 20]. Engineering students need to develop a thirst for life-long learning and harness their human potential in preparation for the 4th industrial revolution.

Future work is currently underway to refine the methodology for Entrepreneurship 1, Entrepreneurship 2 and continue to apply this methodology to the design of new engineering degree programmes at the University of Exeter.

4 SUMMARY AND ACKNOWLEDGMENTS

A pilot module (Entrepreneurship 1) facilitated action research with a methodology that combined Gold Standard Project Based Learning (GSPBL) [2] and EntreComp [3] as part of strategic curriculum development. The methodology for designing this pilot module followed the ‘5 steps for designing a project’ [13] for GSPBL. The team project started with an industry linked launch day with hands on LiDAR and VR technology demonstrations. The planning, delivery and assessment of the pilot module posed challenges but results from reflective reports and academic observations illustrated that the proposed methodology helped students develop competences in Level 3 and 4 of the EntreComp progression model [3, pg. 20] and empowered them to take risks, make their own choices and take control of their learning journey. The authors plan to refine the methodology and continue to apply it to the design of new engineering degree programmes at the University of Exeter.

The work undertaken to develop this module was a team effort and relied on brilliant support from the academic teaching team, education and student support, technical services and innovation and impact and business at the University of Exeter. Our industry colleagues at Teradata UK Ltd and Hoare Lea LLP played a major part in the success of the project launch day.

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Children's University at Budapest University of Technology and Economics

Gy. Dallos
BME, Faculty of Electrical Engineering and Informatics
Budapest, Hungary

L. Farkas
BME, Faculty of Electrical Engineering and Informatics Budapest, Hungary

G. Hornyánszky
BME, Faculty of Chemical Technology and Biotechnology
Budapest, Hungary

M. Lázi
BME, Faculty of Natural Sciences
Budapest, Hungary

M. Lukács
BME EIT, Centre of Innovation and Knowledge
Budapest, Hungary

Conference Key Areas: Talent management

Keywords: Children's University, primary school students, educational summer programs, STEM subjects

ABSTRACT

The very first edition of the Children's University summer camp intended to primary school students was organized in 2015 at the Budapest University of Technology and Economics (BME). Since then, we held the summer camp every year. The concept of the Children's University was similar to that of several foreign initiatives but the camp was unique in its form and content.

Our aims were i) to show the 8-14 year old students -through colorful and diverting activities- the amazing richness of scientific fields covered by BME and ii) to stimulate their curiosity for natural sciences and technology. Our one week program consisted in lectures and seminars and was closed by a symbolic graduation ceremony. In addition, during the week children worked on projects in teams so that they could improve their cooperative skills.

At the end of the week a satisfaction survey was given to the parents and students to get their feedback on the camp. We summarize the results of the surveys taken in 2018.

The Children's camp was a challenge for the university stuff as they got in contact with a much younger age group than usually.

BME students were responsible for taking care of the children during the program and guiding them between the places. The accompanying students were prepared for the task on a specific training.

With regard of the success of the Children's academy, we are now organizing satellite events with a point-gaining system during the whole academic year in order to sustain the interest.

1. INTRODUCTION

The phenomenon that the interest of students is decreasing for the natural sciences, technology and technical sciences (STEM subjects) can be observed even in the developed countries [1,2]. Meanwhile, in the knowledge-based economy there is a growing need for STEM-skilled professionals [3]. The shortage of such professionals may be an obstacle for the economical development. The expert groups of the European Committee also deal in depth with these problems and are looking for solutions [4,5]. The insufficient supply of students eligible for higher education in the STEM field is closely related to the difficulties and eventual deficiencies of the high-school education. Often, the problem starts during the years of primary school [1], hence it is worthy to consider this group of age as well when searching for the soultion. In many cases the high scientific standard of the curricula is frightening because it does not always take into account the age specificities. The present students are “digital natives”, whose mentality, information processing mechanismes differ from those of former generations. It is widely accepted, that young children are not interested in natural sciences but in physical reality which can be perceived by their senses. In Western-Europe it is a long tradition that universities try to arouse the curiosity of children for natural sciences by orginising events that popularise sciences in an age-appropriate manner [3].

Since 2015 in each year, the Budapest University of Technology and Economics organises summer schools entitled Children's University for children aged between 8 and 14 years. Though the idea was inspired by foreign initiatives, our program differs from them significantly.

2. Aim of the Children's University

Within the frame of the Children's University children gain insight into the life of the university, get acquainted with several disciplines in a playful manner and make experiments [6,7].
The goals of the Children's University:

- to familiarize children with different disciplines and scientific methods,
- to provide insight into to the function and rules of the university as well as to the everyday life of students,
- to present the possible choices for their future education,
- to raise the interest of children and improve their critical thinking,
- to create a link between children and university stuff/students.

Our program is the result of the coordinated work of the whole BME community. Technical programs are realized by the teachers/researchers of the eight faculties but stuff from the Central Library, Department of Physical Education and students' organisations participate, as well.

External partners including companies contribute largely to the success of the event in several ways: they offer financial support, but also organize visits or give talks where they provide context and role models.

2.1. Organisation of the program

The summer school is organized in two turns: the first one is intended for children aged between 8 and 10 years, the second one is for 11-14 year old children. In both turns 300 children participate, divided into 14 groups. The groups can be easily distinguished by the colour of their T-shirts. Each group has 3-4 adult mentors, who are responsible for the supervision, safety and comfort of the pupils and for their orientation among the different sites. Supervisors have the task to discuss with children about the scientific programs and university life as well. They are selected from volunteering BME students.
Once selected, they participate on a specific two day long training.
Participants receive a precise time schedule as *Table 1*. for the five days. The weekly program consists of lectures, seminars, leisure time and sport activities.

Table 1. The schedule for five days

<table>
<tr><th></th><th>Monday</th><th colspan="2">Tuesday</th><th colspan="2">Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><td>7:30-8:00</td><td rowspan="2">Arrival</td><td colspan="2" rowspan="2">Arrival</td><td colspan="2" rowspan="2">Arrival</td><td rowspan="2">Arrival</td><td rowspan="2">Arrival</td></tr>
<tr><td>8:00-9:00</td></tr>
<tr><td>9:00-10:00</td><td>Lecture</td><td colspan="2">Lecture</td><td colspan="2">Lecture</td><td>Lecture</td><td>Lecture</td></tr>
<tr><td>10:00-11:00</td><td>Leisure time</td><td rowspan="2">Seminar</td><td rowspan="2">Sport</td><td rowspan="2">Sport</td><td rowspan="2">Seminar</td><td>Leisure time</td><td>Leisure time</td></tr>
<tr><td>11:00-12:00</td><td>Lecture</td><td>Lecture</td><td>Lecture</td></tr>
<tr><td>12:00-13:30</td><td>Lunch</td><td colspan="2">Lunch</td><td colspan="2">Lunch</td><td>Lunch</td><td>Lunch</td></tr>
<tr><td>13:30-14:30</td><td>Seminar</td><td rowspan="2">Sport</td><td>Leisure time</td><td>Leisure time</td><td rowspan="2">Sport</td><td>Seminar</td><td rowspan="3">Project presentation, Graduation</td></tr>
<tr><td>14:30-15:30</td><td>Leisure time</td><td rowspan="2">Seminar</td><td rowspan="2">Seminar</td><td rowspan="2">Project</td></tr>
<tr><td>15:30-16:30</td><td>Seminar</td><td>Seminar</td><td>Seminar</td></tr>
<tr><td>16:30-17:00</td><td>Departure</td><td colspan="2">Departure</td><td colspan="2">Departure</td><td>Departure</td><td>Departure</td></tr>
</table>

The mascot of the summer school is an owl, personified by a teacher of the university. As shown in. *Fig.1.* The Owl participates at the lectures, gives an introduction to the topic and helps the communication between the speaker and children.

Fig. 1. Owl with the pupils in the lecture room

2.2.Technical programs

The lecture and seminar topics cover a lot of different fields of science. The organisers put special emphasis to involve everything from the natural sciences, informatics and technical sciences to the economics and social sciences.
Some examples selected from the lectures and seminars are shown in *Table 2*.

Table 2. Some titles of lectures and seminars

Seminars	Lectures
Physics of medicine	The force of water
It's hard as a stone	Magical physics
Spaces of architecture	How our smart phone is produced?
Why is smart the smart phone?	Magic chemistry
Construction of electrical circuits	SMOG-1 student satellite
Chemhunting	Movement of animals
Do sport smartly!	Odoo, the house of the future
Game with languages	Why the car is a computer?
How to bring down the Sun on the Earth?	Children's' rights in the world
Biosensors	Why is useful the economics?
Roaming in mathematics	About light and colours
Thunderbolts from a close view	What affairs are the monetary affairs?
How thick is a hairbreadth?	Magic molecules in the world of plants
Futuristic urban structures and utopias	The world of sons, sons of our world
Up-to-date energy use	Good or bed advertising
To do or not to do? The health begins in the mind.	On what and from what we build - roaming in geology
INTERNET of the things, or how the washing machine spies?	Sherlock Holmes and the science of the conclusion

Besides the presentation of the various colourful topics, there are activities where children themselves must create, mount or measure something, that is, they have to do manual work.

According to our experience, Children's University means a real challenge even for the experienced university staff as well, since they get in contact with a very different age group, so different educational methodology should be applied.

The project task ensures possibility for team work. Within the frame of the project the teams must find out, which product they would like to develop when they will be adult. The ideas must be shown during the graduation ceremony in a five minute presentation supplemented with graphical illustrations. Due to the live transmission, the parents may follow the event in another room.

At the end of each day, once the pupils have left, the organisers and the supervisors evaluate the daily experiences and discuss the expected events of the next day.

3. Feedback

At the end of the school both the children and their parents complete a satisfaction survey. The results of Children's University 2018 is summarized in Table 3.

Table 3. Results of children satisfaction survey

	Question	average Turn 1	average Turn 2
1.	How would you mark the CU camp?*	4,79	4,56
2.	Did you find it useful?*	4,62	4,35
3.	How would you mark the work of the mentors?*	4,84	4,85
4.	Which lecture was you favorite?**	-	-
5.	Which seminar was you favorite?**	-	-
6.	Which sentence suits you best?****		
7.	Would you come again to CU?***	90%	81%
8.	Would you recommend CU to your firends?***	92%	82%
9.	Did you find new friends during CU?***	96%	95%
10.	Did you hear about the point gaining system of CU?***	69%	65%
11.	Comments	-	-

* average of answers on a 5-scale grade
** interesting that all lectures and seminars were mentioned
*** average of positive answers in percentage

**** Regarding interest in STEM, the children had to choose from the following answers:

Table 4. STEM interest of participating children

I became much more interested in STEM during CU.	56%	40%
STEM interests me and this did not changed.	38%	50%
I am interested in other areas than covered by CU.	6%	10%

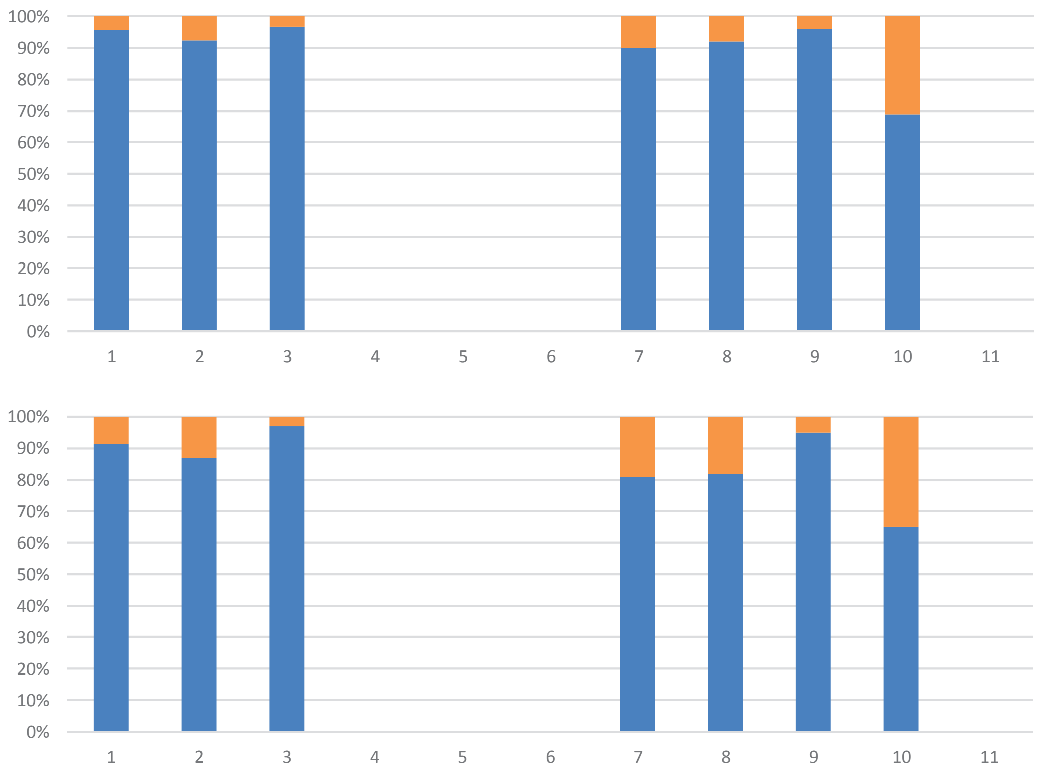

Fig 2. Ratio of positive answers of participating children in Turn 1 and 2

Table 5. Results of parent satisfaction survey

	Question	average Turn 1	average Turn 2
1.	Where did you hear about CU?	-	-
2.	How much was the CU useful as a summer activity?*	4,93	4,85
3.	How much was your child satisfied with CU?*	4,80	4,71
4.	Does CU stenghtened your child's interest in STEM?*	4,80	4,65
5.	How much was your child content after each days of CU?**	99%	98%
6.	How much did your child talk about his/her experience in CU*	4,19	4,31
7.	Did you child find new friendship during CU?**	81%	76%
8.	How much were you satisfied with the mentors?*	4,80	4,71
9.	How much are you satisfied with CU?*	4,88	4,80
10.	Would you bring your child to a CU in the next years?**	99%	94%
11.	Was the fee of CU acceptable?**	97%	98%
12.	Do you know the point gaining system of CU?**	90%	83%
13.	Comments	-	-

* average of answers on a 5-scale grade

** average of positive answers in percentage

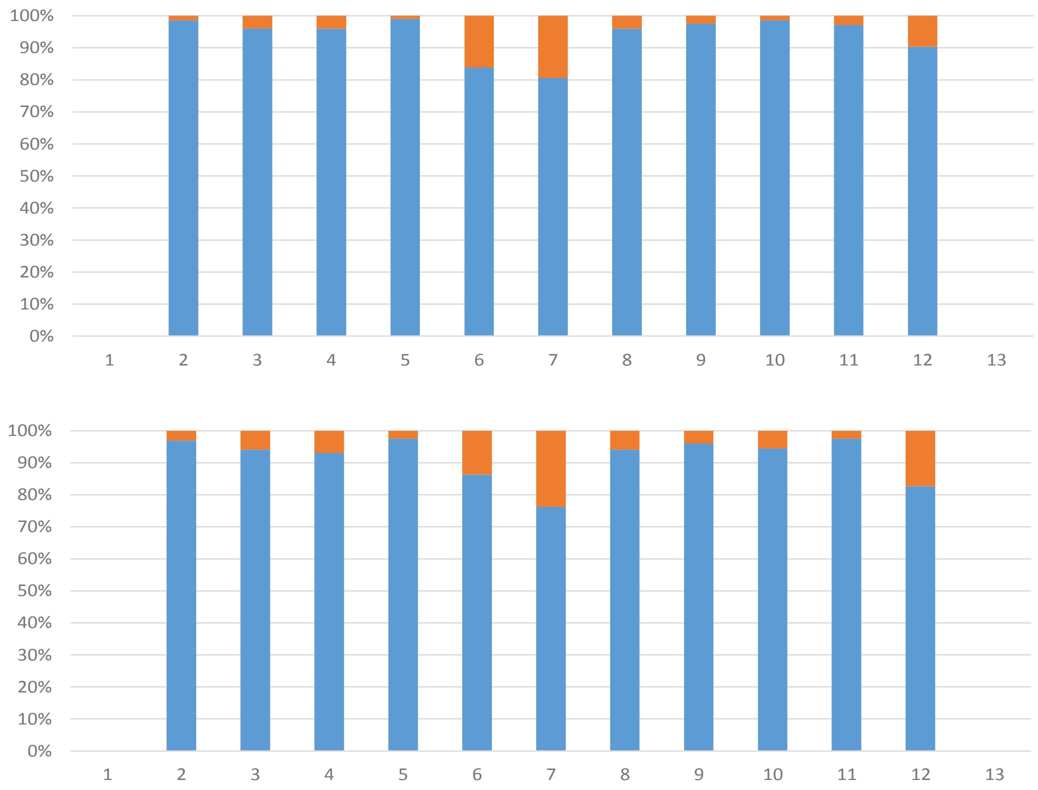

Fig 3. Ratio of positive answers of parents in Turn 1 and 2

Table 6. Results of mentors' survey

Question	average Turn 1	average Turn 2
How much are you satisfied with CU?*	4,37	4,44
Would you come again to CU as a mentor?**	85%	94%
How much were you tired during the days of CU?*	3,89	3,63
Did you find new relationships with mentors coming from different faculties?**	96%	100%
How much was the training useful?*	2,81	3,31

* average of answers on a 5-scale grade
** average of positive answers in percentage

The mentor students see the following strengths of CU:

	Total number of answers	Turn 1	Turn 2
university location	34	22	12
seminars	30	19	11
various themes	30	19	11
team, spirit	26	17	9
lectures	23	15	8
good organizing	19	11	8
project work	14	8	6
leisure activities	9	6	3

As can be seen from the answers above, the interest and success for the summer school is outstanding, both among the participants, their parents and the mentor students.

In order to give the possibility to a maximum number of children to enjoy the programs and to get closer to the world of science the selection of participants happens based on strict rules. Each applicant may participate only once in the summer school organized for younger children and once in the one for older children.

Due to the impressions obtained during the week, by the end of the school the children's interest for the different disciplines is enormous. Most of them is willing to continue the school in spite of the fact that it is in summer holiday. This increased interest must be maintained and even strengthened regularly. Therefore the Children's University does not consist merely of that one week in summer. We organize "sold-out" satelite events every month over the entire academic year. An example is the Children's University Plus, where two lectures and experimental presentations are held. We regularly organize programs on Children's Day and there is also the St. Nicholas Physics. Moreover, we joined the national programs of Everyones' Physics and the Night of Researchers. The curiosity of these events is that the children are accompanied by family members or friends. The knowledge obtained together with an adult accompanying person can be further deepened. Besides, these occasions mean agreable and entertaining family event.

4. Follow-up

Besides the stimulation of the children we would like to measure what programs arouse their interest to the largest extent. An informatical system was developed which allow to follow the attendance of our events. The children can collect points at the different programs (9 points for participating in a summer camp, 3 points for a mid-year event). For these points first a Silver Owl then a Gold Owl diplome can be obtained. The first Silver Owl diplomes was given in this academic year for six children. On the long term it will be interesting and instructive to see the ratio of

Children's University attendants choosing universities focusing on technology or natural sciences.

5. SUMMARY AND ACKNOWLEDGMENTS

In Hungary, BME was the first institution to organize the Children's University in 2015, which was held in each year with great success since then. Mainly the children living in Budapest or in its agglomeration were able to benefit from it. For the participants several follow up programs are organised during the academic year such as Children's University Plus and St. Nicholas Physics.

The authors thank to the Foundation Pro Progressio for its financial support.

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Preparing engineering students for a lifetime of learning
A case study of curricular redesign

J. De Keyzer[1]
KU Leuven, Technologiecampus Diepenbeek, Faculty of Engineering Technology
Diepenbeek, Belgium

J. Lievens
KU Leuven, Technologiecampus Diepenbeek, Faculty of Engineering Technology
Diepenbeek, Belgium

J. Baeten
KU Leuven, Technologiecampus Diepenbeek, Faculty of Engineering Technology
Diepenbeek, Belgium

L. Braeken
KU Leuven, Technologiecampus Diepenbeek, Faculty of Engineering Technology
Diepenbeek, Belgium

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ABSTRACT

In response to the observation that change is the only constant in today's working environments, leading organizations in the fields of education have placed the principle of "life-long learning" (LLL) atop the curricular agenda. Also in engineering education, it is widely accepted that graduating students need to have "a recognition of the need for, and an ability to engage in life-long learning" (ABET 2013). This contribution describes a LLL trajectory that was recently developed at the Faculty of Industrial Engineering Technology, Campus Diepenbeek (KU Leuven & UHasselt). The curricular pathway and the learning environments were designed following Dochy's guidelines for "high impact learning", with student ownership and (self-)reflection as critical components. From the start, students engage in a sequence of curricular activities that integrate the acquisition of soft and hard skills in increasingly challenging problem-based project courses. The learning experiences from this curricular pathway inform the student's development of a personal LLL portfolio that not only charts but also structures and guides the student's personal learning trajectory. This LLL portfolio is initiated by a multi-angled self-assessment, which provides the basis for a self-

[1] J. De Keyzer
Jozefien.Dekeyzer@kuleuven.be

constructed “PDP” (“personal development plan”). Typically, the PDP also accommodates extra-curricular activities (e.g. community service learning, MOOCs, peer teaching,…) selected by the student to complement his or her competency profile. As with the curricular activities, the student then reflects upon these activities - now using the 4Rs model (reporting, relating, reasoning, reconstructing) – and integrates them in his or her PDP, which is, as such, continually reworked.

INTRODUCTION

It is truism to state that today’s working environments are changing at an ever increasing pace [1]. Employees, if they are to prosper within this context of perpetual change, cannot but develop a broad and flexible range of knowledge and skills. The demands on educational programs are nowadays dominated by the call for responsible and motivated individuals that show a critical attitude and ability to reflect and have efficient problem-solving skills [2]. Graduating engineers should, of course, still have strong technical knowledge and skills but increasingly, employers emphasize the importance of personal/soft skills, such as the ability to cope with stress, to be enterprising, innovative etc. [3]. Moreover, graduating engineers have to be able to work not only independently but also in teams and hence, communication skills, such as proficiency in foreign languages, writing reports, giving presentations etc. are crucial [4]. The “T-shaped engineer” of the 21st century is not just a technical specialist with in-depth knowledge of a particular domain or system, (s)he is also broadly formed and possesses boundary crossing competencies [5].

It is next to impossible to teach all of these skills comprehensively within the four or five years of the engineering curriculum. Luckily, the solution lies within the problem. Since jobs are changing, graduated engineers will have to change throughout their career. They need the attitude and ability to continually absorb new knowledge and practice new skills. In other words, they will have to engage in what is now commonly known as life-long learning (LLL). ABET, for instance, states that, by the time of their graduation, students should have acquired "a recognition of the need for, and an ability to engage in life-long learning" [6]. Currently, the importance of LLL is such that it is not just one of many competencies students should acquire, rather "it must become the guiding principle for provision and participation across the full continuum of learning contexts” [7, pp. 3-4], as stated by The Commission of the European Communities in its memorandum on LLL published in 2000.

On one hand, the ascendency of LLL on the educational agenda provides respite to curriculum designers, as the curriculum is relieved of the burden to carry within itself the full range of specialist and generalist competencies. On the other hand, the curriculum should make sure that when they graduate, students possess a positive attitude towards life-long learning as well as the skills necessary to engage effectively in this process.

In the context of this contribution, LLL is conceived of as the process in which self-motivated individuals constantly seek for knowledge and develop skills. LLL can then be defined as a competency that implies:

a) the willingness to look out for and take advantage of formal, non-formal and informal occasions for self-development on professional, social/civic and personal level (**attitude**);
b) this attitude presupposes a LLL **skill set** for self-directed learning (continuous cycle):
    a. the ability to self-assess in relation to ever-changing demands of the industrial, economic and social environment;
    b. the ability to set goals for development;
    c. the ability to plan and execute;
    d. the ability to continuously (re)evaluate the LLL pathway;
    e. the ability to draw learning gains from not only formal but also non-formal and informal learning situations;
c) these skills presuppose **knowledge** of some fundamental concepts and techniques:
    a. frameworks for self-assessment like the core qualities model, SWOT,…;
    b. ways to obtain new knowledge e.g. search engines, educational centres, professional network groups (e.g. ie-net), MOOCs,….

In this contribution, we communicate on our learning trajectory towards LLL for students in Engineering Technology with a focus in Chemistry. This learning trajectory is spearheaded by a dedicated course on Lifelong Learning, but, in line with the vision of The Commission of the European Communities [7], LLL pervades the entire curricular pathway. To enable this broad approach, a didactical concept was selected that could scaffold the entire curriculum, while continuously honing students' LLL competencies. The concept chosen is the HILL-model by Dochy – or "high impact learning that lasts", in full – the tenets of which directly prepare students for a lifetime of learning [2] . First, we explain how Dochy helps shape the LLL curricular pathway. Then, the philosophy and outline of the course on Lifelong learning are explained. Finally, some preliminary observations and remarks are discussed.

1 CURRICULAR DEVELOPMENT ACCORDING TO DOCHY

Throughout the curriculum, we aim to establish a "high impact learning" environment following the ideas of Dochy [2]. The main emphases of this high impact learning environment are summarized in *Fig. 1*.

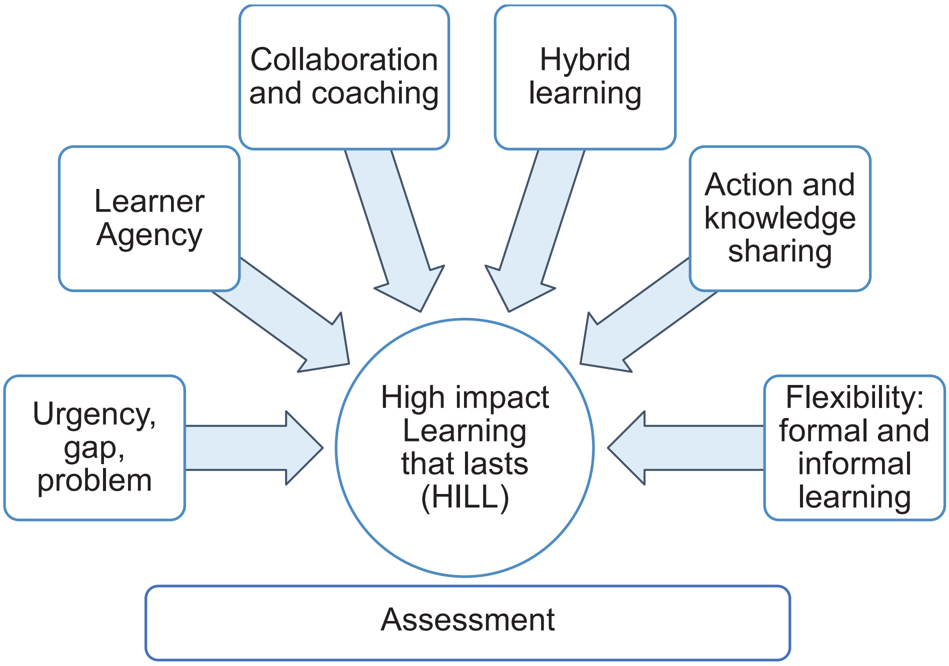

Fig. 1. Elements for high-impact learning that lasts, according to Dochy [2]

We started from the observation that the Dochy principles firmly bolster the acquisition of LLL skills:

- LLL is prompted by the self-critical observation that there exists a **gap** between one's current and desired competencies;
- for effective LLL, **learner agency** is prerequisite as the learner himself, without institutional or top-down prompts, takes initiative to expand his professional repertoire;
- LLL is not a solitary enterprise, but it takes place in **collaborative** interaction with peers and in dialogue with a **coach** (a mentor, a teacher, an instructor, an inspirational role model, an industry leader…);
- LLL in the 21st century takes place in **hybrid learning** environments (F2F seminar settings, online learning, MOOCs,…);
- LLL implies an *action-oriented* attitude, and it is accelerated by **knowledge sharing** in networks of learners;
- LLL is not limited to **formal** learning contexts (seminars, MOOCs, trainings), but the effective LLL learner will also draw learning gains from **informal** and non-formal contexts (in leisure or community service associations, spontaneous work floor interactions, in social or non-profit organisations,…).

Now, how is the HILL-model implemented in our curriculum? One powerful way to incorporate all of these elements, is to organize group project works. For this reason, we include at least one project work each semester throughout the entire curriculum. To avoid, however, that group work becomes a "bolt-on" experience, detached from the rest of the curriculum, we have taken care to ensure that the design of the full curriculum is informed by the HILL tenets. First, the implementation of Dochy in the classic courses and lab sessions will be discussed. Then, the learning trajectory of 'Research and engineering skills', of which the project work is part, will be discussed.

1.1 Classic courses and lab sessions

Courses start from problems, assignments or tasks that young engineers are typically confronted with in their first job. This way students see the **urgency** to acquire the knowledge and skills that are offered to them. Through company visits or industry cases, 'real life' is brought into the class room. For instance, a chapter on heat transfer is started with the task to choose an isolation thickness for a steam conduct – revealing a knowledge gap that leads to the introduction of heat transfer laws. Each course is part of a larger learning trajectory, which is clarified in the first lesson of a course to the students. The end of such a learning trajectory is marked by an assignment in which knowledge from different courses needs to be combined, e.g. at the end of the learning trajectory 'analytical chemistry' students are given an assignment where they have to select, develop and validate an analytical method for a specific (real) problem.

Learner agency is increased by giving a certain degree of freedom to the students, both in the form of optional courses and within courses. For instance, students decide for themselves whether to attend an extra support session or to work independently on exercises.

Professors work with powerful **hybrid learning environments** in which classic methods (textbook, lectures, ...) are blended with new learning methods, e.g. group discussions, peer feedback, electronic learning platforms such as Blackboard (with online courses, evaluations, instruction movies, lab preparation modules...) and Perusall[2], guided self-instruction, polls on conceptual questions, etc. Students cannot simply 'sit and absorb knowledge' but they have to **actively** engage in the learning process, which does not stop when students leave the classroom. This active process also gives the professor or teaching assistant the possibility to give **continuous feedback (informal assessment)** and act as a **coach** in the learning process.

Moreover, students are encouraged to **collaborate** and **share their knowledge**. In some courses this is even part of the assessment. For instance, in the lab of Organic Chemistry, each student is responsible for one type of experiment. This means they have to instruct their fellow students, correct their calculations, observe their work and answer their questions. Only by collaborating, they can all achieve the set goals.

1.2 Learning trajectory 'Research and engineering skills'

The different elements of the HILL model are also strongly represented in the learning trajectory 'Research and engineering skills'. In the first semester, basic engineering skills such as translating a problem into equations, interpretation of graphs etc. are practiced. From the second semester onwards, each semester of the curriculum contains at least one project work (see *Fig. 2*), where students work in groups on a real-life assignment and in interaction with the problem owners (e.g. a company or a research group) (**urgency, problem based**). These (group) assignments include authentic, real life case studies that appeal to students' technological skills as well as their soft skills (communication, project management, team work). Students need to

[2] Perusall (www.perusall.com) is an online, collaborative application that allows students to annotate course material with questions and comments. Perusall is often used in a flipped classroom context.

display an **actionable and collaborative** attitude. They are **coached** by a supervising professor/teaching assistant, but the intensity of the given guidance decreases over the course of the curriculum. Moreover, in order to complete the assignments, students have to manage their own learning process. Students have to define the problem, decide which information to look for, outline their approach etc. In other words, they have to take their trajectory into their own hands (**learner agency**). The **assessment** of these project works combines an output-based assessment (e.g. presentation, report, journal article) with a peer-review process assessment – an approach based on Dochy's earlier work [8]. This peer assessment reviews skills such as finding information, taking initiative, listening, being critical etc. Halfway the project work, a first assessment without grades is done, the result of which is shared and discussed with the students. Through feedback from peers as well as professors and teaching-assistants, students gain insight into their skills. A second assessment at the end of the semester forms part of the grade of each individual student. The consecutive assessments also are the basis of the reflection that students do in the Lifelong Learning course, which is discussed below.

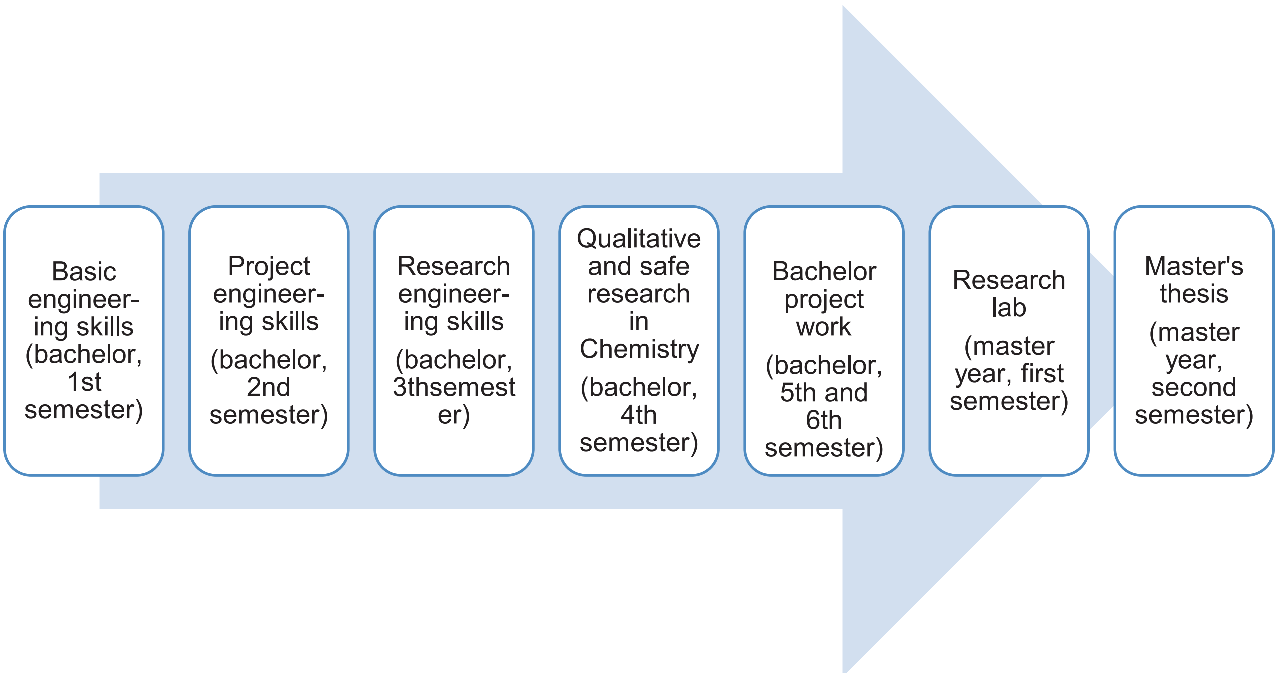

Fig. 2. Consecutive courses in the Learning trajectory 'Research and engineering skills'

2 A COURSE IN LIFELONG LEARNING

As announced above, the curriculum also includes a separate course on LLL. In the course on LLL, the aim is to show students how they can set up a learning path when there is no longer an institution (school, university) that decides for them what they should learn. This course has been running on our campus since 2013 as part of the master program (although the teaching team encourages students to start working on the course from the start of the 5th semester). Within certain boundaries (i.e. minimal activities to be performed), students are given the freedom to determine what they want to learn, which skills they want to develop and how they will do this. They fill in a reflective form on these activities and collect these forms in a portfolio.

However, it appeared from feedback moments, the handed in portfolios, as well as individual conversations with graduated students that we were only partly reaching the premeditated goal. Even if some students really found high learning value in their activities, other students were just ‘collecting hours’. In order to improve this, and to help students set up a well-aimed learning trajectory, a new approach was initiated in 2018.

In the new approach, students perform a context-bound self-analysis, set-up a personal development plan, take actions accordingly, reflect on their actions and update their goals and plan if necessary (see *Fig. 3*). Feedback from the above-mentioned learning activities helps students to formulate their learning goals. To facilitate this process, students are introduced to techniques such as SWOT analysis, SMART goals and the core quality model. In a next step, students are asked to write a personal development plan. This way, they gather knowledge necessary for LLL and work on their skills and attitude towards lifelong learning.

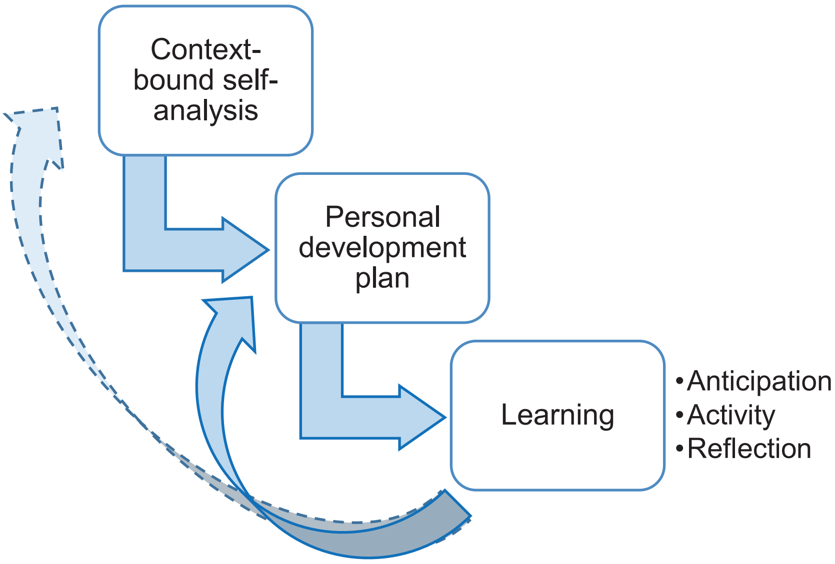

Fig. 3. Cycle of learning

2.1 Context-bound self-analysis

A first part of the course is a self-analysis. In an introductory course manual, students are introduced into frameworks for self-assessment like the core qualities model of Daniel Ofman [9], a SWOT (strength-weakness-opportunities-threats) analysis etc. Then they are asked to do a self-analysis. This self-analysis should be within the given context, namely their role as a professional. It is therefore important that students have at least an idea of this context. This is provided to them throughout the curriculum, for instance in the form of company visits, project work with real-life cases etc. Extra information is provided by referring to the publications of the ‘Prefer’-project, where three different roles for engineers are defined with their accompanying competencies

[10]. A list with competencies and their common definitions is also provided to the students. Since making accurate self-assessment is known to be difficult for novices [11], students are explicitly tasked with integrating reflection on previously received feedback from teachers and peers in other courses (in particular group project work).

2.2 Personal development plan (PDP)

After the self-analysis, students are asked to define goals for themselves and to construct a personal development plan. These goals and the accompanying plan should be SMART: specific, measurable, achievable, realistic/relevant and timely.

The course is split up into three domains:

1. deepening of technological knowledge;
2. broadening of general knowledge;
3. soft skills and taking responsibility.

A student should plan and execute 34 hours of activities. Activities for at least eight hours of each domain should be chosen. Ten hours of activity are free, which means the student can choose to focus on one topic in these 10-18 (in combination with the eight hours of the domain) hours.

Students are free to define and find activities. To support this process, the teaching team offers and updates a page on the electronic learning platform where activities are announced. For the first two domains, these activities can be all kind of learning events, such as seminars, workshops, company visits or online courses (e.g. MOOCs). For the third domain, students should do some type of activity in which they act as socially engaged and responsible engineering students, e.g. acquaint secondary school students with the engineering curriculum, work on science popularization, be a member of the student council, …

After construction of the PDP, students are invited for a first feedback session, which takes place in small groups (four to six students). The PDPs are discussed one by one and both the instructor and fellow students give feedback. The instructor encourages students to further develop competencies that students want to use as their selling point i.e. those things that they really are good at, as well as those competencies that are difficult for the student.

2.3 Learning

Once the personal development plan is set, students can start doing activities in order to achieve their goals. We consider the learning to happen in three steps: anticipation, activity and reflection. For each activity, a reflective form is to be completed. This form starts with ‘anticipation’: already before the activity students should think about which knowledge they expect to learn or which (soft) skills they intend to practice in this activity. A second part of the form is to be filled in after the activity (reflection).

For composition of the reflective forms, the 4Rs reflective model was used [12]. This model states that there are four levels in reflecting:

1. Reporting/responding
2. Relating
3. Reasoning
4. Reconstructing

Rather than providing direct instruction about this model, we used it to compose the questions in the reflective form in such a way that students perform those four steps by answering the questions. In particular, as one of the last questions, students are asked to describe how they would use what they have learned in a future professional situation. They should also compare their reflection after the activity with what they had anticipated.

Using their PDP and the reflective forms, students construct a portfolio. A reflective form about the students input in the group projects work is also added. At the end of the 6th semester another (formative) feedback moment is scheduled. At this point, feedback is given on the way students fill in the reflective forms and the PDP is re-evaluated and updated if necessary.

At the end of the last semester, students hand in their completed portfolio. This portfolio includes a reflection about the progress in the group project work and a last assignment, in which students make an overview of their strengths and how they are able to tackle their weaknesses. Again, formative feedback on the portfolio is given, and the portfolio is graded as 'pass' or 'fail'. An important reason to choose for a pass/fail system with formative feedback is to avoid that students would write 'desired' reflections instead of real reflection.

3 PRELIMINARY OBSERVATIONS

The new approach of the course has been running since October 2018. We can observe that the personal development plans that have been proposed by students are generally of a high quality. An example of a student PDP is shown in appendix 1. Students use the 10 'free' hours to do a variety of activities e.g. organizing a week internship, performing research to validate an idea for a start-up company, following an online course (MOOC), and being engaged in the organisation of a STEM event,…

However, it also transpired that for some students the feedback on the proposed PDP was crucial as they struggled to translate the instructions from the manual into goals of their own. Often, goals were not made sufficiently 'SMART': they were not expressed in way that is specific making it more difficult to assess afterwards if the goals are reached. Because they also handed in their self-analysis, the instructor could jump in with suggestions about goals, how to set them and encourage students by emphasizing their accomplishments and progress.

Some consideration about discussing the personal development plan in small groups needs to be made. On the one hand, this is often less time consuming for the instructor and students may learn from each other. Moreover, students might give relevant additional feedback to each other. Since students got to choose the feedback moment, they were in groups with fellow students they got along well. Fellow students jumped in when students had made wrong or too harsh conclusions about themselves. On the other hand, some student might feel less open in their self-analysis when they know it will be discussed with their fellow students. For this reason, one student asked to discuss the PDP in private with the instructor.

A small-scale questionnaire with 17 respondents, loosely based on Kecskemety et al. [13], was done to assess the influence of the course on the targeted skills and students' attitude towards LLL. The inquiry was taken from students that started but not yet finished the course, as no student following the new approach has already finished the course. 15 out of 17 students report that throughout the curriculum, they have learned to self-asses their competencies. Also, 15 out of 17 students report that they have learned to set goals for themselves and to continuously (re)evaluate their learning pathway. Whereas they attribute the ability to self-asses and to re-evaluate the learning pathway mostly to the entire curriculum, more than halve of the students assign the ability to set development goals to this course in particular. 13 out of 17 students reported a significant increase in ability and skills to set up a PDP after following the first part of the course. Also, 12 out of 17 students claim that they now have developed the willingness to look out for and take advantage of formal, non-formal and informal occasions for self-development. This question was also posed to last year's students (who followed the old approach without PDP) and here 5 out 5 students answered positively. Therefore, it might be assumed that also with the new approach, the students' attitude towards lifelong learning will grow in the course of the second year.

4 CONCLUSION AND FUTURE WORK

LLL is a competency of such far-reaching importance in today's constantly evolving professional environments that no institution of higher education can afford to disregard it. We have decided to embrace LLL as it offers the best possible guarantee that our graduating students will thrive professionally – and continue to do so throughout their careers. One part of the approach was to set up a dedicated course on LLL, in which students acquire the necessary attitudes, skills and knowledge. Students are appealed to as actionable agents and self-directed learners, but at the same time they engage in fruitful and supportive dialogue with peers and coaches. Of course, LLL cannot be taught in a separate course only. To ensure that LLL is not relegated to a curricular silo position, we adopted Dochy's HILL model as a point of reference for the entire curriculum. The Dochy elements effectively scaffold the acquisition of LLL competencies across the curriculum.

For next year, we will provide the students with more examples that highlight good practices, such as the combination of working on language/soft skills and technical skills in an internship. Via social media (e.g. LinkedIn) and other initiatives, we want to give more students the opportunity to get in touch with alumni so that they can arrange short internships. In three years, focus groups with alumni (two years professional experience) will be organized in order to evaluate the current approach. One of the goals focus groups will be to uncover which characteristics of the course are perceived to be effective in contributing to the LLL goals. Also, an evaluation among staff will be set up to monitor acceptance and observed adequacy of the approach.

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ANNEX

Development goal	Development activity	Desired result	Timing/deadline	Facilities needed	Knowledge deepening (8)	Knowledge broadening (8)	Taking responsibility (8)	Free hours (10)
Get more insight into the work of an engineer	2 company visits on open company day	To get a first idea of different companies	Semester 5	Info on website ‘open company day’	2			
	Follow an engineer for 1 dag (incl. survey)	To know what are the typical activities of an engineer in a day	Semester 6	Contact with engineer working in a company	2		4	
Improve networking skills	Follow training	To know how to start a professional conversation with people that I do not know	Semester 6	Training => MOOC is available		5		5
	Helping at info fair	Practice my network skills in a familiar context; I want to address at least three future students	Semester 6 (April 27 2019)	Subscribe myself for info fair			3	
	Attend network event	Show to myself that I can start a conversation with at least two different people in a professional context	Semester 7 (October 24 2019)	Network Event => Limburg engineer-ing event				2
Deepen my knowledge on analytical	Read on chromato-graphic techniques	Understand how chromatography works	Semester 7	Textbook (library or database)	see movie			

techniques, in particular chromato-graphic techniques		(I will know if this succeeded if I can make the instruction movie)						
	Attend seminar or online course	To know the latest developments on GC	Semester 7	Look for relevant seminar or course (look at university websites, KVIV, ask professor N.)	2			
	Make an instruction movie on the use of GC that can be used in the lab	Well-explained instruction movie that is useful for next year students	Semester 8	Contact professor D.	2		1	3
Learn about ethics in profes-sional context	Follow seminar	To know some examples of ethical questions that can arise in an engineering job	Semester 5 (Dec. 12, 2018)	Subscribe for seminar		2		

Closing the feedback loop in the transition from secondary to higher education

Tinne De Laet[1]
Head Tutorial Services Engineering Science
Leuven Engineering and Science Education Center (LESEC), KU Leuven
Leuven, Belgium

Tom Broos
Department of Computer Science & LESEC, KU Leuven
Leuven, Belgium

Maarten Pinxten
Postdoc Leuven Engineering and Science Education Center, KU Leuven
Leuven, Belgium

Carolien Van Soom
Head Tutorial Services Science
Leuven Engineering and Science Education Center (LESEC), KU Leuven
Leuven, Belgium

Greet Langie
vice-dean Faculty Engineering Technology & LESEC, KU Leuven
Leuven, Belgium

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ABSTRACT

Against the background of the increasing need for skilled scientists and engineers, any hurdle in the study career of engineering students is undesired. One of the most important hurdles is the transition from secondary to higher education.
The situation at faculty of Engineering Science at KU Leuven, the largest Flemish (Dutch-speaking part of Belgium) University, is not different. Even more, due to regional regulations, Flemish universities have to accept any student with a secondary education diploma into in the engineering bachelor program, even if the secondary education program does not provide the student with the required knowledge and

[1] Corresponding Author
Tinne De Laet
tinne.delaet@kuleuven.be

competencies. The resulting heterogeneous inflow of students creates an additional challenge.

During the last six years, researchers, educational staff and study advisors of the engineering science program of KU Leuven have collaborated to tackle this challenge. The concept paper will present the overarching ideas around the work that has been performed and provide pointers to the different supporting publications. Hereby, it will offer the unique opportunity for highlighting the connections between the work of our research team and the vision that underlies this work.

This paper seeks to inspire practitioners and researcher in the engineering education field who focus on the transition from secondary to higher education. More specifically, the paper aims to share the underlying vision and shows how a close collaboration between practitioners and researchers can create an added value and impact on the engineering education field.

1 INTRODUCTION

A European Parliament 2015 report on the creation of a competitive labour marker emphasises the increasing need for STEM profiles: "… *the EU faces a shortage of skills in science, technology, engineering and mathematics (STEM), while it has an over-supply of social science graduates*." It furthermore states that "*supplementary initiatives at European and national level are necessary to respond to the bottlenecks in STEM-related jobs and studies*". This clarifies the importance of identifying hurdles in the career of engineering students and developing solutions to minimize these hurdles.

In the career towards engineering, the transition from secondary to higher education is one of the important hurdles [1], [2]. In the transition three phases are typically distinguished, the recruitment phase and activities, examination and application phase, and the registration phase. This paper focuses on the examination and application phase and the first weeks in higher education itself. The actual transition is heavily influenced by the local context, regional and national regulations, and culture. The ATTRACT project [3] has studied the three transition phases in five European countries (Belgium, Finland, Ireland, Italy, Portugal, and Sweden). The project showed that the formal admission requirements both on the level of general admission requirements (school certificate exams, ongoing performance at second-level, entrance exams, …) and additional admission requirements for engineering courses (maths, physics, chemistry, biology) strongly differ between the participating European countries. Beside formal admission requirements, also academic and social challenges influence the transition [4]. While students are aware of the need to adapt their study and learning strategies to the new context of higher education, which adaptations are required and to what extent is less clear. Moreover, the new social context poses an additional challenge as students lack a comparative framework of peers in the first weeks of higher education (social-comparison theory [5]).

Feedback has shown to be supportive for student achievement especially when the type of feedback is adapted to the purpose and the circumstances [6]. Feedback during the transition from secondary to higher education, which is the focus of this paper, has been shown to impact student motivation, confidence, retention, and success [7], [8].

2 CONTEXT

As context influences the transition from secondary to higher education, this section clarifies the context of higher education and the Engineering Sciences programme at KU Leuven. Higher education in Flanders operates in the bachelor-master-structure, the ECTS-system, and the European Qualification framework [9]. Students are directly admitted to professional or academic bachelor's programmes when they have a diploma of secondary education or a (foreign) diploma declared equivalent (except for medicine and dentistry and some programs in performing arts). In this open-admission system, students are permitted to enter any bachelor program independent of their program in secondary education. Entering the Bachelor of Engineering Science therefore does not formally require a strong preparation in mathematics and/or sciences. Tuition fees at KU Leuven are around 1000 euro for one academic year. The open-admission policy results in a more heterogeneous population regarding prior knowledge and skills, which poses challenges to the actual teaching and guidance of students. Not surprisingly the drop-out in the Bachelor of Engineering Science is around 40%.

Interestingly, until 2004 a multi-topic entrance exam existed for Engineering Science in Flanders, which stimulated, as a preparation, a high level of mathematics education in secondary schools and contributed to an international high reputation of the Flemish mathematics secondary school education [10]. Before abolishment of the entrance exam, the first-year success rate was around 70%. After abolishment, the success rate dropped to less than 50%.

Engineering Science programmes identified the need for a positioning test, assessing the mathematical skills of students before entering the bachelor program. In 2013, the three Flemish universities offering the Bachelor of Engineering Science started with such a positioning test, called `ijkingstoets' (www.ijkingstoets.be). The test, typically consisting of 30 multiple choice questions, taken on paper and pencil during two session in summer, measures the ability of aspiring engineering students to solve engineering problems and compares a participant's mathematical skills with the required prior knowledge. The goal of the test is threefold: first, to encourage students that succeed; second, to stimulate students that are less successful to better prepare themselves by entering a remediation trajectory; third, to advise students that badly fail against entering the engineering studies. After a decision of the Flemish Parliament, participation to the positioning test became mandatory in the year 2018-2019 for all students wanting to subscribe to the Bachelor Engineering Science. Whereas participation is mandatory, the test is still non-binding: students that do not pass the test can still subscribe to the program.

3 CLOSING THE FEEDBACK LOOP

After clarifying the context, we will now provide more details on how our work of the last six years has been able to close the feedback loop in the transition from secondary to higher education. Remind that based on literature, we know that providing feedback in the transition from secondary to higher education can support a successful transition. The opportunities for providing feedback and the available data to provide feedback on are however limited.

Since 2013, the so-called `ijkingstoets' allows to provide feedback to aspiring engineering students regarding their mathematical skills and preparedness. The first line of research, elaborated on in Section 4, focused on the **predictive power of the positioning test** for first-year engineering student success. This predictive power was considered an important prerequisite to provide high-quality feedback to the participants. The second line of research, elaborated on in Section 5, focused on the **additional predictive power of the positioning test, the importance of other skills, and the confidence and beliefs** regarding fist-year students success of aspiring engineering students.

The third line of research, elaborated on in Section 6, focused on **the feedback itself after the positioning test.** On the one hand it showed how a **learning dashboard** provides participants with feedback after the positioning test and how **predictive models** can be used to provide interpretable insights.

The fourth line of research, elaborated on in Section 7, is the one that closes the feedback loop. It showed that **activity on feedback dashboards** (third line of research) has **predictive power for student success** itself (second line of research) and therefore creates a useful data source that provides a new opportunity for feedback.

4 PREDICTIVE POWER OF THE POSITIONING TEST

At the SEFI 2013 conference, a first paper was published on the rationale, development, and first-results of the positioning test [11]. As the main goal of the positioning test was to provide feedback to aspiring student regarding their mathematical skills, subsequent research focused on the predictive power of the positioning test for first-year student success [12] and the impact of the positioning test on female students and students with disabilities [13].

The results showed that the obtained score on the positioning test is strongly **correlated with first-year students success** and that the test in particular allows to detect students who have little chance of succeeding in the bachelor [12]. Passing the positioning test is a positive indicator but no guarantee for student success, it was hypothesized that other factors such as motivation, study effort, study method, and stress-handling are still important to this end [12].

Despite its predictive power, the positioning test does not succeed in advising students who badly fail the test, to reconsider their initial choice: less than half of the students that obtain a positioning test score lower than 5/20 eventually decide not to enrol in

the Bachelor of Engineering Science [12]. After enrolment, these students experience big difficulties in catching up on basic mathematics while studying new course [12].
The impact of the positioning test on female students and students with disabilities was studied separately due to the underrepresentation of female students in Engineering Science (15%) and the importance of providing equal opportunities to all students. Students with disabilities scored equally well on the positioning test, while female students obtained lower scores. These lower scores were partially explained by a weaker mathematical preparation in secondary education and the higher number of blank answers, which according to literature originates form the behaviour of more risk-averse female students in multiple choice tests with negative marking [13]. As a consequence we started a research line on alternative scoring schemes for multiple-choice exams that do not affect risk-averse students [14]–[17]. No difference between male and female students with similar grades was observed regarding the decision to enrol after participation to the positioning test [13].

5 SKILLS, CONFIDENCE AND BELIEFS

Beside mathematical skills, learning and studying skills [18] and self-reported confidence in math/science ability and beliefs in future career opportunities [19] have been shown to be supportive for student success. Learning and studying skills measured using the Learning and Study Strategies Inventory (LASSI) differ significantly between UK, Belgium, and Slovakia due to the strong differences in educational context, including admission procedures and rules [20]. The educational context has also shown to affect the beliefs of students in student success [21]. Students in all contexts, however, believed that most academic activities (attending classes, studying hard, following-up student e-mail, etc.) are important for first-year student success. As learning and studying skills are supportive for student success and as students believe they are indeed important to be successful, they provide an important opportunity for feedback.

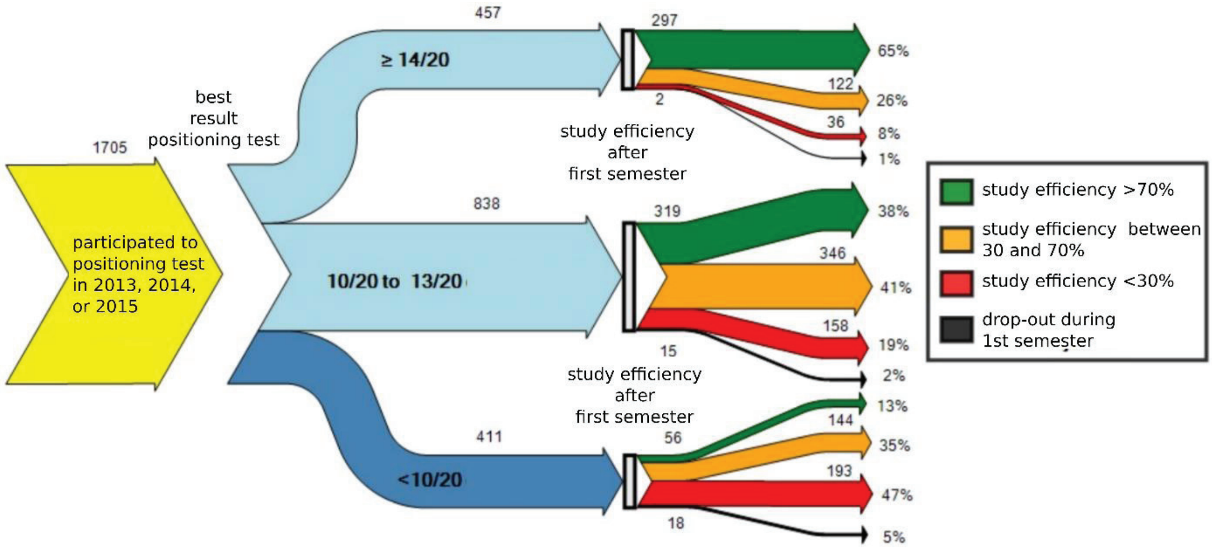

Fig. 1: Sankey diagram visualising the predictive power of the score on the positioning test for 1st semester student success, measured as study efficiency (percentage of successfully obtained credits from the booked ones).

In that respect, the **additional predictive power of learning and studying skills** is important. To this end, KU Leuven studied the incremental predictive power of these skills on top of prior academic achievement and score on the positioning test [22]. They showed that students' motivation/persistence, concentration, and time management skills at the start significantly influenced student achievement at the end of the first year, although the incremental value over prior achievement, measured as the number of hours of mathematics and mathematic GPA in secondary education, was small. Despite the small incremental value, feedback on learning and studying skills is still valuable as they offer opportunities for remedial interventions [22].

6 FEEDBACK REGARDING POSITIONING TEST

The feedback after the positioning test has evolved strongly since the start of the test in 2013. First, the feedback consisted of a personal **email** containing the obtained score, the provided answers, and a link to an **online document** containing a histogram that allowed the participants to compare their own score with the other participants and the correct answers for each of the multiple-choice question. Later, as the study results of the participants were available and the predictive power (Section 4) was proven, visualisations showing the relation between the score on the positioning test and later student success were added (*Fig. 1*).

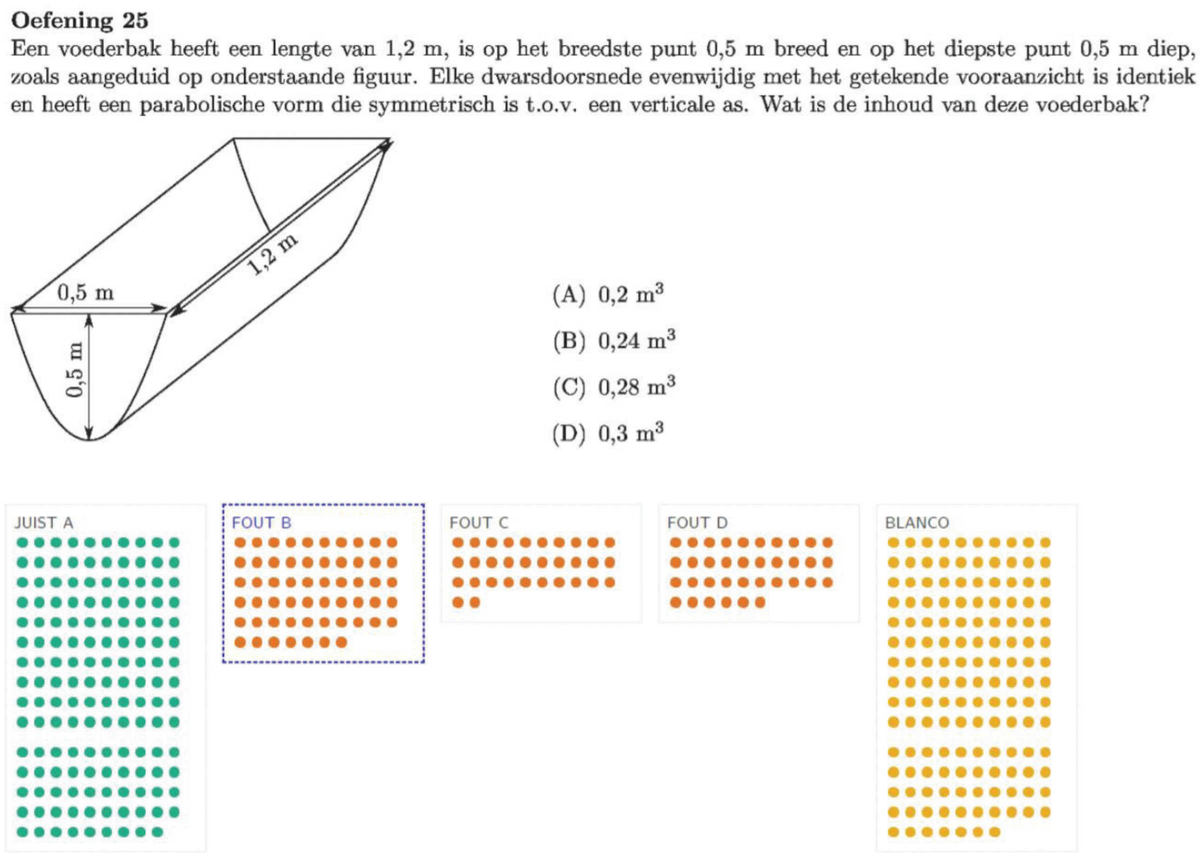

Fig. 2: Feedback on one question of the positioning test. The current student provided answer B (indicated by the boxed answer), which is wrong. The correct answer is A. Each dot represents the answer of one participant.

In 2018, a **feedback dashboard** [23] was developed within the STELA project (stela-project.eu) that provided additional feedback. A demo-version of the dashboard can be accessed at https://feedback.ijkingstoets.be/ijkingstoets-11-ir-ignore/feedback.html?fc=11ir0demo Participants are provided with more details on how other participants answered each question (*Fig. 2*). The dashboard furthermore provides feedback regarding prior academic achievement of the student (GPA of mathematics in secondary education and study advice of the teacher board), and three learning skills (motivation, concentration, and time management), which were measured using a questionnaire, including three scales of the LASSI questionnaire, during the positioning test. For each of these dimensions the participant receives a visualization showing how he/she positions with respect to the other participants, and how this dimension relates to student success.
After the positioning test, students received a link and personal login to the dashboard. Furthermore, student guidance counsellors of the faculty could, after permission of the participant, use the dashboard during a personal feedback conversation [23]. Further research focuses on how the feedback can be optimized and whether a more textual or visual presentation is most effective [24].

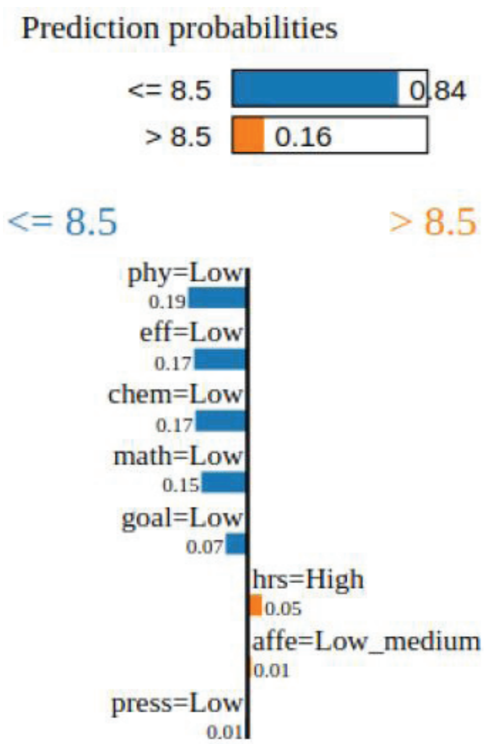

Fig. 3: Example of the output of LIME (Local Interpretable Model Agnostic Explanations) when predicting if a student is at risk (grade point average ≤ 8.5) or not (grade point average > 8.5). The probability that the student is at risk is 84%. The blue factors contribute to the student being predicted as at risk: lower prior academic achievement in physics (phy), chemistry (chem), mathematics (math), and low preference for pressure (press) and goal strategies (goal). On the positive side (orange) the student had a high number of hours mathematics in secondary education (hrs) and low to medium affective strategies (affe). The numbers indicate to which extent the factors contribute to the prediction.

The current feedback is limited to descriptive feedback, visualized to support the interpretation by the users. This feedback is provided for each of the dimensions (positioning test score, prior academic achievement, and learning skills) separately. **Predictive models** have the potential to combine these different dimensions into an overall score that represents the `odds of success' of the student in the bachelor. However, such predictive models are only useful when they provide interpretable insights. We found that existing techniques such as LIME [25] can be used to create visual insights on the contribution of each of the individual factors to the prediction (*Fig. 3*). As a result, the user can interpret what dimensions are contributing to the potential success of the student and what dimensions contribute to the potential drop-out [25]. Future work consists of testing if the resulting visualization can be used by student advisors during a feedback conversation, if the visualizations provide added value to the descriptive feedback, and if a dashboard can be developed based on the visualizations.

7 FEEDBACK USAGE AS A PREDICTOR FOR STUDENT SUCCESS

On top of the feedback in the positioning test dashboard, a learning dashboard was also developed to provide students with feedback on their learning skills in the first weeks of higher education. After completing the LASSI survey in the first week of the academic year, students received a link to their individual dashboard providing feedback on motivation, concentration, performance anxiety, use of test-strategies and time management. A demo is available at: https://learninganalytics.set.kuleuven.be/static-demo-lassi/. We showed that the use of the dashboard positively relates to first-semester student success, both for the positioning test dashboard [25] and for the LASSI dashboard [26], [27] and that this dashboard usage has additional predictive power for first-semester student success [under review]. This means that the deployment of feedback dashboard creates useful learning traces, i.e. new data reflecting the engagement of the student with the programme, that can again be used as a source for feedback. In short: use of feedback creates an opportunity for feedback. This is a valuable finding considering the sparsity of the data sources in the transition from secondary to higher education.

8 CONCLUSION & FUTURE PERSPECTIVE

This paper provided an overview of the research and work performed to support the transition between secondary and higher education at the Bachelor of Engineering Science, KU Leuven. This paper hereby not only provides an helicopter view to the work performed but also shows how a close collaboration between practitioners and researchers can create impact on the engineering education field. We believe that the paper can inspire other practitioners and researchers in the engineering education field that focus on the transition from secondary to higher education.

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Project-induced individualized acquisition of competences in a Bachelor's degree course

S. Di Nardo
Lecturer for Product Innovation
Lucerne University of Applied Sciences and Arts
Horw, Switzerland
E-mail: silvio.dinardo@hslu.ch

C. Wagner[1]
Lecturer for Energy Systems Engineering
Lucerne University of Applied Sciences and Arts
Horw, Switzerland
E-mail: claas.wagner@hslu.ch

M. Raschke
Lecturer for Product Innovation
Lucerne University of Applied Sciences and Arts
Horw, Switzerland
E-mail: markus.raschke@hslu.ch

J. Schwarz
Lecturer for Empirical Methods
Lucerne University of Applied Sciences and Arts
Lucerne, Switzerland
E-mail: juerg.schwarz@hslu.ch

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ABSTRACT
The aim of this pilot-module was to test how individualized learning can be structured when based on a precise, pre-defined task. Each individual task was part of a group task, solving a specific problem from the industry. Each student defined within such industry project a subtask and the individual learning outcomes respectively. These learning outcomes did not only serve to complete the subordinate group task, but aimed at the acquisition of defined competences. Experts supported the students in the process of defining their individual learning outcomes. This ensured quality and

[1]Corresponding Author : claas.wagner@hslu.ch

quantity of the learning outcomes. Additionally, the students were supported by coaches to reflect their learning process and learning strategies.

The pilot module is designed in such a way that it closely reflects learning in a professional context: completing a common task based on the contribution of individual subtasks is the foundation for individual learning processes. Thus, the pilot module is similar to the concept of Team Academy, but on a much smaller scale (3 ECTS module).

In the evaluation of the module, the learning coaches noticed that managing the group task and managing the individual learning project in a self-directed way is rather complex for a single 3 ECTS module. Especially the forming phase of the groups took too much time and prevented students to start their individual learning projects in a timely manner.

INTRODUCTION

This paper presents a pilot module carried out within the Lucerne University of Applied Sciences & Arts Bachelor study program Business Engineering / Innovation. The primary objective of developing this 3 ECTS elective was to evaluate the feasibility of deriving highly individualized learning projects from a practical problem from industry which has to be solved by a group of students.

The learning processes of students in educational (tertiary-level) institutions differ significantly from those in which adults engage in professional (work-place) settings. In a professional setting learning is generally motivated by and closely associated with a concrete assignment, and the learner's compilation of content from various subject areas as he/she tackles this assignment resembles the work of an artist creating a mosaic. The pilot module creates a learning situation which corresponds more closely to the needs and approaches of the working professional

The basic concept of the pilot module is shown in Fig. 1: A group of students is taking care of a practical problem from industry. The industrial project is acquired by students, the formation of the groups is self-organized. The group breaks the project aims down into subtasks which can be handled by individual group members. Based on these subtasks, each student then develops his / her learning objectives in two steps: 1) Writing a success story: After completion of the learning project, in which professional situations will the student be able to demonstrate his / her newly acquired competencies? 2) Detailing the success story: which competencies are needed in order to master the situation described in the success story?

The responsibilities for both the industrial project and the individual learning projects lie in the hands of the students. According to their needs, they have the possibility to get advice either from content experts, who are experts in the subject area of the individual learning projects, or from learning coaches, who are experts in learning processes and methodologies.

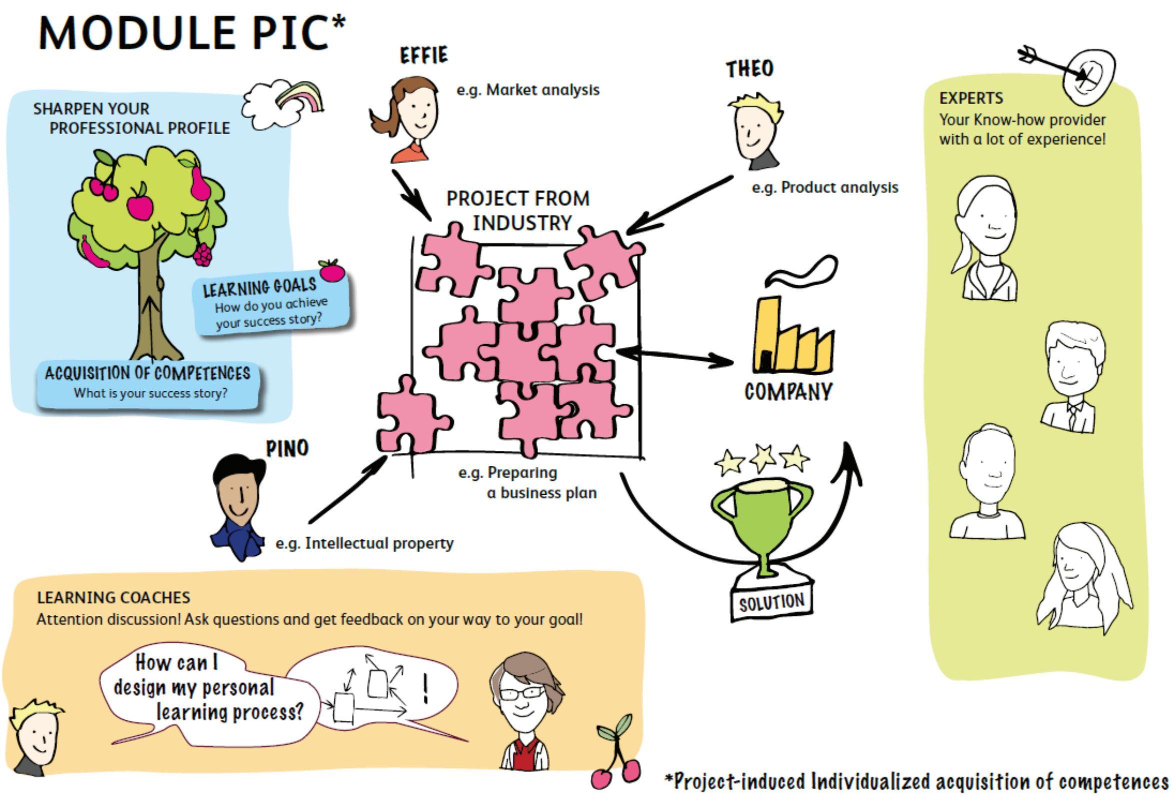

Fig. 1. Concept of the pilot module

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This paper first presents the theoretical background of the pilot module, followed by a description of the underlying methodology. Findings of the module evaluation are then presented. The final sections reflect on and discuss the methodological approach as well as potential improvements and the further development of the module.

1 THEORETICAL BACKGROUND OF THE MODULE CONCEPT

The engineer's prospective professional environment is growing ever more complex due to the fast pace of technological change and, especially, digitalization. Consequently, engineers must acquire new strategies to develop their competencies [1]. Traditional tertiary institutions no longer live up to these challenges [2]. They must not only impart knowledge but also competences required for autonomous learning and self-organization.

For some years now, educators have been turning from traditional motivational psychology towards theories which focus on the attainment of goals. Early on, motivational theorists such as Deci and Ryan [3] shifted their interest from the effects of external influences on motivation to the subject's self-direction. According to their well-known Self-Determination Theory, motivation is derived from three universal, innate psychological needs: competence, autonomy and social integration. Subjects are more motivated to take action a) if they believe their behavior will afford them greater competence (self-efficacy), b) the more freedom they have in initiating and implementing a certain behavior (autonomy) and c) the more social interaction or connectedness the behavior fosters (gain in interpersonal relatedness).

A concept for a teaching module with highly individualized learning goals has been described in [4]. In this pilot study the focus was on maximizing each student's individual degree of freedom in designing their own learning project. Each student was moreover responsible for acquiring the self-defined target competencies. According to his / her needs, the student could get support from learning coaches and from content experts. This module satisfies each of the psychological needs identified by Deci and Ryan [3]: The module relies not only on the initiative of participants but in particular on their efficacy; greater autonomy is the core concept of the module; and social interaction and connectedness developed among the module participants, who have several extensive group meetings.
The individual learning projects were not linked by a common group assignment.

One acquires the ability to organize oneself primarily through exercising self-organization. Relevant academic literature refers to educational settings designed to foster self-organizational competence as »self-directed learning« [5] or, often synonymously, as »self-organized learning« (»SOL«).

There is no standard definition for SOL or self-directed learning. "Nonetheless, the approaches have a common denominator: Their focus is on the learner, who initiates and organizes his own learning processes. Objectives such as the promotion of self-determination, self-directed activity and responsibility for one's own learning process are to be found in many approaches." [5]
Examples of SOL applied to a specific, common task or mission. Especially worth mentioning are the Action Learning [6] and Team Academy [7] theories.

The pilot module that is described in this paper was designed to combine highly individualized learning goals with an underlying common group project. The learning goals are individually derived from the project and may cover much more than what is needed to solve the project task. Therefore the concept is similar to Action Learning and to Team Academy, though framed in a 3 ECTS project module. O'Neil, Yorks and Marsick [8] have categorized the different approaches in Action Learning in a four-level Action Learning Pyramid. This pilot module is located on level three, stepping up from level one (problem solving and implementation of solutions) and level two (problem re-framing, learning a process for learning from work experience) by adding personal learning goals, emphasis on reflection and learning styles.

2 TEACHING METHODOLOGY

This section describes the methodology underlying the design and implementation of the pilot module.

2.1 Selection of team projects and student participants

Preliminary to the module start all students were invited to submit ideas for the group projects. These group projects had to fulfill the requirements of being relevant for a specific company and being manageable by a team of 3-5 students within the predefined time frame (workload 90 hours per student). After pre-selection of appropriate projects by the lecturers in charge, the student initiators of the group projects pitched their ideas to all other interested students. Subsequently the students were asked to organize themselves in project teams of appropriate size and to divide the project into individual subtasks, for each of which one student assumed responsibility. A total of 15 students within different semesters participated in this pilot module.

2.2 Establishment of individual learning objectives

The first assignment for each project group was to define the overall project goal. Additionally each participant had to write a personal success story based on the chosen individual subtasks. Such a success story was to describe the specific situation which they wished to be able to master after completing the module, i.e. which competences the student wished to acquire during the course of the module. Subsequently, the students contemplated which competences they already had and which they would need to acquire in order to accomplish their success story. To enable students to formulate individual learning objectives, a ‘competence pyramid’ based on Bloom’s cognitive taxonomy was introduced [9]. The success story together with the competence pyramid also served as the basis for the final module exam. The following figures show examples of a success story and competence pyramid.

After this module I will be able to explain the advantages of Scrum to the CEO of a company in order to simplify the management of complex projects. I will be able to explain how difficulties in a project can be identified in a timely manner. I can describe limitations and assessment criteria for Scrum.

Fig. 2. Sample success story

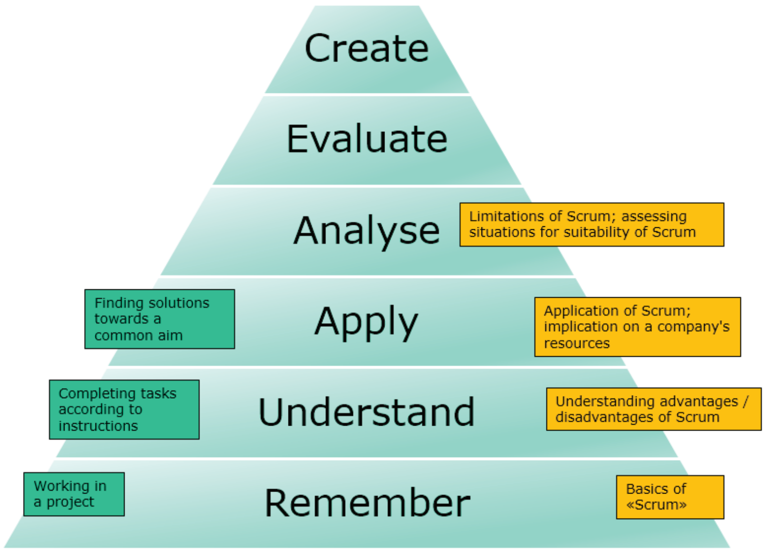

Fig. 3. Sample competence pyramid (in green: existing competences, in yellow: targeted competences)

2.3 The learning process and evaluation of learning progress

Each student was assigned a content expert possessing expertise in the content area chosen. These content experts were responsible for a) assessing the individual success stories and learning objectives with respect to whether the learning objectives were sufficiently challenging but also manageable within the scope of the module and b) assessment of their students' achievement in the final module examination. In addition, the students were given the option of coaching sessions with the content expert for expert advice and with the learning coaches to reflect on their learning process and, if appropriate, adjust their course of action. In a mid-term steering meeting the students of each project team presented the current status of their attainment of learning objectives as well as the level of progress of the overall group project and received individual feedback.

2.4 Assessment

Assessment was threefold, consisting of a group presentation in which the overall project achievements were to be highlighted, as well as assessment of each individual's acquired professional expertise on the one hand and acquired learning competencies on the other. The aim of the group presentation was to show to which degree the project objective had been fulfilled and how the individual sub tasks had contributed to this goal. For the individual examination each student was asked to demonstrate the newly acquired competences. The students themselves contemplated and decided in advance what they wanted to present in order to prove their mastery of the content. They simulated a situation which corresponded to their success story. In the final part of the individual examination the student's content expert and the learning coach asked clarification questions to the content and learning process. The success story and the competence pyramid served as benchmarks for the assessment of the student's newly acquired expertise.

3 MODULE EVALUATION

The pilot module was evaluated using three methods: students' evaluation, feedback of content experts and reflection of learning coaches/module responsible. The latter is integrated in the discussion chapter.

3.1. Students' evaluation

The students were asked in the beginning (week 1), middle (week 8) and end of the module (week 14) to quantitatively answer the following two questions, using the online questionnaire tool Qualtrics®.

Question 1: To which degree do/did the following persons/aspects contribute to your individual learning project (Assign a percentage!)? Assessment of each of the following was requested: team, common project aim, learning coaches, content experts, internet, and other persons not participating in the module.

Question 2: Please assess: To which degree are you contributing/have you contributed to your individual learning project in comparison to the above-mentioned persons/aspects (Assign a percentage!)?

The results were analyzed statistically with IMB® SPSS® version 25. Due to the small sample size (n=16), a non-parametric statistical analysis with a level of significance of 5% was employed.

As Figure 4 shows, the analysis of question 1 revealed that the internet as well as the common task were the main aspects contributing to the individual learning project. Furthermore, the group was felt to contribute less and less to the individual learning project over time. The statistical analysis shows, however, no change in comparative significance for any contributing factor over the course of the module.

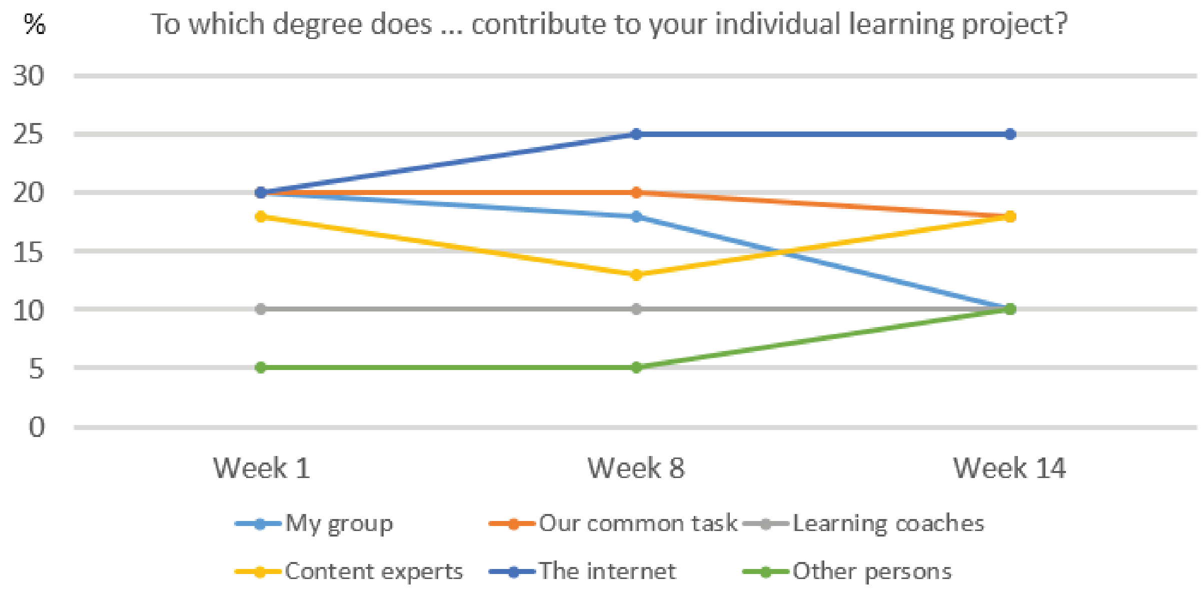

Fig. 4. Results of question 1 – contribution to individual learning project

The analysis of the answers to question 2, as depicted in figure 5, shows that the students quantified their own contribution to the individual learning project at the beginning of the module as approximately 60%, whereas they attributed to all other persons/aspects combined approximately 40%. In the middle of the module, these values increased to 72% (own contribution) and decreased to 28% (other persons/aspects). In the second half of the module the attributions changed slightly to 67% and 33% respectively. The differences from week 1 to week 8 are statistically significant, the differences from week 8 to week 14 are statistically not significant.

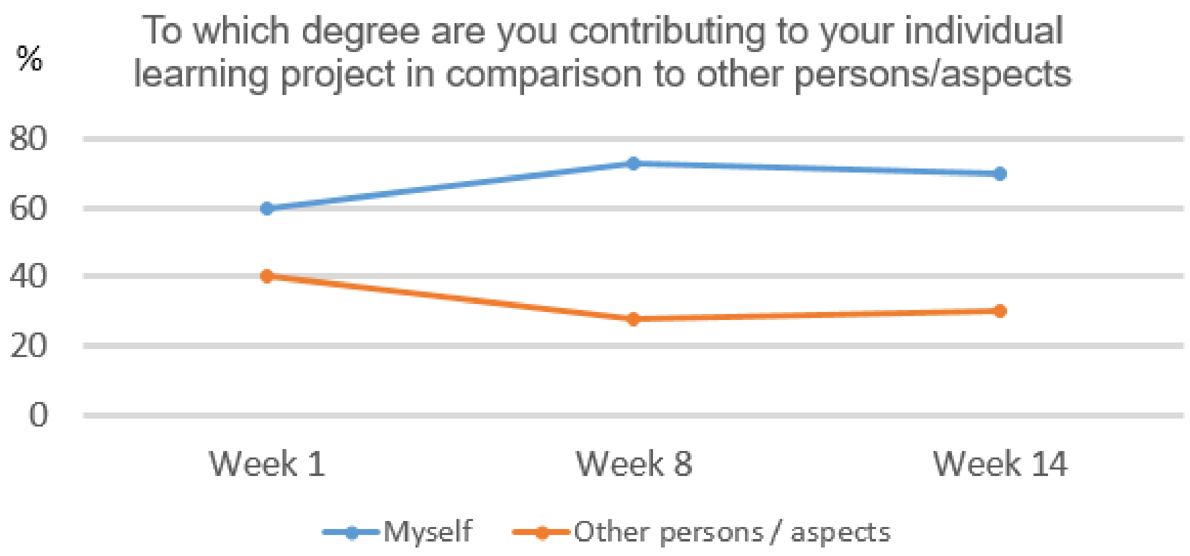

Fig. 5. Results of question 2 – degree of individual versus other persons'/aspects' contribution

In addition to the quantitative analysis described above, the students were asked in open questions after completion of the module to give feedback regarding motivation, support provided in the module for their learning process, professional relevance and level/amount of learning. Selection of individual learning goals and achieving these goals with self-determined time management were factors which students mentioned as motivating. On the other hand, using the competence pyramid as a tool for understanding current and envisioned competence levels as well as organizational issues within the teams were mentioned as demotivating factors. Relevance to the professional world was an aspect which supported the learning process, whereas various students would have wished to have closer contact to the content experts or even regular checks of their individual learning progress for a better support of the learning process. Students were satisfied with the amount of their learning and understood the professional relevance of such module. Some students suggested that the module should be extended to a 6 ECTS module due to the comparatively high level of complexity of this specific learning setup.
The specific feedbacks mentioned above are not representative for the whole group, but were chosen rather to convey an impression of what was received well and what might want further improvement. All students recommended continuing to offer such a module and affirmed its vocational relevance.

3.2. Feedback of the content experts

The content experts were asked to give feedback concerning this concept of individualized learning. This feedback can be summarized in the following findings:

- It is not clear if students' motivation is higher than in traditional modules. There seems to be a high motivation at the beginning of the learning project, which decreases in the course of the project.
- Employing Bloom's pyramid to facilitate the description of learning objectives is an effective method. However, for students and for the content experts to be

able to apply it, a clear introduction, some training and a common understanding are necessary.

- The students are challenged not only with their main learning goals, but in this setting also with several aspects of project management. These aspects of project management should be accounted for by adding them to the individual learning pyramid.
- The setting up and start of the learning project is the most crucial part and needs quite intense and thorough support by the content expert. The quality and intensity of the relationship between expert and student can vary considerably during the course of the module, depending on the student's needs and skills. Individualization of coaching (timing, intensity, duration, objectives) is necessary in such a setting.

4 DISCUSSION

As opposed to traditional course modules, the lecturers in this pilot module hand over to the students the full responsibility for determining the thematic orientation of their work, defining their learning objectives and organizing their learning process. The students are part of a group that solves a practical problem from industry. This group task is the source for the learning projects of the individual students.

The main conclusion of the assessment of this pilot module is that the combination of a group task with individual learning projects seem to exceed the scope of a 3 ECTS module. Several feedbacks from students, the qualitative feedback from the content experts and the impression of the learning experts/module responsible support this conclusion. Forming the group and organizing the group task took too much time and left the individual students in substantial uncertainty concerning their learning goals. This might have led to the content experts' perception that in some cases motivation decreased in the course of the project. Furthermore, quantitative findings reveal that students' assessment of their own contribution to their learning project compared to the contribution of other persons increases in the first weeks of the project, i.e. students overestimated the contribution of other persons at the beginning of the learning project.

Nevertheless, many aspects of the pilot module were evaluated positively by the students, content and learning experts, including:

- Individualization gives students the possibility to strengthen individual competence profiles.
- Self-organization of learning projects allows highly individualized time management.
- The setup of the module examination allows the students to prove their newly acquired competences on the one hand. On the other hand, students reflect on their learning process and can hereby identify success factors for their own individual learning strategy.

For the Bachelor's program in Business Engineering, this pilot module has proven the feasibility of individualized modules. To reduce the complexity experienced in this pilot module, a future implementation in the curriculum will focus on the individual learning projects omitting an underlying common group project. This simplified module structure has been validated and described in [4].

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Cross Disciplinary Capstone projects for undergraduate engineering double degree students – the good, the bad and the ugly

K Dini[1]
Swinburne University of Technology
Melbourne Australia

EC Levin
Swinburne University of Technology
Melbourne, Australia

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ABSTRACT

In the context of engineering education, “Final Year Projects (Research)”, also known as “Capstone Projects”, are used to demonstrate students’ final achievement based on the skills, knowledge, and experience gained through the whole engineering degree program. In another words, these subjects are designed to bring together all aspects of students’ experiences. Also, it is believed that students should demonstrate professional skills such as: team work, and communication skills as well as knowledge in the field of engineering. For double degree students studying both Engineering and Business at Swinburne University, Australia the final year projects require students to combine and demonstrate their expertise and skills in both disciplines – Engineering and Business. This paper investigates the pedagogy in the final year research project subjects for double degree students. The researchers are investigating the practises relating to the supervision of these multidisciplinary capstone projects in order to improve the learning and teaching experience for students and academics,. Interviews have been conducted with supervisors from both disciplines. Preliminary findings indicate that most supervisors would be happy to work more collaboratively to develop a clearer understanding of the problem under investigation, using cross disciplinary perspectives, with a key focus on critical points during the semester. A superior solution to the problem being investigated can only be achieved through working collaboratively together.

[1] Corresponding Author
K Dini
kdini@swin.edu.au

1 INTRODUCTION AND LITERATURE REVIEW

Most academic staff in engineering and technology programs believe that the final project for engineering students (known as Capstone) should be used to demonstrate professional skills in addition to practise in the field of knowledge of the engineering discipline. Non-governmental organisations, such as the Accreditation Board for Engineering and Technology (ABET), encourage students to gain experience in team work, communication and technical engineering design processes through their degree programs including in final year projects (ABET, 2009).

Employers are chasing 'T-shaped' rather than 'I-shaped' graduates. 'I-shaped' professionals predominantly have highly specialised knowledge whereas 'T-shaped' professional are able to blend 'deep knowledge in a field with inter-disciplinary intelligence, reinforced with a strong set of people or soft skills, which facilitate the spanning of boundaries (collaboration) within and outside the organization' (The Collegiate Employment Research Institute, 2012). Final year projects in Engineering, where students demonstrate their professional skills in addition to applying their engineering knowledge, have been part of the curriculum for many years. They facilitate the development of core soft skills such as oral and written communications, team work and time management (as expected by ABET) as well as technical engineering design processes helping graduates become 'T-shaped' professionals. Such projects have been traditionally focussed on a single field of knowledge and have been used to demonstrate students' final achievement based on the skills, knowledge, and experience gained through the whole engineering degree program (Ward, 2013). The ultimate goal is to develop graduates with professional engineering skills such as data interpretation, application of theory, problem solving, and design, along with soft or employability skills.

For double degree students studying both Engineering and Business at Swinburne University of Technology, Australia, the final projects are designed to help students combine and demonstrate their expertise and skills in two disciplines – Engineering and Business. Final year students may be completing Engineering specialisations such as Mechanical, Civil, Robotics & Mechatronics, and Electrical and Electronics. There is also a broad range of Business specialisations covered including Entrepreneurship and Innovation, Finance, and Management. Students undertake a yearlong research project with two supervisors, one from Faculty of Science, Engineering and Technology (FSET) and one from the Faculty of Business and Law (FBL). A few of these projects have been done in collaboration with industry partners.

Capstones by their nature are multifaceted and complex. Lee and Lorton (2015) define capstones as 'substantial culminating learning experiences that take place in the final stage of an educational course, offering closure and a focus for the sense of achievement that comes with completion' (p. 1). Capstones require careful design and skilful teaching to maximise the outcomes for all stakeholders. There is a growing body of literature on Capstone units much of which is focussed on the objectives (Rasul, et al., 2016), forms (Ku & Goh, 2010), and curriculum design (Lloyd, 2016; Ward, 2013). To date little attention has been focussed on the pedagogy and how to prepare and develop academics to teach into integrated cross-disciplinary Capstone subjects.

This paper investigates the pedagogy in the final year research project subjects for double degree students. The researchers who co-convene the subjects, one from Engineering and one from Business, have identified issues and problems relating to the students' learning experience throughout the year long project. These issues can be summarised as lack of acknowledgement by some engineering supervisors that students are undertaking a joint rather than a single degree and hence the project needs to cover both engineering and business domains; lack of clarity as to how project topics are determined; and lack of communication and collaboration between supervisors from the two faculties resulting in differing expectations.

This study investigates these issues in order to provide guidelines for the effective running of multidisciplinary capstone projects at undergraduate level, to optimise the learning and teaching experience for students and academics.

2 METHODOLOGY

Since 2015, Swinburne University of Technology has been offering joint Capstone projects to final year double degree students completing both Engineering and Business degrees. A joint Capstone experience has been developed which inextricably link both disciplines whereby about 100 students per year complete research projects, generally in teams of up to 4 students. Ethics approval was granted to conduct interviews with experienced supervisors from both disciplines, to explore the following issues:

1. To assess whether engineering and business supervisors understand the rationale for offering joint Capstone subjects

2. To determine the level of cross faculty interaction in relation to the supervision of the projects

3. To identify how research project topics are determined.

In total 21 supervisors were interviewed including 13 academic supervisors from Faculty of Science, Engineering and Technology (FSET) and 8 academic supervisors from Faculty of Business and Law (FBL). Interviews were recorded and transcribed and themes were categorised.

3 FINDINGS FROM INTERVIEWS

3.1 Engineering supervisors

Thirteen interviews were conducted with engineering academics who had experience in the Capstone supervision role. All participants had supervised both single and double degree project teams. The first issue explored related to the reasons for offering joint Capstone project subjects. A wide range of responses were received. Some academics did not provide any comments and just focused on their role as engineering supervisors, saying for example *'I am only expert in my field'* and had no comments about other fields; others mentioned that it is a good approach, *'but it depended on the topic itself, some topics were suitable for both engineering and business related and some are pure engineering themes'*. One or two supervisors mentioned that offering joint Capstones was part of the university's policy.

The second issue explored related to communication between the engineering and business supervisors. Most of participants said that they had very few joint meetings with their counterparts. Some noted that they met them only during the presentations which are conducted at the end of each semester. Respondents often mentioned that students had separate meetings with their two supervisors. This may have been caused by the fact that the students themselves had organised for different meetings times with each supervisor. Also, it was clear from engineering supervisors that they mainly had communication with the subject convenor from FSET (one of authors of this paper) and had not approached the business coordinator of these subjects. Sometimes, their questions did not relate to the business part of the project so they believed they should not contact the business academic directly.

The third issue explored related to the way in which research topics are determined. Participants were asked if they prefer to identify a topic themselves, allow students to suggest a topic, or seek an industry partner and work on topic development with them. Again, a variety of responses were received with some supervisors welcoming all options, whilst some others preferred only to supervise projects on topics relating to their expertise and nominated by themselves. They stated different pros and cons for each options and then said that it depended upon personal interests and the nature of the topics. For example, industry projects are authentic and help students prepare for the real world, but some supervisors feel that they may be out of their comfort zone or area of expertise to supervise these projects. For student initiated topics some academics felt that whilst students were highly motivated to complete a project they had self-selected, students lacked the expertise to properly define the scope and could end up with either a superficial outcome or unrealistic expectations of what could be achieved in the given time frame by a student team. One of the disadvantages of engineering academics nominating the topic related to the fact that some academics are working in theoretical or technical areas where there is a lack of synergy with a business area.

When asked if they would be prepared to supervise projects on topics nominated by business supervisors, there were virtually no positive responses to this suggestion as the engineering supervisors could not see how this option might work.

Capstone projects have been offered by FSET for a couple of decades for single degree students. Therefore most of the engineering supervisors were familiar with the way these units were delivered, supervised and assessed. From the interviews as well as feedback from the students, it seems that the engineering academics' approach to the final year or Capstone projects is based on their previous experiences in the single degree and they are not prepared or interested to change their mind-set and approach for double degree students. This may be due to self-preservation as many of the academics interviewed concurrently supervise single and double degree students sometimes with similar research topics, therefore, switching from one mind-set to another one may not be an easy task for them. It seems that the respondents prioritise the engineering themes over the business themes of projects for double degree students, as these students are likely to be primarily employed as graduate engineers and draw on their knowledge of business later.

3.2 Business supervisors

Eight interviews were conducted with business supervisors who had experience in the supervision of the double degree projects. There are fewer Business supervisors involved in the FYRP than engineering supervisors as many Business academics supervise multiple teams each year. Many of these academics had also supervised Business Capstone projects, which are all based on finding solutions to authentic problems from industry clients. When the business academics were asked why they think the joint Capstone projects were offered, the majority of responses identified the benefits of offering multidisciplinary projects. They thought it is a good approach to require students to consider the business components of the engineering projects. The wording they used varied, but the general feelings were positive. One supervisor said: *'So I reckon, from my perspective it's so important, and I think every technical field, like engineering and medicine and all that sort of stuff, needs some form of understanding of business...'.* Another participant said '*It's really beneficial for them to actually know things such as commercialisation, or investments, or basically how to get products from a concept stage into a commercialised product'.*

In response to the question relating to collaborations between themselves and supervisors from FSET most of respondents reported that they had not developed a strong relationship with the engineering supervisors. Some had managed to have one or two meetings during the semester. In one case, there were no meetings at all, whilst in another case there were many joint meetings. Several respondents mentioned the difficulties of finding a mutually convenient time that suited both the academic supervisors as well as the students who worked on the project, as many students have commitments including studies and part or full time work.

With regards to communication with both subject convenors (subject coordinators), the business supervisors stated that there were no problem with communication during semester and they were equally happy approaching and liaising with either or both subject convenors.

Interestingly, in regards to the question relating to the nomination of the research topics, almost all business supervisors pointed out that they did not want to initiate the research topics. One said: *"That would be scary"*. Almost all respondents said that starting off a project with a business theme without an engineering theme would be extremely complex, especially if it is not known if there will be an available engineering supervisor with the expertise to support and supervise the project. Business academics were also uncertain they could readily nominate a research topic that would be of interest to the double degree students.

On the other hand, almost all business supervisors mentioned that they would like to have conversation with engineering supervisors before the commencement of semester so they could co-develop the topic, or work together to find a suitable business topic that dovetails with the engineering topic. They thought it would be helpful for them to understand the engineering topic first, and then they would be in a better position to propose the business theme that students could focus on.

Finally, when asked whether it might be a good idea to approach research centres to help with the identification of multidisciplinary projects the majority of respondents did not support this idea. They felt that it was likely to cause more difficulties and challenges for academic staff as well as students, and they did not feel the research centres would be prepared to engage with undergraduate students. Research centres have clear performance indicators relating to income and publications and working with undergraduate students on final year projects falls outside their scope. A summary of the key findings in presented in Table 1 below.

Issue	**Engineering**	**Business**
Understanding the rationale	• Seems like a good approach • University requirement • Unsure	• Identified the benefits of multidisciplinary projects
Cross faculty interaction	• Few joint meetings • Only through formal presentations • Communications via the convenors but not between supervisors	• Some had developed relationships and held joint meetings • Difficult to coordinate and find mutually convenient times
Initiation of project topic	• Some were open to a variety of methods • Others preferred to focus on their areas of expertise • Identified pros and cons but insistent that topics needed to be engineering led	• Had no interest in initiating the topic • Happy to co-develop topics with engineering • Felt that research centres had no interest in UG projects

Table 1: Summary of findings by discipline area

4 DISCUSSION

After interviewing academics the researchers tried to locate models to assist to bring the academics from both disciplines together. Multidisciplinary teaching is not uncommon in areas relating to health related disciplines but little has been published in relation to such practices in other disciplinary combinations. The literature on team teaching, defined as “All arrangements that include two or more faculty in some level of collaboration in the planning and delivery of a course” (Davis, 1995, p.8) provides some practical guidance and notes that there are four areas where pedagogical variations can occur namely in planning, content integration, teaching and evaluation. Shibly (2006) emphasises the importance of careful planning when teaching in interdisciplinary teams, and notes however that this does not guarantee that the intended outcomes will be achieved.

A chapter in the book *Engineering Practice in a Global Context, Understanding the Technical and the Social* edited by Williams, Figueiredo and Trevelyan (2013) was identified where Adams and Forin (2013) present a model to address cross-disciplinary practices. Adams and Forin (2013) undertook a study ‘to investigate critical differences in the ways people experience and make sense of cross-disciplinary practice in engineering contexts’ (p. 105). From interviews with professionals including some in educational and/or research contexts; they developed the framework presented in Figure 1 which provides a useful framework for capacity building within the teaching team.

There is a need to move beyond the traditional constraints of the disciplinary boundaries and mind-sets which involves communication and collaboration. This is more challenging than it may appear as some really bright people find it difficult to work in new ways (Adams and Forin, 2013). Relationally, the progression from Category 1 to Category 4 represents increasingly complex ways of experiencing cross-disciplinary practice and a growing awareness and comprehension of cross-disciplinary practice.

The first and lowest level category illustrates cross-disciplinary practice as working together with people who have different training to effectively find a better solution. Critical attributes of the experiences associated with this category include: (1) knowing what you and others contribute and points of synergy, (2) recognising disciplinary differences in what people do and how they communicate; an iterative process of asking questions, challenging assumptions, and listening for understanding, (3) being comfortable with asking for information that might seem obvious to an expert in that domain, and (4) taking personal responsibility to be an effective collaborator (Adams and Forin, 2013, p. 109).

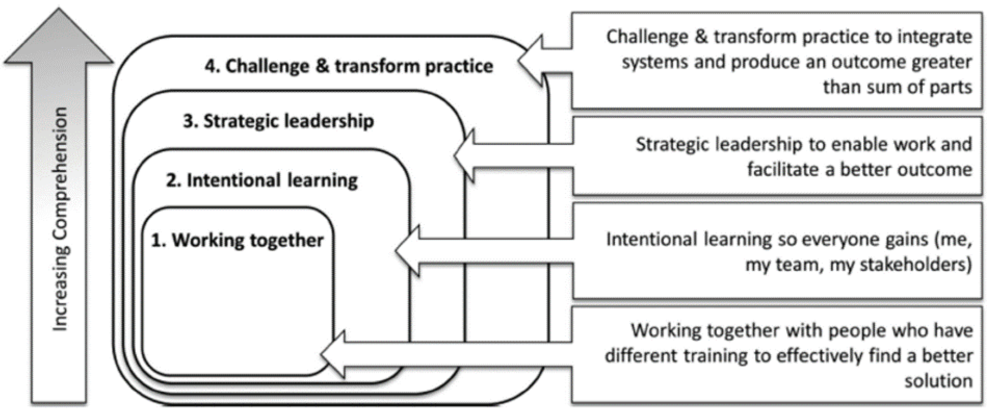

Fig. 1. Hierarchical model depicting ways of experiencing cross-disciplinary practice

(Source: Adams and Forin, 2013 p.109)

Whilst the 4 categories are hierarchical and aspirational, at this stage, the main focus for the researchers in this study is to develop a plan to implement the first level, that is to unify the teaching team so they are able to work collaboratively, using a consistent approach. If this can be achieved, there will be ultimately superior outcomes for all stakeholders. This, in turn, may organically lead to the second stage, which is Intentional Learning. It also found that the third stage of the model, Strategic Leadership, which is very important in the current case of interdisciplinary Capstone projects, already exists as the introduction of the Capstones and the development of the FYRP has been supported by senior management at Swinburne for many years. They are fully supportive of increasing collaboration between supervisors.

Findings from the interviews of both engineering and business supervisors confirm that although in some instances there was some interaction and co-supervision generally there was a lack of communication and collaboration between the counterparts. Overall, they had no or very few joint meetings. Aligned with Adams and Forin (2013) the first step to facilitate effective cross-disciplinary supervision is to get the supervisory panel to meet and work together throughout the FYRP journey in a meaningful way and thereby develop an understanding and appreciation of the problems under investigated from a multidisciplinary stance.

Implementing this requires a strong and well-designed plan therefore a series of forums have been planned at strategically important times throughout the academic calendar. The first forum occurred well before the commencement of the semester, with four principles aims. Firstly so staff from the two faculties could meet one another; secondly to assist with the identification of suitable topics ensuring that both Engineering and Business disciplines were equally incorporated; thirdly to encourage ongoing collaboration and co-supervision; and finally to provide academics with an opportunity to ask any questions or seek clarification on expectations. The next forum was held about one month into the semester, once all project teams had been formed and supervisors had been allocated, as well as research topics finalised. The focus of this forum was to explain all the assessment tasks and marking rubrics, and again answer any questions from the supervisors. The third forum will be held about two thirds of the way through the semester during which time the assessment tasks will again be explained, as well as the marking process, but the main focus of this forum will be to give staff an opportunity to discuss any issues that they or their teams may be facing.

In the second semester the plan is to reduce the number of forums to allow academics to focus on co- supervising their student teams. One forum will be held during the first month of semester, as a welcome back meeting, to maintain the momentum and traction from the forums in the first semester, and also to explain the expectations and assessment tasks for the final semester. The researchers are contemplating using a discussion board on the learning management system about two thirds of the way through the semester, which will focus on any hot topics, issues or concerns that the supervisors may be facing. The discussion will be moderated by the co-convenors and offer staff the opportunity to virtually share their experiences with one another. Through these forums both physical and virtual it is hoped that the first stage of Adams and Forin's model will have been achieved, and all supervisors will develop consistent approaches, perceptions and mind-set.

With relation to the identification of suitable research topics the interviews revealed that it is preferable for project topics to be nominated first by engineering supervisors, and then, through conversations with the business supervisors, design or define the business theme for the particular project. Whilst industry led authentic projects are preferred these can be difficult to source, negotiate and supervise. It seems unlikely that research centres would be interested in working with FYRP students, for a variety of reasons, so this option will not be pursued.

5 CONCLUSIONS AND RECOMMENDATIONS

Joint capstone projects such as the ones offered at Swinburne University to students studying double degrees combining Engineering with Business provide graduates with a unique opportunity to draw upon and integrate their learnings and apply these to a complex cross-disciplinary project which sets them up with the skills expected by industry. An innovation as complex and important as this needs careful management and design to ensure that the intended outcomes are achieved, and stakeholders have a sense of achievement and pride in the experience and outcomes. This does not happen on its own; it must be coordinated as some academics are used to only working within their own discipline areas.

Whilst to date the co-convenors have tried to accommodate students' requests as well as supervisors idiosyncrasies this has led to mixed messages, inconsistent expectations as well as poor experiences for some. Therefore a more strategic and carefully orchestrated approach is being trialled, with a lot more effort and energy invested into the management, coordination and formalised opportunities for collaboration and communication between supervisors (as described in section 4 above), in order to maximise the outcomes for all stakeholders. This should result in improved learning as well as superior experience for students and academics. In addition, it will provide a role model for the graduates as they transition to the workplace, highlighting the power of working collaboratively across discipline boundaries.

Preliminary findings indicate that most supervisors say they would be happy to work more collaboratively to develop a clearer understanding of the problem under investigation, using cross-disciplinary perspectives, with a key focus on three critical points during the first semester, and two critical points in the second semester. Having said that, this requires leadership and direction. The ultimate aim is to create a pedagogical framework to guide supervisors, so that holistic outcomes can be achieved which respect and appreciate the cross-disciplinary nature of the problems under investigation. This should hopefully offer students an optimal experience in their final year of study, as they graduate and become young professionals working in complex and evolving contexts.

6 ACKNOWLEDGEMENTS

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Performing engineering digital literacies in context

T. D. Drysdale
The University of Edinburgh
Edinburgh, Scotland

J. Scoles
The University of Edinburgh
Edinburgh, Scotland

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ABSTRACT

In this paper, we present the results from an intervention that is based on engineering students being introduced to coding using a programmable sun-tracker simulation. Our study is underpinned by two arguments. Firstly, that it is helpful to introduce engineering students to digital literacies - such as computational thinking, automated control, and coding - at an early stage in their degree programme. This will better prepare them to respond to the complex data acquisition, analysis and reporting and machine control tasks that they are likely to face in their later professional work. Secondly, if educators reduce the time between teaching students coding concepts and then applying these to a learning activity clearly and contextually linked to their specific discipline, then this will increase student engagement with programming and digital literacies skills. An intended side-benefit of the intervention was to reduce anxiety in the target cohort, a group of first year students in their first semester, who had been tasked with producing a physical two axis sun-tracking solar panel, without any formal training in electronics or programming (aside from the intervention). The intervention was conducted by a morning briefing on sun-trackers (50 minutes) and an afternoon session (90 minutes) of group work with a purpose-built webapp that combined an interactive 3D animation of a two-axis sun-tracking solar panel, including simulated sensor data, Blockly graphical programming language, an output graph, and a scoring system. The evaluation was by survey before and after the intervention, and results indicated a reduction in anxiety by nearly two-thirds.

1 INTRODUCTION

In a recent survey of 22,000 UK post-compulsory education students, 82% said digital skills were important to their career, but only half of the higher education students thought their courses would "*prepare them well for the digital workplace*" [1]. The study also reported low usage of interactive digital media, such as simulations, that "*provide rapid intrinsic feedback*." Although these results were not specific to engineering, it can be argued that there is an even higher need for digital skills in engineering graduates. Therefore, one can expect that engineering subjects will be among the earlier adopters of new and improved approaches to developing digital skills in their students. Consequently, developments in engineering education in this area can potentially have a greater breadth of impact than just within engineering.

Yet what digital skills are most important to our engineering graduates? Confusion has arisen in the past due to a trend of lumping together everything 'digital' under the singular term '*digital literacy*', and then focusing only on a subset of the possible literacies. Goodfellow and Lea [2] highlight the distinction between 'digital literacy' as a range of skills or capabilities located 'within' an individual, and 'digital literacies' as a more complex engagement with a shifting, dynamic 'range of socially and culturally situated practices'. Therefore, we prefer the plural '*digital literacies'*, with an explicit indication of which specific literacy or literacies are being considered, for example, the current study on coding relates to digital creation literacy, see [3].

In this Paper, we present and evaluate an intervention intended to reduce the anxiety around the introduction of coding to a cohort of first year engineering design students. The cohort were predominantly interested in mechanical engineering, and their course culminated in needing to control machinery using code. In this study, 65% of participants reported that programming was important or very important to their future career.

We argue it is important to reduce students' anxiety and negative connotations towards digital creation (coding) due to coding's inherent value in affording good practice in professional work. For example, a widely used introductory tool to numerical analysis are spreadsheets. Yet data can easily be skewed through inadvertent errors which are difficult to spot because of the hidden-by-default nature of formulas. For example, in the Austerity paper by Reinhart and Rogoff [4], they made a simple error in setting the range of a summing formula that markedly skewed the public debt-to-GDP ratio by excluding five countries, Australia, Austria, Belgium, Canada, and Denmark, from the analysis [5]. That example is not an engineering analysis, but similar pitfalls await an engineer conducting calculations in a spreadsheet. On the other hand, using code for data analysis is much safer. Recorded data can be kept in a read-only file where it cannot be inadvertently altered, data-manipulations are not hidden, and there are additional internal consistency checks that can be performed on code or scripts that help alert a user to potential errors. A code-based numerical analysis can be applied to different data sets, and it can be applied to test data to validate the operation. By comparison, re-doing a spreadsheet to suit different data may introduce new errors. Students capable of performing numerical analysis in code are therefore better prepared for professional practice where it relates to data handling. Examples of useful languages for numerical analysis include Python, R, and Octave. For Python, the `numpy`, `scipy` and `pandas` libraries provide numerical, scientific and data handling respectively.

We also argue that the current teaching of coding and programming is often decontextualised from the social, political, cultural, and material practices of everyday engineering work. This can lead to students, who are unfamiliar with the concept of partitioning problems, to fail to intuitively grasp the relevance of a skill presented in the abstract. For example, an engineering student who is not studying electronics or computing may not appreciate the relevance of digital literacies to their future career, and a traditional approach to teaching programming is so abstract that it is unlikely to correct that deficiency until later in the course. This approach delays students' gratification in seeing an immediate benefit to understanding a seemingly complex skill, and thus disengages them from learning.

The rest of the paper is structured as follows. In Section 2, we argue for the reframing of skills to encourage the sector in moving beyond treating them unhelpfully as *cognitive knowledge to acquire* to better describe them as *sociomaterial enactments*. We describe how this reframing leads to subtle but important differences in the design of interventions that relate to developing digital skills that better prepare students for professional practice. In Section 3, we explain the methodology of our intervention. In Section 4, we evaluate the results and reflect on the wider impact for the engineering education field.

2 REFRAMING SKILLS IN THE DIGITAL ERA

The metaphors we use in our everyday language are extremely important, but often over-looked, in how we construct our ontologies about what 'knowing' and 'learning' is and does. The dominant rational, cognitive, and human-centred perspectives in engineering education position 'knowledge' as a reified and de-contextualised outcome, and metaphors of transfer encourage educational practices to simplify, codify and commodify knowledge. Engineering students are commonly treated as rational problem-solvers, those who "learn as individuals, largely by applying formulas and rule to the solution of structured, 'right-answer' problems" [6] and fail to take into account the "human social performance" in engineering [7].

This cognitivist model has been criticised for ignoring the social, material and cultural dimensions of knowledge and learning processes. This is also the case for most policy and research into digital literacies [8, 9] which fall short of highlighting the ways in which these dimensions are integral to how literacy practices are achieved and performed in work and learning. Gourlay and Oliver [8] argue that, in the translations of recent empirical work, "*the nuanced nature of the data has been rendered less visible, which results in framing digital literacies as 'quantifiable, relatively stable, generic and transferable entities', which have been 'abstracted away from any specific, situated instance [and] whose defining features can be identified as residing in the individual*."

Along with Gourlay and Oliver, we argue that a sociomaterial perspective can help to position digital literacies as successful, co-constitutive social *and* technical achievements, which foreground the more nuanced, messy and materially-mediated aspects of learning, and foreground the 'specific, situated instances' [8]. Sociomaterial approaches aim to de-centre the traditional emphasis on the individual human subject, which positions 'knowledge' as a static and abstract idea that exists independently 'out there' to be acquired. Instead of placing the human at the centre of inquiry, metaphors of relationality, situatedness and emergence are favoured [10]. These help to conceptualise knowledge and learning as being *performed*, or enacted, into reality, through relationships and connections with various artefacts – computers, teachers, webapps, observatory data sets, classroom spaces, timetables, rendering software, and so on. Therefore, learning is firmly situated in action, and emerges as a performance through different practices and processes. Importantly, the focus on *relationality* means that the theoretical gaze does not separate humans from non-humans, which troubles more established educational theories that may frame, for example, the classroom as a 'container' for educational practices and the learner as a separate 'free-floating' individual [11].

This has important consequences when thinking about designing simulation-based learning activities to teach coding and programming. If we shift from trying to design learning activities that are based solely on the concept of abstracted knowledge transfer and acquisition, to a focus on the material affordances of the simulation and learning activity, then students enter into learning spaces that invite tinkering, playfulness and surprise. Here, 'right answers' are not necessarily predetermined but can emerge through the material and social relations unfolding in the learning activity.

3 METHODOLOGY

The intervention was framed as a problem-based learning session [12], in which students study an open-ended problem in small groups. Our groups were typically of 6 – 8 students working together at tables equipped with a computer and large, wall-mounted monitor. Each group had 90 minutes to work on trying to control a virtual solar panel track a moving sun, to capture as much energy from the sun as possible.

3.1 Overview of the intervention

The students were in the first semester of an engineering degree, taking a newly developed course that had not run before. Approximately 100 students were in the class, of which N=35 consented to take part in surveys associated with the intervention. It was stressed that non-participants would experience the same education experience, with the same free and open access to the web application.

Students attended a briefing during a 50-minute lecture in the morning. Before revealing the intervention, consenting participants were surveyed to determine their attitudes to engineering, their studies, and the physical project that they were working on in their groups (see section 3.2). During the briefing, the students were introduced to the apparent motion of the sun relative to the earth, the atmospheric model in the simulation (that leads to lower light levels and red light at sunrise and sunset), and the cosine law for calculating the relative energy extracted from a solar panel, based on its angle relative to the sun.

Then the webapp was introduced, and a link given so that students could follow along in class if they wished. The webapp is described in Section 3.3, and combined a model of a solar panel, with student-editable code to control it. The location of the virtual solar panel was shown to the students (a neighbouring observatory, whose GPS coordinates had been entered in to the sun almanac controlling the virtual sun position). This real-life connection to the observatory acted as 'specific, situated instance' [8] and was intended to increase student engagement as it reduced the abstraction of the task. Then the use of the Blockly graphical programming language was demonstrated to the students, by using it to show that the virtual data obtained from tilting the solar panel matched the cosine law, as shown on the graph.

Next, the task for the afternoon was introduced, including a description of how to use light sensors and baffles to cast a shadow. An example tracking solar panel was shown, and the representation and function of the virtual light sensors was explained and demonstrated by plotting sensor data on the graph. Students were alerted to the fact that this was an embodiment of an important class of control problem (tracking a moving object, such as a ship targeting an aircraft, or a ground station targeting a satellite) and because it is an example of classic control problem that has much more immediate relevance for students, because it is a visible, familiar phenomenon (motion of the sun) than tracking a satellite which they cannot see. This allowed the students to concentrate on understanding the technical aspects of controlling a tracker, rather than worrying about what was being tracked.

The afternoon session explicitly did not have a traditional lab sheet to encourage exploration. Instead, verbal assistance was given as appropriate to each group. The cohort was split into two, with back-to-back, 90-minute sessions, due to the limited capacity of the group-working room. The students in the first session did not have the opportunity to brief the incoming students for the second session.

The main goals of the session were to:

a) Understand that a solar panel that tracks the sun will collect more energy;
b) Recognise that the magnitude of the difference between two sensor values indicates the magnitude of the pointing error to the sun, in one rotational axis;

c) Recognise that four sensors can track the sun in both azimuth and elevation;
d) Appreciate that the strength of the corrective drive signal applied to the machinery needed to depend on the size of the error and the characteristics of the machinery;
e) Appreciate that useful solutions do not have to give perfect behaviour, rather that meeting specification can be enough in the early stages of development.

At the end of the afternoon session, students completed another survey on their experiences, relating to satisfaction of use, perception of quality of the webapp, and their attitude to the project following the intervention. Given the longer-term goal of having the students perform well in their physical project, no formal collection or accounting of the results was to be taken, to avoid giving the impression that the session was anything other an exploratory experience intended to enhance their preparation for the physical project.

3.2 Survey design

Two surveys were conducted. The first survey was administered before the briefing, to gauge interests, experience of and attitudes towards technology and engineering. It was intended to reveal whether students were operating altruistically (malleable intelligence mindset [13]; focused on learning for its own sake) or strategically (fixed intelligence mindset; aiming to maximise performance), although results were within norms expected and not further explored in this paper. The second survey was offered at the end of the intervention, and asked the students to reflect on their experiences, as well as to indicate their emotions before and after the intervention, using the 21-factor epistemic emotion scale [14].

3.3 Webapp design

The user interface to the webapp is shown in Figure 1, with annotations showing where the WebGL 3D model, Blockly code, sensor model, graph data and menus are. The

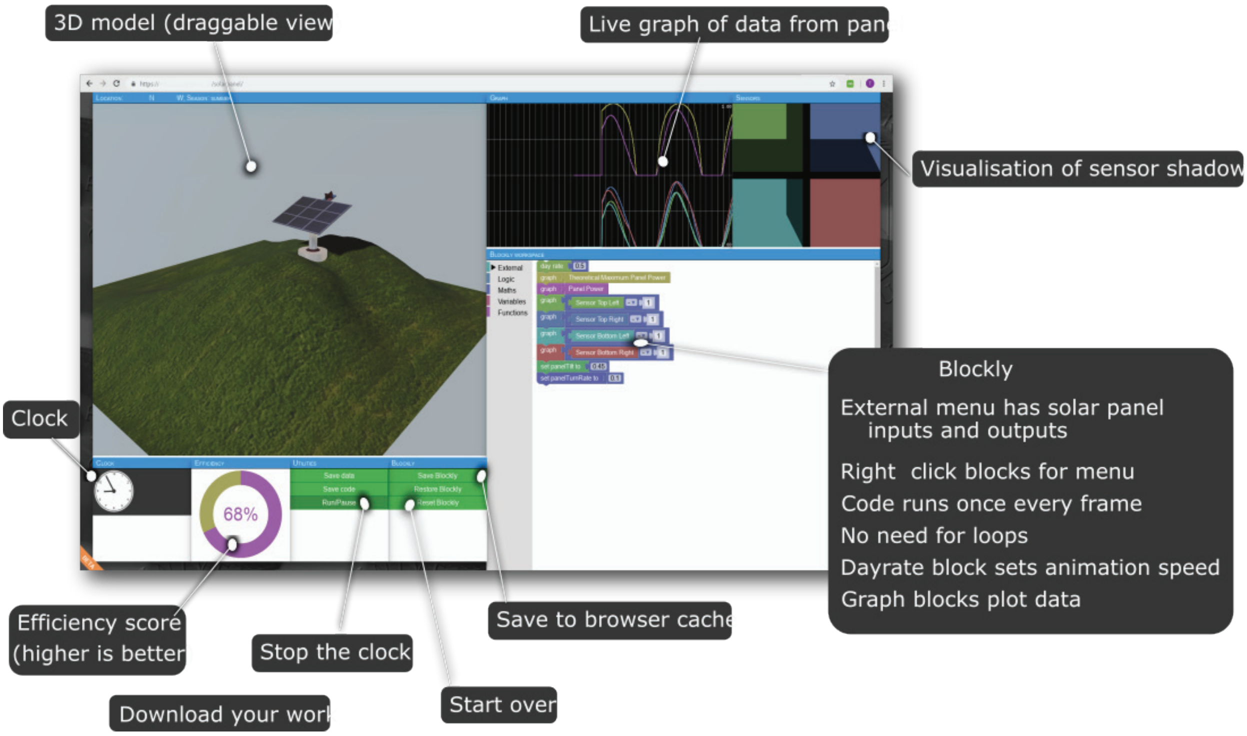

Fig. 1. Webapp interface (annotated)

Webapp was implemented in Javascript and served from a static HTTPS server. The WebGL model was based on a 3D model created from scratch in Blender, using public domain textures. The animation and control were achieved using THREE.js. The sensor shadow view was not rendered well by WebGL, so it was implemented as a canvas so that well-resolved shadows could be produced efficiently. The standard Blockly blocks were supplemented by blocks that could read and write to and from the global variables controlling the animation, and reporting on the state of the simulation (e.g. intensity of sun, power generated by the solar panel, sensor signals from the sensors), inspired by integrations of Blockly with virtual and remote laboratories [15,16].

4 EVALUATION

4.1 Usage

Figure 2 shows the usage of the webapp, via the count of analytics logging messages A small number of students followed along in the class. The WebGL simulation is known to be intensive on battery life, and since this was the first lecture of day, it was only fair to warn students of this. As a result, it is likely some students chose not to follow along so as to preserve battery life in their laptops. Here, the social and material relations in the students' learning practice is highly evident: the ability for students to access power points in interactive teaching sessions will shape the outcome of the learning process. Most students first interacted with the webapp in the afternoon. A number of students returned to the webapp the next day, showing that interest in the problem had been piqued. This is also consistent with the sentiment recorded in the Jisc survey that over 70% of HE learners agreed that with digital resources [1], *"I can fit learning into my life more easily",* and *"I am more independent in my learning."* Again, a sociomaterial perspective highlights that the classroom is indeed not the container in these instances of learning; different learning enactments are afforded when the student and simulation can work together remotely via the webapp and internet.

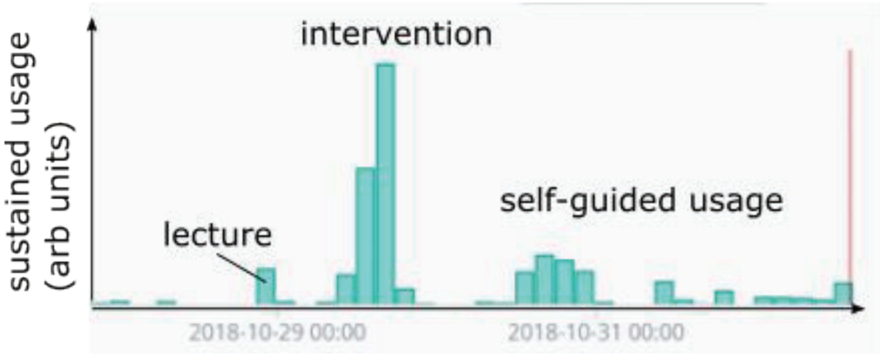

Fig. 2. Usage of the webapp

4.2 Attitude

Epistemic emotional data was collected on a 21-point scale, and collapsed into the seven main groups for analysis, as shown in Figure 3. The main outcomes of the session were that curiosity fell slightly (compensated for by an increase in surprise), while anxiety fell significantly. Overall, positive emotions reported remained constant, while there was a reduction in negative emotions (Fig. 4), as intended.

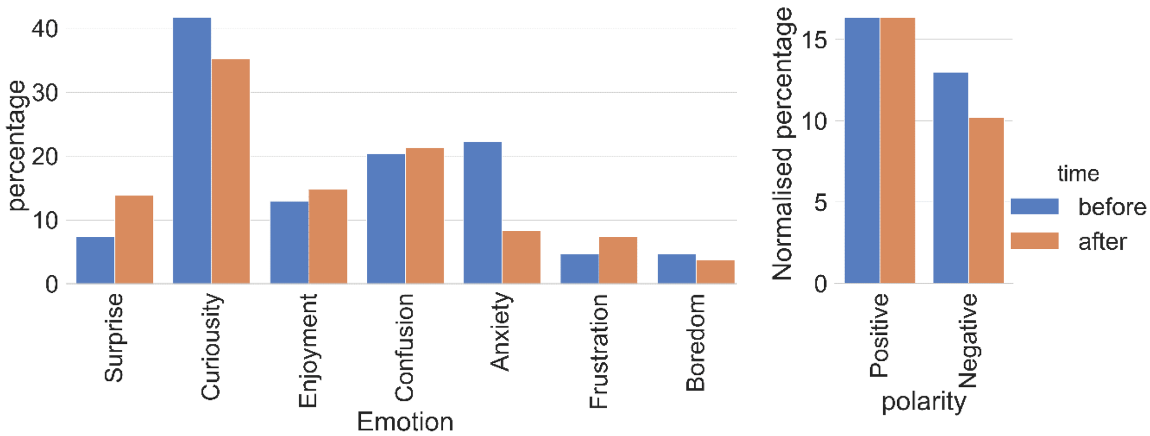

Fig. 3. Epistemic emotions before and after intervention

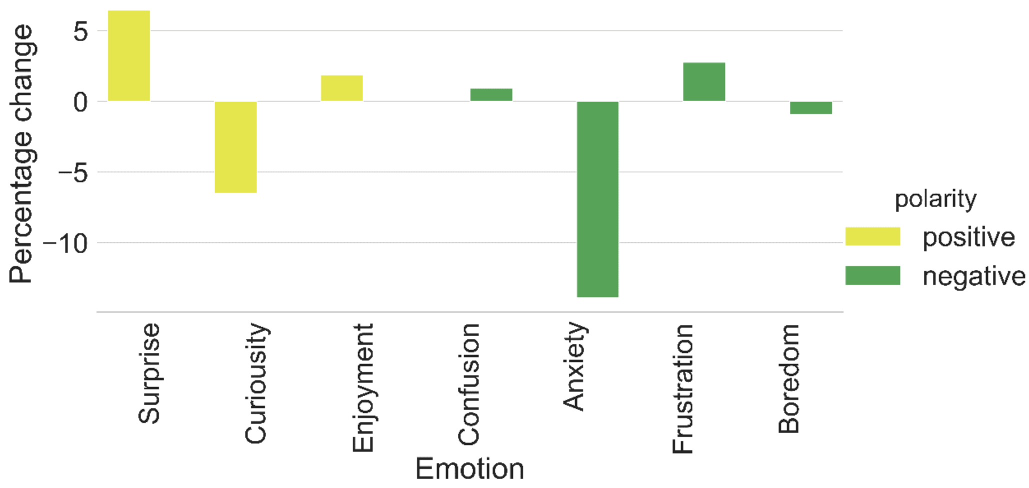

Fig. 4. Percentage change in epistemic emotions before and after intervention

4.3 Achievement

The outcomes from the session were not explicitly assessed. Inspection during the sessions revealed that the majority of students achieved a partial solution, with some achieving near-complete solution. One group did not proceed far beyond the initial screens. One of the most creative solutions came from an individual who came late and was working alone, who used a stochastic rather than deterministic approach. They pointed out the specification and scoring did not require an efficient solution!

For their final physical deliverable at the end of the course (a working solar panel tracker with two-axis control), we suggested to groups that they either use an Arduino microcontroller or an analogue control circuit (of which an example circuit diagram was supplied). Over two thirds of the groups chose to program a microcontroller to control their solar panel tracker, which was a higher percentage than we anticipated given the complexity entailed. This was not inconsistent with the reduction in anxiety that occurred after the intervention.

4.4 Improvements to the intervention

Some students were slowed down by a flaw in the interface. Looping constructs were inadvertently made available to the students via the Blockly toolbox. If they used them, the single-threaded Javascript interpreter became stuck in evaluating the code in an endless loop and could no longer able to update the rest of the user interface. This forced the Author to reveal to the affected students some details of the code's architecture. This prompted useful conversations that opened up the black-box of programming for the students, which showed them how the effects of human and non-human's relations were "constitutively entangled" in these coding practices [17].

An improvement would be to run the Blockly evaluation in a separate thread (via using a Web-worker). Explicit synchronisation with the animation would be required, although the option could be retained to do this in one or more ways. For example, synchronisation could be based on a notional computational speed for the Blockly controller made relative to the animation speed, so that performance is invariant between different computers or smartphones that the students are working on (important if solutions are being submitted to a server for automatic marking). Alternatively, an `interrupt` model could be introduced that triggers on every animation frame, although this requires additional explanation to the student. Both models are representative of real-world programming practices, but consideration needs to be given to ensuring the initial experience is relatively straightforward while also allowing deeper exploration.

A related issue is stopping the evaluation function cleanly when the code needs updating. This can potentially be handled by decorating the implementation of loops with boiler plate code that will cause any loop to exit when the code is flagged as being stale. The ability to write one's own implementation of the code underlying each Blockly block is of great help in solving these sorts of issues.

A relatively straightforward improvement to propose is automated testing of both the simulation, the data it provides, and the running of various Blockly programmes, so that modifications can be checked to ensure no new bugs are created. This becomes more relevant when the core code forms the basis for a remixable starting point for other activities.

A final improvement is to create an equation parser block so that more experienced programmers are not frustrated by the cumbersome Blockly syntax. This is important for allowing other staff to more fully enjoy the experience and probe for weaknesses and inconsistences in the underlying simulation model.

4.5 Wider impact

The intervention can be customised to suit other engineering or science specialisms by modifying the model, simulation engine, and user interface. This requires some technical input. It is not necessarily expected that academics themselves will already have, or wish to develop, the skills required to adapt the example code. We argue that education institutions should consider employing in-house resource to handle this type of digital content creation in support of curricula, analogously to the way that staff are already employed in machine and electronic workshops to design, develop and test physical artefacts in support of practical work. There is no suggestion that an academic must personally machine the artefacts used in their laboratories, although they may very well have designed, specified or helped evolve them. Admittedly the skill-sets are entirely different for digital content creation, but in our view, it is equally valid to consider a mixture of academics and non-academic staff working together to support the digital side of teaching delivery. Finally, we have started to show that a sociomaterial approach to understanding digital literacies shifts how we conceptualise learners as individuals who rationally acquire knowledge to understanding learning as a social and material performance, which should focus on specific, situated instances that are highly contextualised. In these properly supported spaces, experimentation and playfulness can emerge, which we expect to lead to a reduction in student anxiety, and increase graduate preparedness.

5. CONCLUSION

A sociomaterial approach to teaching digital literacies, such as coding, motivates the creation of interventions that all students to contextualise engineering practices that are new to them. We created an online simulator to allow students to tinker with the concept of controlling a solar panel. The exercise was not assessed, but out survey results indicated a reduction in student anxiety relating to their overall task of producing a real solar panel at the end of the course.

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Post-humanistic *'practices of community'* for non-traditional laboratory work

T. D. Drysdale, S. Kelley, A.-M. Scott, V. Dishon, J. Scoles
The University of Edinburgh
Edinburgh, Scotland

A. Weightman
The University of Manchester
Manchester, England

R. J. Lewis
Cardiff University
Cardiff, Wales

S. Watts
The University of Bath
Bath, England

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ABSTRACT

Many traditional campuses face pressure on physical laboratory estate, making it difficult or impossible to simultaneously satisfy an enhanced level of active learning for an increasing number of students. Non-traditional practical work (NTPW) approaches such as virtual or remote labs can be delivered digitally, reducing estates pressure. There is emerging evidence that NTPW activities, especially when mixed with traditional laboratories, produce as-good or better educational outcomes than traditional laboratories alone. This hints at the idea that technology offers not just a replacement for existing practices, but the opportunity for enhancement, including directing and evaluating students through collaborations between teachers and non-human remote laboratory entities. Inspiration and insight can be drawn from critical post-humanism, which explores what happens when non-human actors exert influence in education. We look to understand the effect of widespread introduction of NTPW on students' practices during study and also in their subsequent professional practices. We use the field of Science and Technology Studies, to find a description of how students will come together in the socio-technological

environment created by non-traditional practical work. Like the world in which our graduates are going to enter, sociotech environments can be difficult to predict, which challenges the idea that best practice is a 'thing' that should be solidified, static, or final. It instead emphasises that practices (plural) are multiple, non-finalised performances that evolve over time. This must be reflected in the implementation, evaluation and support given to both staff and students.

1 INTRODUCTION

Engineering education needs to turn out better graduates to meet societal and industry needs, while demand levels simultaneously require us to graduate large cohorts. The MIT report on the global state-of-the-art in engineering education highlights this challenge:

> *"How do we deal with this expansion [of student numbers]? How do we still engage students early on with the world of engineering? How do we show them the messiness of engineering, the political and social aspects? ... How do we do this beyond the capstone project? This type of education, the type of education we want to have, is expensive. So how do you do this for all students, large cohorts of students, without compromising on everything?" [1].*

Engineering education can only address these issues at the scale required by adopting non-traditional practical work (NTPW). NTPW is a group term to describe online digital alternatives such as simulated, virtual and remote laboratories. We also need to complement our existing understanding of engineering education with insight about relationships between students and NPTW activities, with a focus on improving student capabilities in real-world professional practice.

In Section 2, we highlight problems associated with traditional practical work, then explain NTPW and its benefits, including where NTPW activities could potentially take on some of the role of the human teacher and address some of the challenges of scale. In Section 3, we discuss the contributions that NTPW can make to navigating the curriculum, and enhancing graduate attributes that are relevant to their future careers in a rapidly evolving professional environment. In Section 4 we give an update on our progress toward understanding how NTPW should be implemented and evaluated across multiple institutions, and how we should support *practices of community* created by teachers, technical staff, and student co-creators.

2 PRACTICAL WORK IN THE AGE OF ACTIVE LEARNING

2.1 Traditional practical work

Traditional university campuses were often conceived and built at a time when fewer students were enrolled, and when there was less emphasis on practical work. Now, there is an increased desire for active learning, i.e. practical work that goes beyond simply following step-by-step lab sheets. Engineering's hierarchical knowledge structure means that active learning approaches from other fields are typically adapted into more managed forms, for example problem-based learning (PBL) becomes design-based learning (DBL) or project-based learning (PjBL), whose educational appropriateness is broadly accepted [2]. These approaches are expensive and staff-intensive so they are typically limited to small cohorts, or are driven by individuals who manage to 'make do' despite being under-resourced [3]. Therefore, it is not possible to conceive of these methods being broadly adopted at scale. Even just modernising traditional laboratories on largely conventional courses is prohibitively expensive and therefore out of reach for many Universities.

Leaving aside cost, long lead times and working lives mean building-based solutions cannot be rapidly implemented or changed in response to developments. Within a physical building, activity timetabling is also problematic. Timetabling is one of the main barriers to students being able to freely select optional courses within a single programme and year of study, let alone facilitating students in different years, or on different programmes, to come together on projects involving peer-instruction or interdisciplinary working.

Physical laboratories also lag behind other elements of higher education provision in terms of their support for diversity and inclusion. If we want more diversity in the engineering profession, then we need to support not just larger cohorts, but also cohorts with more diverse needs. Physical laboratories arguably are one of the last high-stakes activities on campus. Sessions cannot typically be rescheduled or repeated if missed for reasons such as caring commitments. While lectures can be recorded, this is not a suitable solution for labs. Supporting diversity also means supporting a diversity of student engagement modes including private experimentation and thinking time [4]. So how then to create an alternative format to support diversity, accessibility and inclusivity? We argue that NTPW activities are an effective, resource sensitive, and pedagogically sound solution that can address these issues.

2.2 Non-Traditional Practical Work

At one level, NTPW is attractive because of its reduced delivery costs. For example, simulated and virtual experiments can be entirely delivered from a server, at any scale, at any time, to any location. Remote experiments still require apparatus but require less physical space because they can be boxed and stacked. Sets of equipment can be split up and hosted in several smaller locations that would not otherwise be used for teaching or research laboratories, such as cupboards, bookshelves, corridors, mezzanines, and basements.

Because of the inherent safety that is designed into NTPW, staff are no longer needed to over-see every hour of practical work, and this allows a significant extension of the time students can meaningfully engage with the laboratories, by being able to engage outside of the traditional setting as well as within in it. Currently, many traditional laboratory courses are pushed for time, so students are brought in to a strict schedule, taught as much as possible in the allotted time, then they must leave quickly to let the next group in.

The inherent timetabling flexibility also opens new opportunities for interdisciplinary project working, with cross-year student teams. This is highly desirable because professional engineering practice does not take place wholly in silos. Cross-year project groups can be found in Design programmes, where the students form a design agency led by the older students and staffed by the younger students, who pitch for work from clients that include course staff and external (genuine) clients [5]. A similar approach is attractive to engineering, and NTPW offers a route to delivering this experience.

NTPW is also more than a lower-cost replacement for traditional practical work because it has been shown to offer equal or better outcomes [6]. The causes of the improved outcomes are at least in part because of affordances that cannot typically be reproduced in traditional settings, such as visualising invisible fields. Optimum educational outcomes appear to be obtained when traditional laboratories are retained, and students benefit from a mixture of the approaches rather than relying on either approach alone [7].

3 CURRICULUM CONTRIBUTION

3.1 Guiding self-exploration

One of the challenges discovered in adapting problem-based learning (PBL) to engineering is that it requires the students to direct their own study of the material. This can be risky in such an exact, technical and hierarchical subject where concepts built on ‘wrong knowledge’ are harmful [2]. This implies a need for even smaller groups, and more direction from the staff, ensuring that the required mathematical and physical knowledge is in place. This can make PBL in engineering either prohibitively expensive or risky. While PBL is primarily focused on students acquiring cognitive knowledge, similar principles presumably apply to students undertaking self-directed study in the application and integration of knowledge, such as during PjBL. How then to make staff sufficiently available throughout the extended duration PjBL (weeks or months), where student activity is not constrained to office hours?

A post-humanist [8] approach provides a fruitful ground for appreciating the potential in this space. By adopting a viewpoint in which non-human agents, such as technological artefacts, are of equal status to human participants, critical post-humanist approaches offer a refreshing perspective, particularly because they emphasise that technology should be valued on its own terms, rather than on how well it can replace humans [9]. As Edwards [10] points out, the ‘post’ in post-human is not anti-humanistic: “*it is not ‘after’ in terms of going beyond, but in terms of offering a constant experimentation with or questioning of the human*”. Bayne’s exploration of using a chatbot to interact with students on a digital humanities course motivated us to see that NTPW activities are potential collaborative partners that could bring their own agency to bear in assisting student learning [9] by fulfilling some teacher-like functions, such as hinting, guiding or even challenging students.

NTPW activities have hardware and software designs that naturally set a scope for the exploration that students can undertake, but within that scope there should be room to provoke students to think about surprising and unexpected results, and explore different sets or variations of parameters without rushed to complete or having to worry about being negatively judged for the particular route of their learning journey. The values of a malleable intelligence (such as exploring and practicing) are desirable, and can be communicated by NTPW activities. However, these activities should not be countermanded by the presence of a step-by-step procedural lab sheet, but instead encouraged by the actions of the teacher-like functions. There is already the potential for a significant amount of hinting and guidance that can be embedded in the user interface.

User interface design then takes on renewed pedagogical importance, as opposed to being driven purely by aesthetic or usability requirements. Students receive both intended and unintended messages in traditional work, and the same holds true for NTPW. Without understanding the hidden messages being transmitted by the interfaces, there could be inconsistences from one part of an interface to another, between experiments, or between the interface and any artificially-intelligent communication capability. Getting this right could well mean multiple design and interaction languages to cater to different degrees of open-ended-ness. This is a key motivation for a shared software infrastructure, so as to reduce duplication of effort.

As the students move to more senior years, user interfaces should become more open-ended. For project work, activities might be programmed directly by the student and/or the data analysed in Jupyter notebooks [11]. On this journey from school-like bounded environments, to work-like open-ended environments, the interplay between students, NTPW activities and staff can be viewed as an educational collaboration.

Taking a posthuman perspective can help us further interrogate this teacher-like effect of non-human NTPW intermediaries on student practices.

3.2 Developing professional practices

Graduates are destined to enter a world in which social and technological aspects are intertwined. They must navigate professional practice that will take place in environments that educators will struggle to predict. This challenges the idea that best practice is a ‘thing’ that should be solidified, static, or final. This immediately provides a tension against the idea of a having a fixed behaviour that we are trying to teach a student within a given activity. Therefore, a diversity of solutions should be expected in a NTPW activity, within bounds that are set only as tightly as needed for the coherence of the overall programme of study. It also has consequences for conceiving of the social, and material, construction of the learning that takes place through NTPW practices.

Although definitions of practice are often contested [12], we follow Schatzki’s definition of practices as “*embodied, materially mediated arrays of human activity* *centrally organized around shared practical understanding*" [13]. A crucial element of this definition is the notion of practices as being '*materially mediated'*; that is, we cannot understand practice without considering the role of non-human actors in everyday human activities. *Practice* is widely cited as being integral to issues of knowing and learning at work, via the notion of '*communities of practice*' (CoP) [14]. When newcomers come to practise a particular practice, they do so primarily through interaction with others who are experienced. Knowledge and learning are thus increasingly understood as socially constructed, where newcomers learn social and cultural practices through apprentice-style learning from older colleagues.

This is an issue for professionals working in emerging engineering industries because, due to the relative newness of the industry, there is a lack of expertise from longer-serving employees who legitimise references to past knowledge practices. Given the rapid pace of development in industry, it is increasingly likely that graduates will find themselves in this situation. So, how can engineers in emerging industries learn from others if the practices and knowledge are yet to be developed, or are changing so rapidly they fail to stabilise? In this case the term '*community of practice'* is better transposed as '*practices of community'* [13]. That is, rather than a community existing *a priori*, containing the knowledge and determining the activities, the latter term foregrounds the activities as generating a community, which is precariously held together by people, relations and materials.

What then can be done in higher education to provide experience of this? Subject knowledge has been chosen for its long-term relevance, and staff are authorities, so it cannot be done in the existing curriculum. We argue that NTPW activities offer a rapid refresh and update cycle (unlike conventional laboratories), which opens the way to giving students experiences with leading edge technological concepts, and to observe the behaviour of senior students, tutors, and staff when handling newer concepts themselves, before the concepts and practices around those technologies have stabilised.

4 IMPLEMENTATION, EVALUATION AND SUPPORT

4.1 Implementation

Academic participants from three UK Universities are actively engaged in comparing institutional drivers, barriers, and challenges. This has already generated a variety of use cases and externalities, such as differing commitments and operational policies (e.g., information security). All three institutions involved have identified a need for NTPW across all modalities, and a desire to move beyond treating NTPW interventions on a separate basis.

In order to support the kinds of learning described above, we require an interoperable infrastructure that works across institutions, which brings together all forms of NPTW in a consistent manner. This is intended to lower the barrier to usage of NTPW by course organisers who are not software developers. This implies integration with learning management systems, and federated authentication. Since learning management systems differ from institution to institution, LTI integration would be an obvious choice to consider, and the latest version (LTI 1.3 Advantage) offers some opportunities to present an “app store” of experiments for integration.

Booking and management functions would be required for synchronous remote laboratory experiments and other modalities will have their own variation of use cases, for example, virtual laboratories may contain datasets that range from openly accessible, to those that are restricted to a few or one student. A common or interoperable approach to data provenance, micro-payments, evaluation, grading and feedback will also be required.

We expect that our individual institutions may want the option of hosting the services themselves or outsourcing them. This suggests multiple, individually-complete NTPW services that may serve one or more campuses, and that can interoperate with each other to share activities and services, or pool equipment.

This overall set of requirements suggests favouring microservice-based architectures, with discovery and federation, which are able to be extended by adding new microservices as required. We are currently working on developing the architectural design of an initial prototype of this system, beginning with a minimum viable set of features and evolving the infrastructure and interfaces in response to feedback from staff, students, and developers.

4.2 Evaluation

Evaluation of student learning outcomes due to NTPW will be difficult to separate from other interrelated aspects of the curriculum in which it is embedded. Student exam performance before and after the introduction of specific NTPW activities will be affected by year-on-year variation in student cohorts, and limited to assessing cognitive aspects. Cognitive aspects are only a subset of learning evaluation. The performative skills should result in a change in the affective domain, which can be assessed by surveys with a greater or lesser degree of reliability in the self-reporting. Well-constructed NTPW activities will contribute to shifting students away from a fixed model of intelligence, typically developed by the teach-to-the-test mindset prevalent in secondary education. Tests that indicate the adoption of a malleable view of intelligence can give an indication of the development of graduate attributes that are better suited to coping with professional practice. A more insightful approach would be to run focus groups to collect qualitative evidence. That evidence could also assist in posing and prioritising future developments

Over a longer period of five to ten years, we would expect to see a change in the behaviour of graduates as reported by employers, and by comparing qualitative statements from students about their first few years of their careers. This would require a longitudinal study, so as to capture views from current students who will have had less exposure to NTPW both before they leave, and after they enter the workforce. These could be complemented by surveys on 21 attitudinal scales and through the development of a question bank that is intended to elicit student views on issues relating to professional skills. These can be combined with interviews with academic staff and tutors on their impressions, and potentially ethnographic study as appropriate.

In terms of assessing students, a specific example of how assessment strategies could change in light of our discussion in Section 3 is that a diversity of solutions within the class could be foregrounded and explicitly valued as a component of the mark. Then, there is no longer the implicit assumption that the best way to get good marks is to figure out which is the solution favoured by the teacher.

Student feedback is ripe for enhancement, by moving to a model where students are able to access feedback on demand. A straightforward example is providing a service to which students can submit work for feedback on the aspects that can be deterministically calculated (e.g., waveform shown on graph is as expected or not). We also expect to see benefits in this area from teacher-in-the-loop automation [15], where AI approaches are used to label student interactions. These approaches surface triaged information for the attention of the teacher, which could be modified to present carefully contextualised and scaffolded comments that can prompt the student. The teacher can then act on the information, or not, according to their judgement of what the student will benefit from most. Current developments focus on open-ended environments with well-defined actions. Further developments are needed in this area to accommodate NTPW activities in which the interaction is via programming or involves interacting with analogue data.

We also envisage adapting this approach to track and analyse the short-term cause and effect of any interventions by AI within the experiments, thus contributing to the overall activity evaluations as well as individual student performances.

4.3 Staff support

Delivering new NTPW experiments to prepare students for professions where practices have not stabilised (Section 3.2) will require a change in mindset; to reject the comfort of re-delivering familiar material year on year. Teachers will inevitably require support in developing and delivering these activities, scaffolding student expectations, developing appropriate assessment strategies, and having these approved in regulations and accredited.

Existing academics are not expected to develop new digital literacies sufficient to turn them into content creators, although this practice is encouraged where appropriate to the individual's interests and experience. Given the specialised nature of digital artefact generation and remixing, with all the edge cases, security implications, and performance/maintenance implications, then the required expertise is not trivial. For those who do not already work with coding in some way, the barrier and investment is likely to be too high to overcome.

In the first instance, academic colleagues would access pre-existing activities. When it becomes necessary to customise or remix those activities, or create entirely new ones, then an appropriate model can already be found in the existing traditional laboratory ecosystem. Traditional campuses often run a mechanical workshop with a team of designers, fitters, turners, and machiners, and laboratories themselves are often overseen by dedicated technicians who understand the relationship between the pedagogical approaches and the laboratory apparatus. There is no reason to assume that this model would not work in the case of NTPW, with the mechanical and electrical workshops continuing to provide physical structures, whilst a team of software developers, with a mixture of capabilities, would handle the translation of academic ideas into activities, and manage the reliable delivery of them.

These developers would likely benefit from community interaction with their opposite numbers at other institutions. The best vision imagines annual conferences or workshops to share their experiences and practices, as well as various digital means that are ubiquitous in open-source projects. Versions of these events internal to institutions would be relevant to academics interested in contributing, as well as new developers, and experienced developers who work in different disciplines across campus. Usage of NTPW is envisaged not just in engineering, but broadly across campus.

5 CONCLUSION

The burden of producing large cohorts of engineering graduates who are well prepared for their future careers can now only be met by a substantial infusion of NTPW into coursework and, eventually, assessment. The economic and pedagogical arguments are both in support of this because adding new NTPW activities costs less than increasing the traditional practical work provision, and opens up new ways of learning that were not previously possible. Academic staff can be assured that NTPW is intended as a complement and extension to traditional practical work, and that existing traditional practical work provision must be retained in order for students to achieve the best educational outcomes. Teacher-like functionality emerges in NTPW activities beginning with the interface and hardware design and, viewed through a *post-humanistic* lens, is seen to complement rather than compete with academic staff, because technical artefacts do not replace humans but instead have their own value to offer. Institutional support is ultimately necessary, but more affordable and better value than the alternative of increasing only the traditional practical work offering. The pooled infrastructure we envisage permits a phased adoption that is further de-risked by adapting developments in response to ongoing evaluation, with *practices of community* emerging to support academics, those in new support and development roles specific to NTPW, and student co-creators.

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Enhancing Laboratory Learning Experience

A New Experimental Setup For Power Electronics And Electrical Drive Education

P. J. van Duijsen
Caspoc Simulation Research
Alphen aan de Rijn, The Netherlands
p.vanduijsen@caspoc.com

D. C. Zuidervliet
The Hague University of Applied Sciences
Delft, The Netherlands
d.c.zuidervliet@hhs.nl

C. F. M. Dirksen
The Hague University of Applied Sciences
Delft, The Netherlands
c.f.m.dirksen@hhs.nl

Conference Key Areas: Innovative Teaching and Learning Methods

KEYWORDS: TEACHING, POWER-ELECTRONICS, EXPERIMENTS

ABSTRACT

This paper presents the use of a new experimental setup for power electronics and electrical drive experiments in teaching Electrical and Electronics Engineering bachelor students. The setup is developed in the context of educational innovation and is configured to closely resemble industrial appliances that are used in power electronic converters for DC-DC, DC-AC and AC-DC conversion. The hardware allows students to perform laboratory experiments with voltage levels below 60 volts and under 200 Watts, to comply with DC grid LVDC standards. Applications range from battery charging, solar panel maximum power point tracker, DC-DC conversion to single phase and three phase AC applications such as motor drives, grid-tied connected inverters and wireless power transfer. Moreover, the applications can be tailored to apply in other disciplines, such as Mechanical Engineering and Mechatronics. A set of experimental assignments guides students from theoretical principles, via idealized simulations to measurements. Finally, students perform laboratory experiments in which they are assessed on their verification of the theoretical and simulation results together with measurement outcomes. Since the setup is constructed in the same way as an industrial application, typical measurement results due to parasitic components, are visible to the students. Compared to commercial educational training hardware, the industrial construction is more close to reality and better prepares students to understand the working of power electronics and electrical drives. The combination of the industrial design approach and multidisciplinary flexibility of hardware, laboratory experiments provide students a realistic and enhanced learning experience.

1. INTRODUCTION

Learning by doing is a method where students can learn technical skills using laboratory assignments. Especially in electrical engineering, laboratory skills are essential for understanding in depth the working and behavior of typical applications and components. Simulation and Animation is one of the methods for students to gain some knowledge on the working on circuits and components [5][6][7][8].

Experimental setups and laboratory assignments are common practice in the study of electrical engineers, however little is known on the acceptance and achievements by the students. In this study we present an improved version of a laboratory setup[9] that can be applied to a variety of applications and we conducted a survey on the use of the experiments and the laboratory set up. Based on the outcomes of the survey, the assignments and the laboratory set up can be improved.

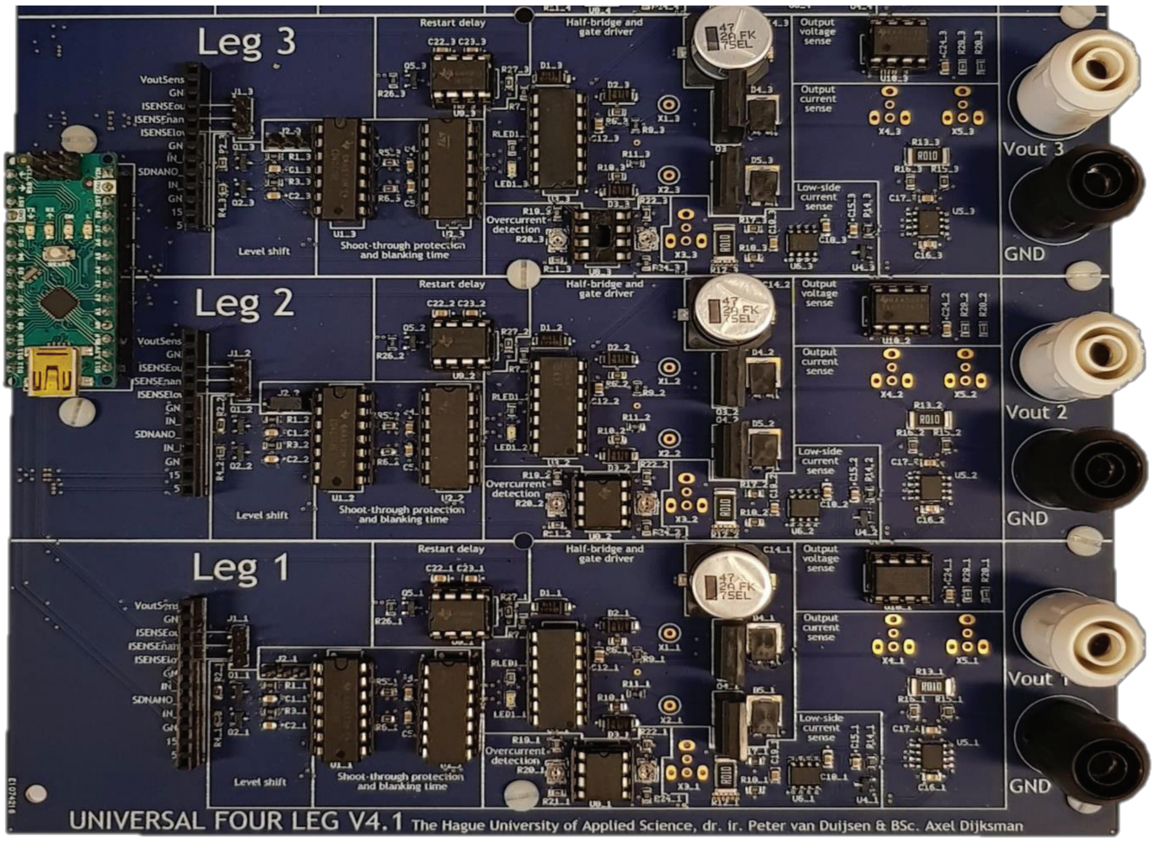

Fig. 1. Three Legs of the fully assembled Universal Four Leg with an Arduino Nano.

The Laboratory assignment is built around the theory from the lectures[1] and has to be practiced using simulation[2] and measurements[9]. First the students have to prove their knowledge with simulation assignments. After approval, they have to examine the working of the Universal Four Leg board and do measurements on the board, explaining the functions of all components. In Fig. 1. we see the fully assembled Universal Four Leg also known as the U4L. After a short explanation of the working and components of the experimental set up, an example is given of a student assignment. Secondly we describe the methodology we used to conduct the survey and the evaluation of the results from the survey.

2. EXPERIMENTAL SETUP

The U4L can be used in various experiments. Mainly the applications are diverse on one hand, but on the other hand they mostly converge to the same type of hardware topology. In many applications, ranging from switch mode power supplies with synchronous rectification, half bridge, single phase full bridge to three phase full bridge the totem-pole connection of two Mosfets like in *Fig. 2* below dominates. Therefore the U4L is constructed from four independent half bridges that can be configured to create the various topologies.

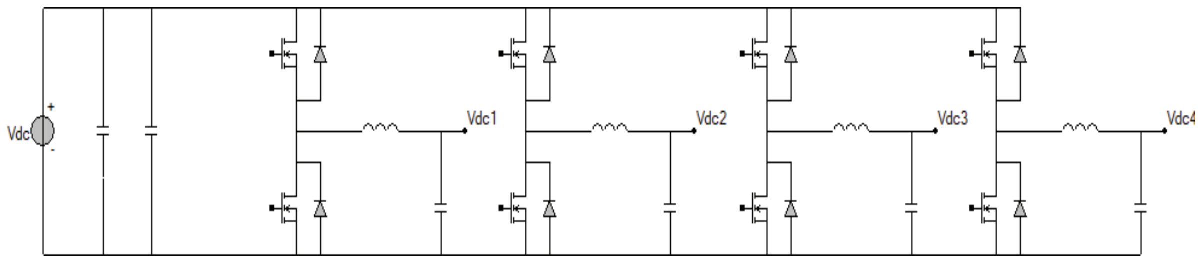

Fig. 2. The topology of the Universal Four Leg

The control and protection of each half bridge as well as the measurement circuits are equal for all four half bridges. Therefore it is possible to us only a single leg to build a switched mode power supply but by combining three legs, one can build a three phase inverter.

ELECTRIC CIRCUIT

Each leg on the U4L is configured to work independent of the other legs. Therefore the description of the used circuit is limited to a single leg. It starts with the level shifting of the input signals to be compatible with *3.3* volt and *5* volt systems. It is followed by a shoot-through protection and logic blocks to prevent over-current. The over-current is measured on the low side Mosfet and on the outgoing current. Using a jumper, the user can switch between the two measured signals. All current measurements and output voltage measurements are buffered using a high bandwidth Op-amp. The current signals are filtered to remove the spikes from Mosfet switching and the output voltage is averaged.

APPLICATIONS

The main applications are the DC grid related experiments and three phase motor control experiments. A typical experimental set up for a DC grid using a solar module and Li-Ion battery is elaborated in this section.

DC Grid

Switched mode power supplies are the emerging applications that are always required to control the amount of DC power that flows between source and load. The applications are numerous. Using a single leg, the Buck, Boost and Buck-boost converter can be configured. The on-time of the Mosfet switches of the converter are controllable and the amount of voltage and current at the output of the converter are measurable and can be used in the control of the converter. The control of the converter itself is done external to the U4L and can be either an analog or digital control.

Battery charging and discharging

Battery charging mostly implies constant current and constant voltage supply to charge the battery. The constant current supply is achieved by controlling the output voltage of the converter such, that the output current remains constant. As soon as the voltage level of the battery rises above a certain level, the control of the converter is changed to a constant output voltage. The charge current can be measured and as soon as the battery is filled, that charge current will drop below a certain level indicating that the battery is fully charged.

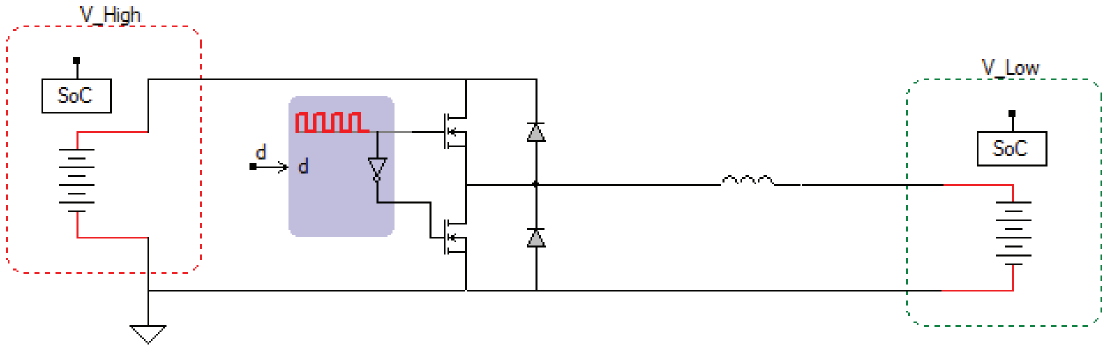

Fig. 3. Battery charging and discharging topology.

The control of the charge current is simply done by setting the on time of the high side Mosfet such that the outgoing current just reaches the maximum current. Discharging the battery is also possible by simply controlling the low side Mosfet instead of the high side Mosfet. Again the maximum current is controlled, but now with the on time of the low side Mosfet.
In this way a charging and discharging of a battery is done using the same topology and only by controlling the on time of the high or low side Mosfet, the power flow can be controlled as shown in *Fig.3*.

Solar MPP

For solar applications we basically control the voltage over the solar panel to the maximum power point value {MPP}. Using a boost converter topology where the output voltage of the boost converter is constant, the value of the input voltage is controlled. The amount of current flowing out of the solar panel is simply defined by the voltage-current characteristic for the solar panel for the given solar insulation.

Bidirectional power control

Applying the bidirectional Buck-Boost converter, the power flow in a DC grid can be controlled. Therefore a single leg can serve multiple purposes in a DC grid, such as voltage and current control, including maximum current protection.

Analog and Digital control

With some external components, a breadboard, solar panel and rechargeable batteries, students can build various experiments. The U4L preliminary fulfills the role of a basic circuit that does the power processing. Using external inductors and capacitors filters can be built for connecting auxiliary loads and supplies like a solar panel or a rechargeable Li-Ion battery. The control of the U4L can be performed in two ways. A digital control or an analog control. Both have their advantages and disadvantages such as easy access for the analog control and flexibility for the digital control.

In *Fig. 4* the set-up of a MPP controller for a solar module is shown. The solar panel is connected via an inductor and capacitor to the first leg and digital multimeter is used to measure the average current from the solar module to the U4L.

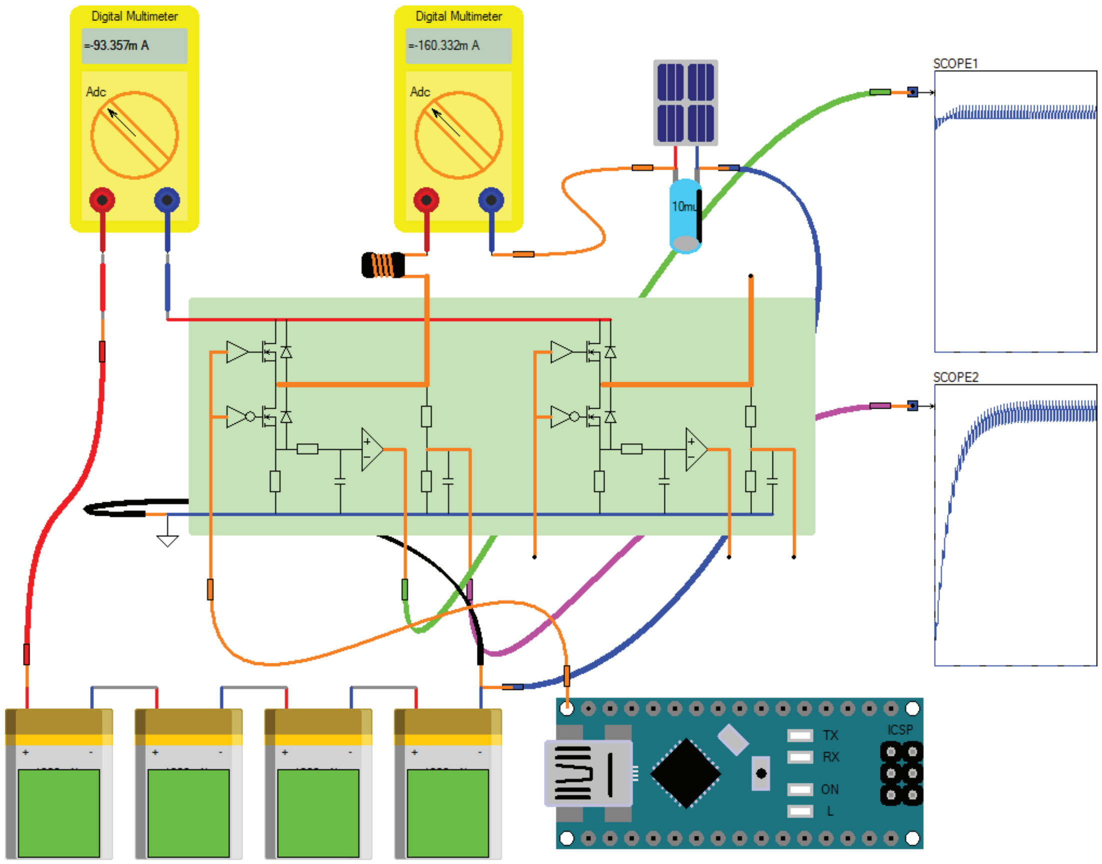

Fig. 4. The U4L with Arduino in a MPP controller for a solar module configuration.

Four Li-Ion cells are connected in series to make a DC voltage of *15* volt. The current flowing in and out of the battery is measured by a digital multimeter, measuring the average current.

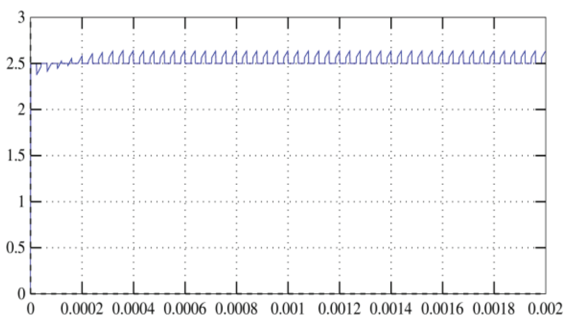

Fig. 5. Scope 1.

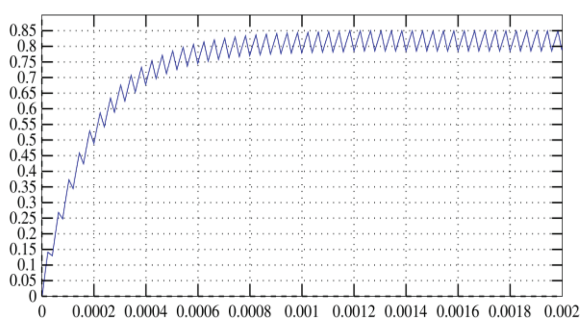

Fig. 6. Scope 2.

Fig. 5. shows the output current as seen by the low side current shunt. Its signal is centered around *2.5* volt, being the zero offset.

Fig. 6. shows the output voltage as measured and buffered using a resistive divider.

The control is done using an Arduino Nano [3] microcontroller which generates a Pulse Width Modulated signal with constant frequency and duty cycle. This PWM signal is input for the first leg of the U4L. The output is coupled to the solar module via a series inductance and a small parallel capacitor. In this way a synchronous boost converter is created between the solar module and the DC link, being the four Li-Ion cells in series. The current measurement inside the U4L and the buffered output voltage are displayed in *Fig.5* and *Fig.6*.

The purpose of the assignment for the student is to regulate the U4L in such a way to optimize the energy harvesting from the solar module. By regulating the voltage across the solar module, the maximum power point can be achieved. Students have to find the optimum duty cycle for this. The figure above *Fig.4* shows the simulation of this set up. The digital multimeters show the average current of around 160mA for the solar module and 100mA for the DC link current. During the simulation the State of Charge [SoC] of the batteries is displayed in the batteries and running the simulation for a longer time, the students can predict how long it takes to charge the batteries. Increasing the solar intensity in the solar module, default set to 200mW/m^2, shows that the student has to adapt the duty cycle to stay at the maximum power point of the solar module.

Since reprogramming the microcontroller involves time and knowledge of the students, the second assignment makes use of an analog controller, see *Fig. 7* below.

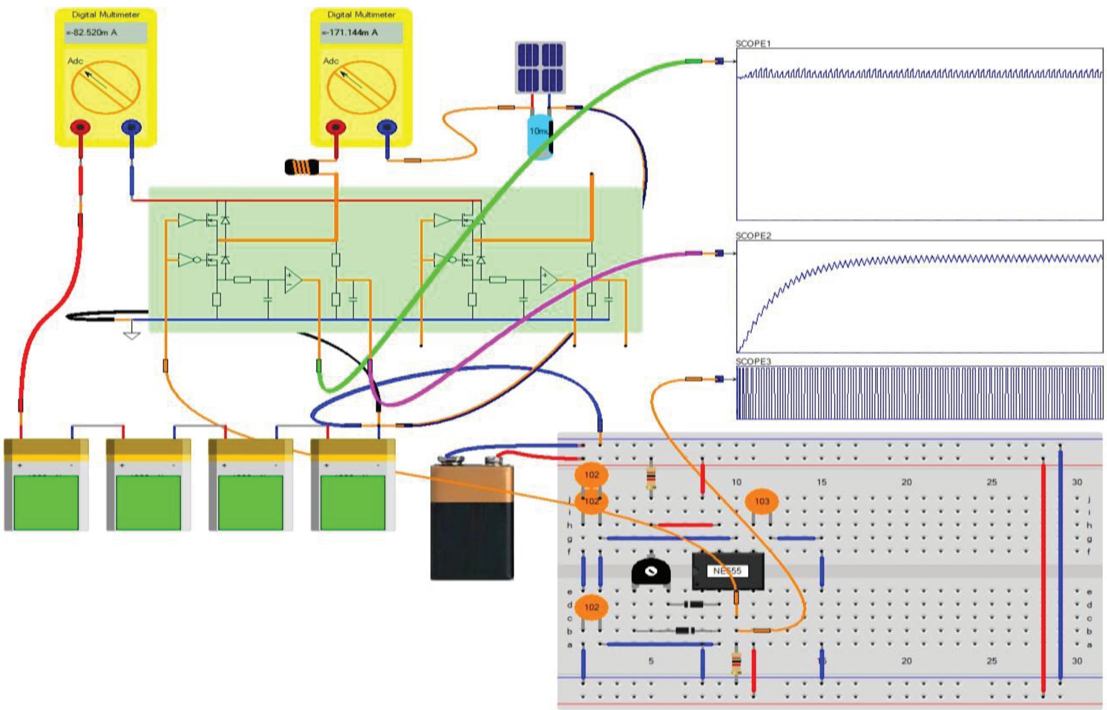

Fig. 7. Combining the U4L with analog circuits constructed on a breadboard.

Here the analog control has to be constructed on a breadboard using various electronic components. The aim is to create a square wave signal with fixed frequency that can be varied in duty cycle. Using a simple NE555 and a variable resistor. The output of this analog control can directly be coupled to the input of the U4L and the power supply for the breadboard comes from a 9volt battery.

3. LABORATORY ASSIGNMENTS

The Power Electronic class [1] introduces the theory of DC to AC inverters. For the laboratory assignments the students will use their knowledge gained during the lectures. The knowledge both mathematical and circuit topology give a good base for the students to start with the first simulation assignments. The simulations assignments are done with the Caspoc Simulation Software [2]. Students can open the simulation models corresponding with each assignment. Starting with a pre-configured configuration of all the components needed to build a DC to AC inverter, see *Fig.8*. After getting familiar with the simulation software Caspoc the student get more challenging assignments. Explaining measurement outputs and explaining circuit behaviour when changing circuit parameters. The nine simulation assignments will be documented with answers to the questions, including calculations and screenshots of the simulation results. All simulations together give a full understanding of the working principal of the U4L.

After completing all the simulation assignments the students may continue assemble the U4L PCB, a snipped of the PCB is shown in *Fig. 9*. The soldering process of the U4L will be split up in function segments. Every segment has its own assignments with corresponding questions and measurements. For a higher success rate there is a logic build op from soldering the power supply until the Mosfet power stage. At every segment measurement the current will be limited to prevent big short circuit currents, this to make it safe in use. The students also get familiar with soldering THT and SMD.

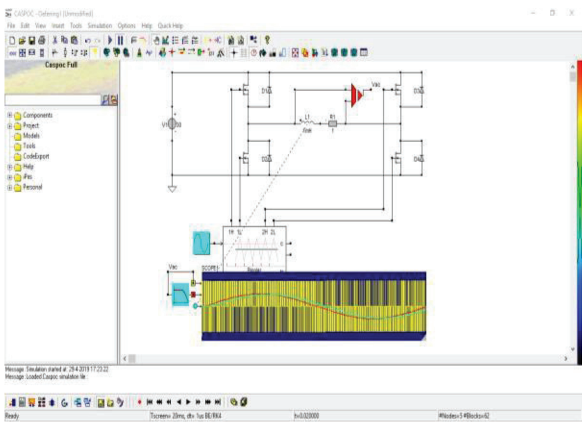

Fig. 8. Caspoc Simulation Inverter Model.

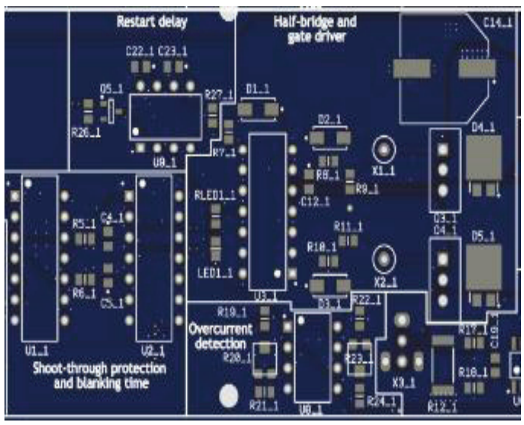

Fig. 9. A segment of the U4L PCB.

<u>There are nine simulation assignments witch contain the following subjects:</u>

1. DC to AC inverter model
2. Change Parameters
3. Measurements and Calculations
4. Blanking Time
5. Bipolar Mosfet & IGBT Currents
6. Unipolar Mosfet & IGBT Currents
7. Inverter Current Control
8. Charge Pump Gate Driver
9. Inverter Output Voltage

<u>There are seven build assignments witch contain the following subjects:</u>

1. The Power Supply
2. Shoot Through and Blanking Time
3. Mosfet and Gate Driver
4. Measurements Output Voltage and Current Sensing Low-Side
5. Current Sensing High-Side
6. Current Amplifier Low/High-Side
7. Shut-Down, Restart Delay, Overcurrent Detection

4. METHODOLOGY

In order to understand the perception and experience of the hardware in a laboratory training, the presented experimental setup was implemented in the third year elective Power Electronics. During the laboratory training, students have fully access to the hardware and have to complete assignments spread over four sessions. The course is mandatory to attend. A questionnaire with both closed and open-ended questions was designed to seek feedback on student's experience. It consists of:

- Five statements for evaluating student experience of the laboratory assignments
- Four statements evaluating student experience of the hardware
- Four open-ended questions that collected feedback on the laboratory experience and the use of the hardware

Responses to the statements are measured using a 5-point Likert scale, ranging from "1" as strongly disagree to "5" as strongly agree. Both statements and open-ended questions were presented in Dutch. Out of the 39 students, 22 responded to the questionnaire after the seven week laboratory training was finished.

5. EVALUATION

Before the U4L was used in the laboratory, it was reviewed by five students that have worked on further development and improvement of the hardware as part of their research or project. Outcomes show that students easily applied existing knowledge in the use of U4L and particularly liked the design and the variety of possibilities. They acknowledged that they were familiar with the internal components, however, students did not particularly gain new knowledge and skills during their use of the U4L. Also valuable feedback for improvement was given on the performance of the microcontroller. The overall experience was rated a 7.4 (on a scale from one to ten).

During the laboratory training, the U4L was incorporated in a setup related to a series of laboratory assignments. Student's comments on the assignments were neutral to positive when it comes to their interest and understanding in power electronics and student's development of knowledge and skills (*Table 1*). Students point out that they are able to see functions of the hardware when performing the measurements. Hence, theory was visible in practice and better understood. Moreover, the assignments provided a realistic example of power electronics application in real life. In contrast, students raised also some criticism on the laboratory assignments. This is further clarified by the answers on the open-ended questions. Students report that they have spent more time than desired on soldering smd components. While soldering smd is an assumed prerequisite, it turned out that students were insufficiently capable of soldering the smd components. This resulted in a delay in the execution of the assignments. Overall, all students suggested to pre-assemble the smd components.

Feedback on the U4L was neutral to positive. Students perceived the hardware as interesting. This is in line with student's feedback on the use of the U4L, which was reported as stimulating (*Table 1*). Moreover, students report that they identified the link between theory and practice while working with the hardware. Furthermore, the U4L resembles a realistic representation of practice. The main criticism on the technical aspects concerned the lack of test points.

In the upcoming power electronics labs a number of control boards and load boards will be provided, so students can perform measurements on various applications. E.g. electrical loads are varying in power level, both single phase and three-phase. Pre-designed analog controllers such as P, PI and PID controllers are preparable as control boards,. Students should also be provided with U4L boards, containing pre-assembled smd components and empty logic IC's. This will give students more time left for doing more measurements related to the power electronics experiments.

Table 1. Survey results evaluation of the laboratory training (n = 22)

Survey items	**Scores (count)**					**Median**
The laboratory assigments…	1. Strongly disagree	2. Disagree	3. Neutral	4. Agree	5. Strngly agree	
make me enthusiastic about power electronics	1	7	9	4	1	4
contribute to my knowledge and skills	0	5	6	11	0	3.5
allow me to gain better understanding of power electronics	2	6	2	11	1	4
helped me in being confident operating a development board	5	8	1	6	2	2
were of satisfying quality	8	8	5	1	0	2
The use of the Universal Four Leg was…						
easy	2	4	10	5	1	3
good to understand	3	2	9	6	2	3
stimulating	1	0	7	13	1	4
satisfying	2	6	10	4	0	3
	Mean					
To what extent do you think the U4L approaches a realistic situation [1 = not at all; 5 = to a great extent]	3.14					

"When you perform the measurements, it is much better to understand how the hardware works. It gave me a better understanding of the hardware and the theory was easier to understand."

"All functions and features that were given in the lecture were reflected on the printed circuit board. The U4L looked nice and was well designed, but the majority of students lacked prior knowledge regarding soldering of small smd components."

6. CONCLUSIONS

This paper presents the use of a new experimental setup for power electronics and electrical drive experiments. The purpose of this study was to explore students perceptions of their user experience with the Universal Four Leg and to present a way of how to implement a setup in a power electronic laboratory training. The U4L is configured to closely resemble industrial appliances that are used in power electronic converters for DC-DC, DC-AC and AC-DC conversion that allows students to learn on an industrial construction that is more close to reality, giving better insight in the working of the appliances via experiments. A set of experiments have been developed that will guide students from theoretical principles, via idealized simulations to measurements. At the end of the laboratory training the student should have learnt the basics of power electronics and are able to simulate, design and measure power electronic systems. And how to use the U4L as a tool in future projects.

Learning by doing is a method where students can learn technical skills using laboratory assignments. The authors expected that the combination of the laboratory assignments and the U4L would clarify the link between theory and practice. Next it was expected that it would increase students interest in power electronics. Feedback on the experience of the laboratory assignments show that students identify the relation between theory and practical application and that this contributed to a better understanding of power electronics. Furthermore, they report that the use of the U4L was stimulating and that they perceive the set-up as realistic. This is in line with the purpose of the authors, since the setup is constructed in the same way as an industrial application it offers students an experience more close to reality. Therefore, it is expected that the level of motivation and satisfaction increases [4]. According to experience-based learning approach, experimental learning requires both thinking and doing which stimulates reflection on the experience. This evokes openness towards new experiences and consequently continuous learning [10]. Moreover, it prepares students to better understand the working of power electronics and electrical drives as typical measurements results are visible, providing students with complete education.

Comments on the current setup also provided suggestions for a change in approach and laboratory setup. Main comments from students were about the complexity of soldering smd components. This resulted in a reduced time for further measurements on the Universal Four Leg. In a next phase, more attention on student's prior knowledge and skills should be taken in account. The experimental setup and equipment is currently being used at the Hague University of Applied Science

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Development of Nuclear Power Plant Basic Principle Simulators as Tools for Nuclear Engineering Education

Sándor Fehér
Institute of Nuclear Techniques, Budapest University of Technology and Economics
Budapest, Hungary

Szabolcs Czifrus
Institute of Nuclear Techniques, Budapest University of Technology and Economics
Budapest, Hungary

János Lőrincz
Institute of Nuclear Techniques, Budapest University of Technology and Economics
Budapest, Hungary

Tamás Varju
Institute of Nuclear Techniques, Budapest University of Technology and Economics
Budapest, Hungary

Attila Aszódi
Institute of Nuclear Techniques, Budapest University of Technology and Economics
Budapest, Hungary

Gyula Csom
Institute of Nuclear Techniques, Budapest University of Technology and Economics
Budapest, Hungary

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ABSTRACT

Our Institute has been developing PC-based nuclear power plant (NPP) basic principle simulators for over 30 years. The main goal of this development is to provide the nuclear engineering education at the university with tools capable to illustrate the fundamental physical processes going on in the primary and secondary circuit of an NPP. The simulators were integrated into our training courses in the last three decades. The firstly developed primary circuit basic principle simulator, PC^2 is still the most often and most widespread used one despite the fact that it was written for old DOS operating system and thus nowadays is of restricted applicability. Therefore, the development of a new PC^2+ simulator started in 2016 based on the training experience accumulated and with support of a national research grant. Its scope of simulation is practically the same as that of the old PC^2 but it has various model extensions and new features. The graphical user interface (visualization/interaction) program module and the simulation model computing module are two separate programs (executable codes) which may run on a single or on two different computers as well. This feature of PC^2+ allows for using it via internet and opens new possibilities both in classroom exercises and distant learning.

1. INTRODUCTION AND HISTORY

The development and use of PC-based basic simulators has a long history of over three decades. The International Atomic Energy Agency plays an important role in coordinating the simulator development work of various universities and research institutions and in organizing the exchange of information. Their regularly organized technical meetings indicate that there is still a significant need for the development of PC-based basic simulators today [1], [2].

In the last three decades, five different PC-based simulators have been developed at our Institute:

- PC^2 – primary circuit basic principle simulator (DOS, 1987-88);
- REMEG – reactor trip analyser (DOS, 1989-96);
- STEGENA – steam generator analyser ('part task simulator') (DOS, 1991-93);
- SSIM – secondary circuit basic principle simulator (MS Windows, 1993-95);
- PC^2 for Windows – primary circuit basic principle simulator with a more complex calculation model (MS Windows, 1997-99);

With the exception of the program REMEG, all the above simulators are related to the WWER-440 nuclear power plant type. Accordingly, they show the fundamental processes, construction and control principles of a PWR with the aid of a WWER-440 as example. The program REMEG, on the other hand, makes it possible for students to study the phenomenon of reactor trip, using the example of the small power Training Reactor of our university.

2. SHORT DESCRIPTION OF OUR SIMULATORS

2.1. PC^2 primary circuit basic principle simulator

PC^2 is an educational tool designed for use in nuclear engineering higher education and nuclear power plant training centers for NPP fundamentals training (FIG.1.). The PC^2 program runs as an interactive and real-time simulator capable to illustrate the control principles and the fundamental reactor-physical, thermal hydraulic processes going on in the primary circuit of a PWR nuclear power plant. Therefore, the simulation model was designed to demonstrate a wide range of primary circuit operations, control of the plant and response of the system to malfunctions. Capabilities include reactor start-up, power range operations and study of xenon-poisoning in accelerated mode.

In order to improve effectiveness of training, PC^2 was furnished with important features. Users can modify program constants, freeze and continue simulation, save simulation history and replay it, restart simulation under the same conditions, choose from real-time/fast-time/slow-time simulation option and make snapshots.

The PC^2 package consists of the software (executable under DOS or in DOSBox under MS Windows) and educational exercises, of which the most important ones are the following:

1) Introductory exercise (a survey, how to use, extent of the model)
2) The effect of reactor physical parameters (delayed neutron fraction, neutron generation time, etc.) on the operational characteristics of the primary circuit
3) The effect of reactivity coefficients (Doppler, moderator temperature) on the operational characteristics of the primary circuit
4) Study of self-control capability and power control system

5) Study of Xe-poisoning from reactor physics aspect
6) The effect of Xe-poisoning on the operation
7) Critical experiment and reactivity measurements
8) Investigation of different operational situations
9) Study of main circulating pumps breakdown transients
10) Study of emergency shutdown, turbine breakdown, etc.

These exercises have become fundamental elements of the courses on nuclear energy at our Institute.

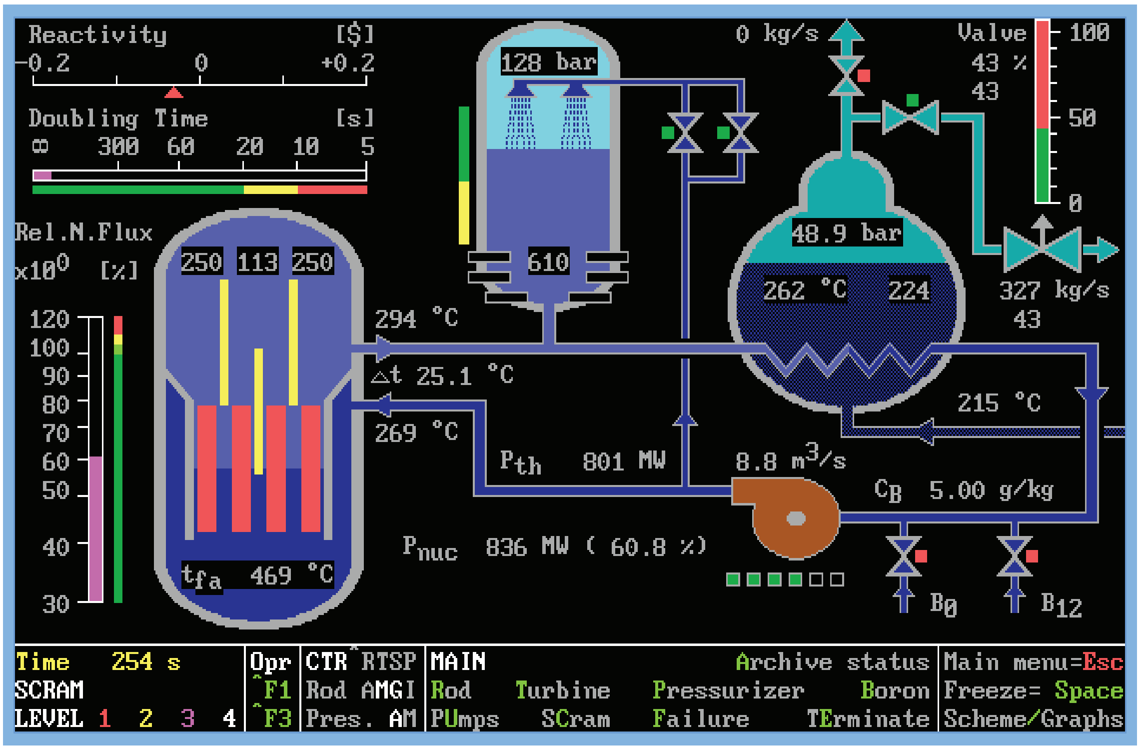

FIG. 1. Primary circuit schema of PC^2 (DOS) simulator.

2.2. Remeg reactor trip analyzer

The program solves the coupled system of point kinetic equation with 6 delayed neutron groups and the equations of heat transfer from the fuel pin to coolant through the cladding for a reactor trip caused by a reactivity insertion. The time dependence of the reactivity insertion can be given as input. The user can modify the default values of nuclear, reactor physics and thermal hydraulics parameters like the effective delayed neutron fraction, moderator and fuel temperature coefficients and their temperature dependence, heat transfer coefficients between fuel-clad and clad-coolant, specific heat of materials and their temperature dependence.

2.3. Stegena part task simulator

The STEGENA can be considered as a simulator/analyzer program ('part task simulator'), using which one can perform detailed studies on the thermodynamic and thermal hydraulic processes going on in the steam generator of a WWER-440 nuclear power plant (FIG.2.). In order to use the STEGENA simulator more efficiently a training program consisting of six student exercises has also been developed.

The simulation model has been designed to demonstrate a wide range of steam generator operation: heat transfer from the primary to secondary circuit, steam generation on the secondary side, feed-water input, steam extraction, measurement and control of the secondary water level.

At the calculation of heat transfer from the primary to the secondary side, heat transfer equations are solved in one-dimension (along the primary coolant tubes), thus the program illustrates not only the time dependence but partly the spatial dependence of the processes, too. This feature is of special importance in making the model more realistic.

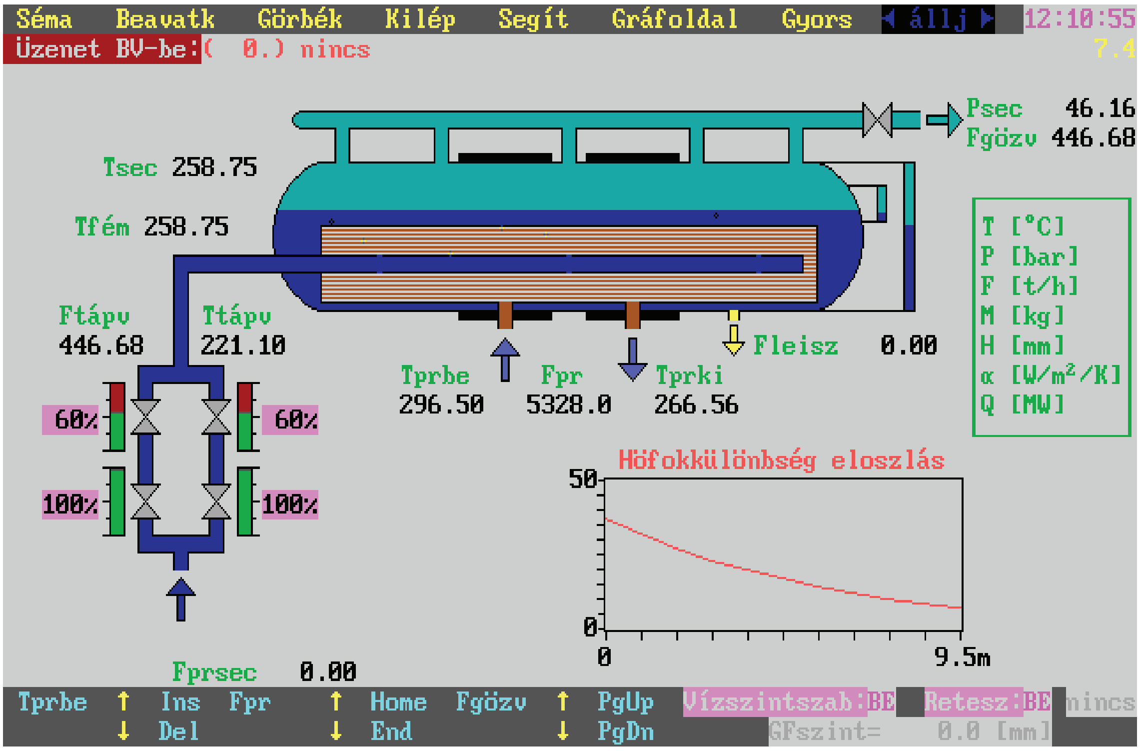

FIG. 2. A schema of STEGENA simulator.

The simulation program allows the user to set the values of some construction parameters of the steam generator, e.g. the inner and outer diameter, the heat transfer coefficient and the number of the primary coolant tubes are all changeable. It is also possible to take into account the fouling, the leakage from primary to secondary side and the leakage originated radioactivity in the secondary circuit.

2.4. SSIM basic principle simulator

SSIM illustrates non-stationary thermodynamic and thermal hydraulic processes of the secondary circuit of a WWER-440 nuclear power plant (FIG.3.). Since the secondary circuit operates with two, practically independent, saturated steam turbines, SSIM models only one of them with the corresponding feed-water system and three steam generators in order to save computing power.

The simulator program allows to study stationary and non-stationary processes as well. During simulation the user can interact with the simulated processes, changing the values of various parameters (e.g. reactor thermal power, turbine load, temperature and flow rate of the condenser circulating water, etc.) or initiating failure of different components (e.g. condensate-pumps, feed-water pumps, high pressure feed-water pre-heaters, re-heaters, moisture separators, etc.). The model is extended to simulate the control systems of the water level in the condenser sump, feed-water tank, steam generators and control of the turbine for-pressure.

Detailed schemes illustrate the structure and important process parameters of the main components. The thermodynamic characteristics of the fluids in the main components are visualized by auxiliary diagrams.

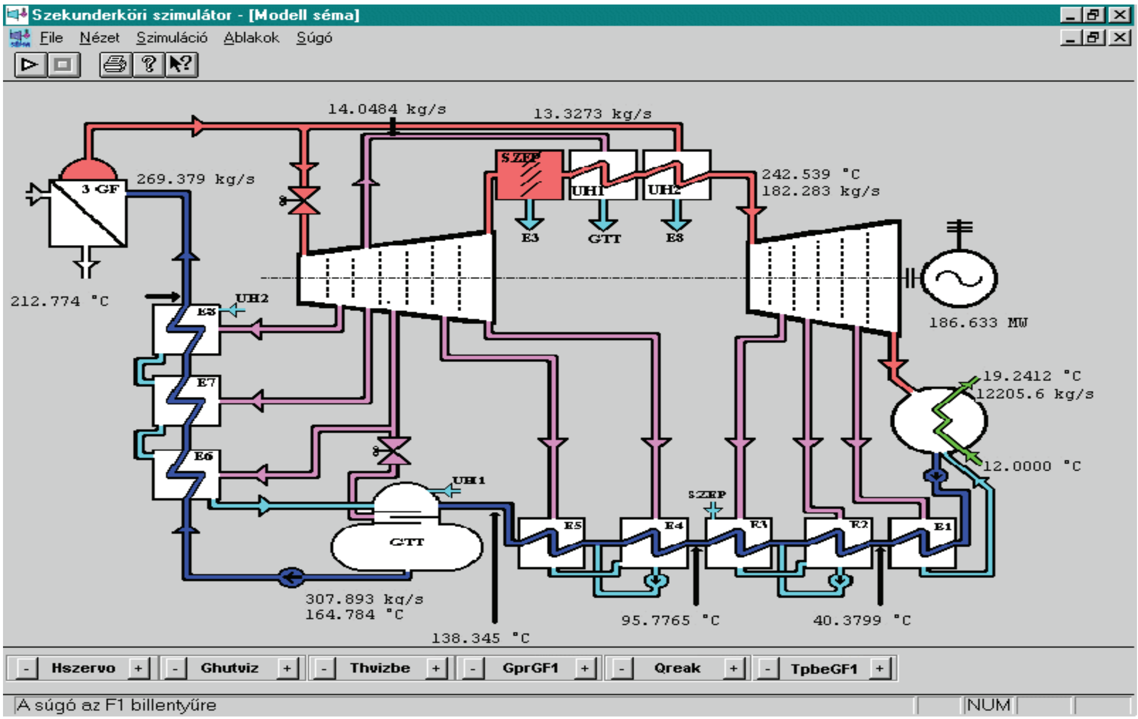

FIG. 3. A schema of SSIM simulator.

In order to make effective use of the SSIM simulator program, the SSIM package includes a detailed model description and a training program consisting of 10 different student exercises.

2.5. PC^2 for Windows basic principle simulator

'PC^2 for Windows' is an improved version of the original PC^2 primary circuit basic principle simulator with a more complex model (FIG.4.).

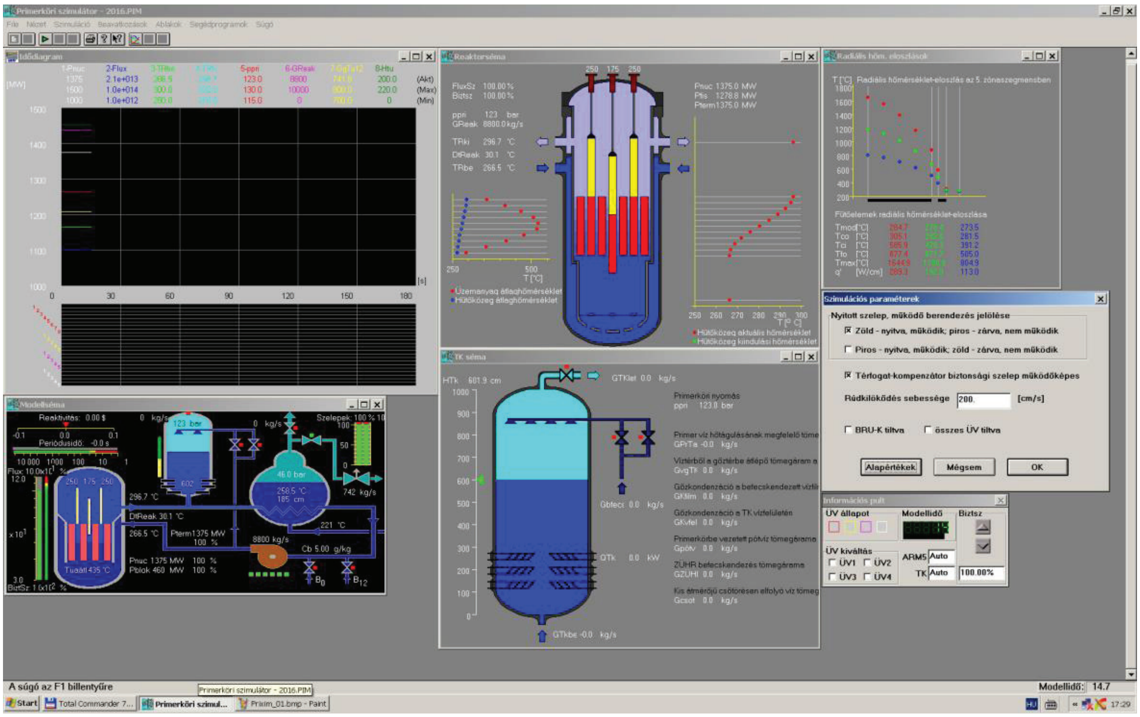

FIG. 4. A screen using 'PC^2 for Windows' simulator.

Most important features of the renewed simulator are the following:

- six primary loops are modelled separately (accounting for the interactions), with the main circulating pumps and steam generators;
- the loops are modelled by dividing the primary circuit to 84 control volumes;
- more realistic modelling of the main circulating pumps;
- thermal hydraulics modelling of the primary coolant and of the steam-generators can account for the reverse flow in case of pump failure;
- natural circulation is modelled correctly in case of drop of all pumps;
- pressurizer phenomena are modelled using non-equillibrium thermal hydraulics.

Separate windows illustrate the structure and process parameters of the main components. There are also several diagrams showing the thermodynamic characteristics of the main components to help the understanding of ongoing phenomena.

3. INTEGRATION OF SIMULATORS INTO EDUCATION

The mentioned simulation programs have been integrated into the training courses of our Institute. Normally the programs are used in a computer lab course of some nuclear topic. Most of the students encounter the simulators three to four times during their studies, each occasion being approximately four hours long. For many years, a course named 'NPP simulation exercises' was organized, every occasion of which was dedicated to computer simulations. Nevertheless, during this course not only our self-developed simulators but other computer programs, such as ANSYS CFX and APROS were also presented. At the beginning of the 2000s, a course named 'Simulation methods' was held four times. In frame of this course, students had the chance to learn from the experiences obtained during the development of the simulators.

In accordance with the above facts, a large amount of experience on both the development and application of simulators have accumulated at NTI in the last two decades. One may consider strange that even today the most often and most widespread used simulator is the one developed first, i.e. the PC^2 primary circuit simulator. Most probably this fact has been caused by two circumstances. On the one hand, the calculation model of this simulator is practically analogue to the volume of knowledge presented during the lectures on reactor physics (theory) and thermal hydraulics. On the other hand, the user interface is simple enough so that students can learn it very quickly and thus they may gain interesting simulation experience and new knowledge even during a single 4-hour-long exercise. With more complex tools, such as the simulator 'PC^2 for Windows', getting to know the controls properly may take several hours. Therefore, such tools can only be used for longer courses (which span several occasions). Another intelligent trait of this simulator is that the graphics screen representing the time behaviour of physics quantities is very easy to understand due to the well thought–out ergonomic design.

4. RENEWAL OF BASIC PRINCIPLE SIMULATOR PC^2

The basic principle simulator PC^2, which is used most often at our Institute, was developed in DOS operating environment and in Fortran source code in the second half of 1980s. The renewal was absolutely necessary since today it is practically impossible to run such programs on modern, mostly 64-bit architectures without functional errors.

A plan for the renewal was developed about a decade ago. Nevertheless, the actual work was only started at the end of 2015 in frame of the National Nuclear Research Programme supported by the National Fund for Innovation and Development. The renewal is practically equivalent to fully replanning and recoding the program.

4.1. State of new PC^2+ development

The simulators model and graphical user interface are two separate programs (executable codes), which may run on a single or on two different computers. Their basic development has just been finished and tested, but we plan to continue it with further features. The current state is illustrated on FIG. 5-8.

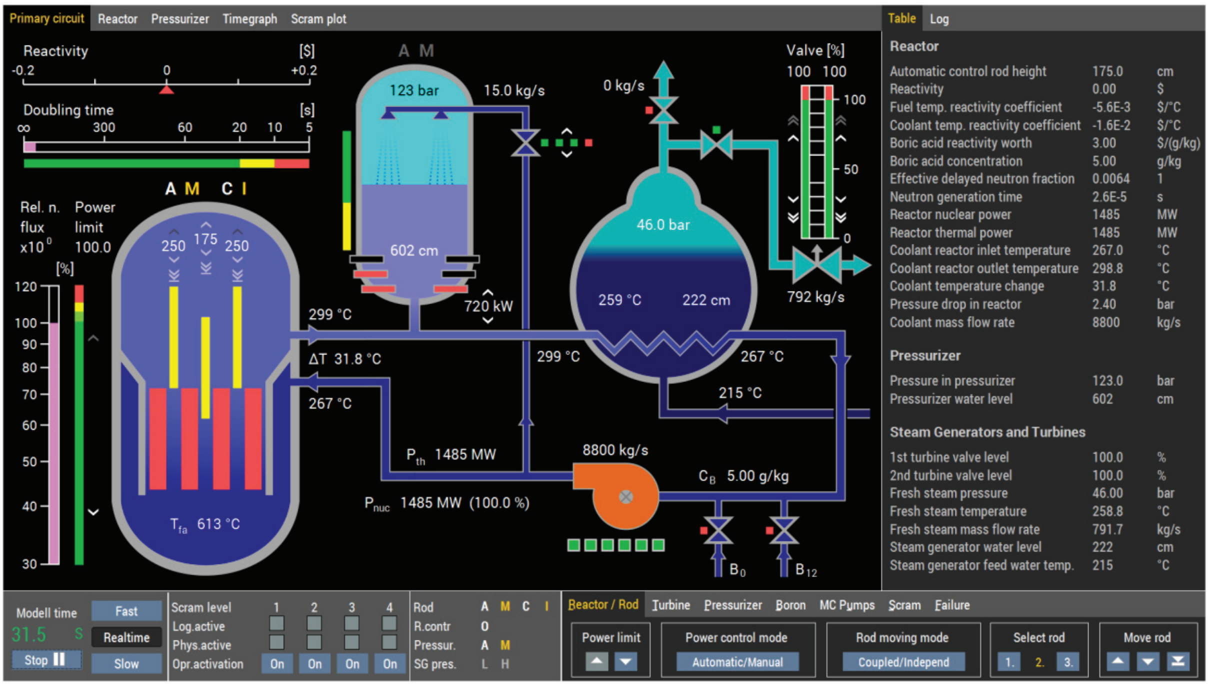

FIG. 5. Primary circuit schema in the new PC^2+ simulator.

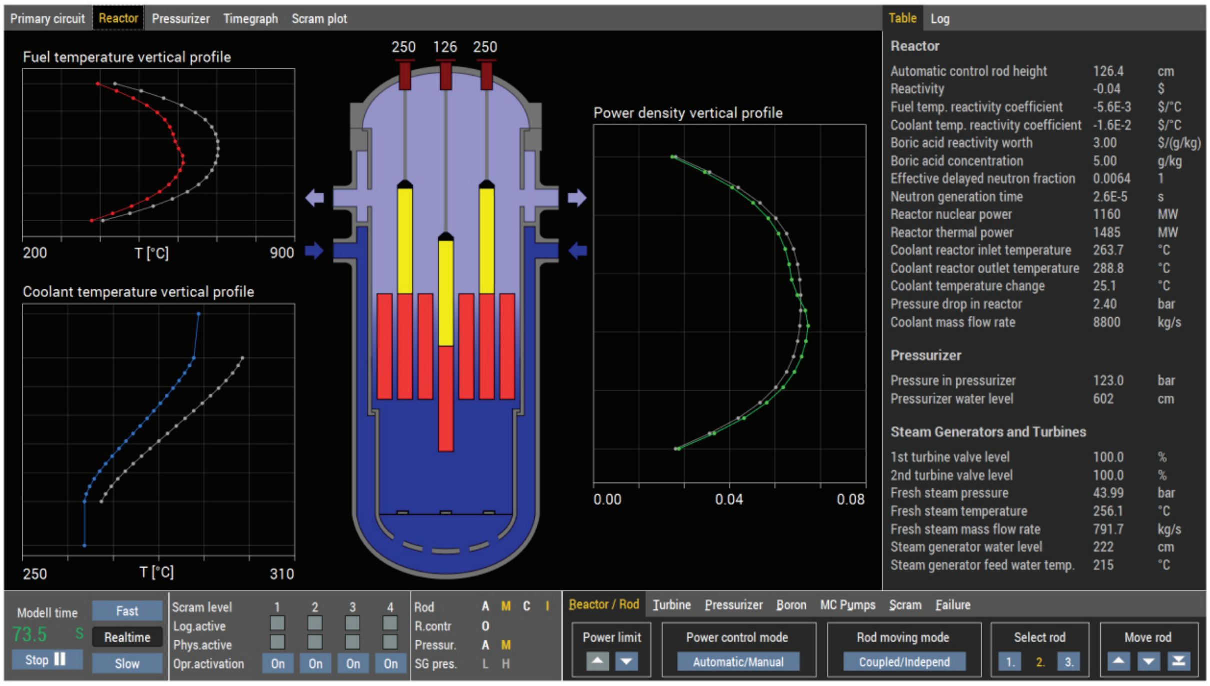

FIG. 6. Reactor schema in the renewed PC^2+ simulator.

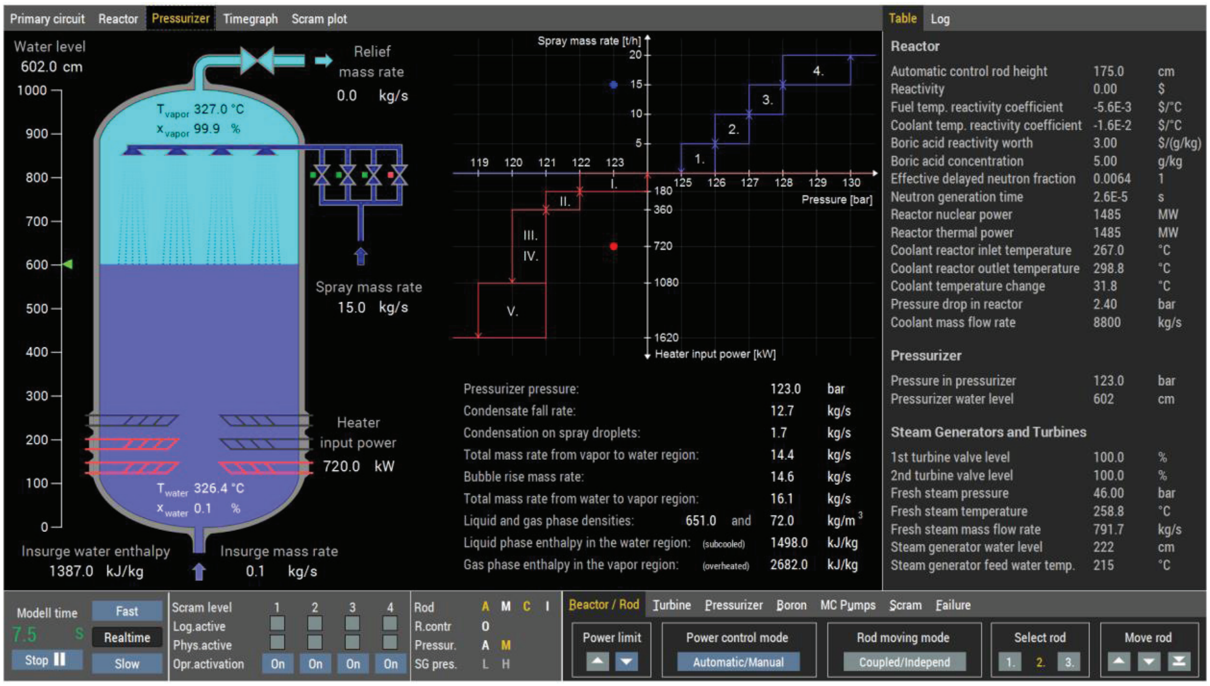

FIG. 7. Pressurizer schema in the new PC²+ simulator.

FIG. 8. Timegraph screen in the new PC²+ simulator.

There are five main schemes on the upper left side, one of which illustrates the whole primary circuit (FIG. 5.), the next two show the more detailed structure of the reactor vessel (FIG. 6.) and the pressurizer (FIG. 7.) with their most important parameters, while the last two contains time diagrams of seven parameters selected from more than 300 calculated (modelled) quantities (FIG. 8.) and all the scram signals. On the right side of the schemes, users can keep track of the chosen quantities or the simulator logbook. Finally, there is a control panel at the bottom of the screen with the model time, scram signal and state indicators, and the control buttons. Action buttons are placed not only on the control panel but on the primary circuit schema as well.

4.2. New capabilities of PC^2+ for education

The new simulator has many useful features for education, most of which have already been implemented, while the others are under development.

One of the most important virtue is that the graphical user interface program module and the computing module are two separate programs (executable codes), which may run on a single or on two different computers as well (in the second case, TCP/IP network connection must exist between the computers). There is fast, message-based communication between the two program blocks. This feature of PC^2+ opens new possibilities both in classroom exercises and distant learning.

In conventional cases (both program modules run on a single computer), students can run their own simulation and control the system independently. However, the ability to run the modules on different computers allows several new ways of use. Three examples are the following:

- The calculation model runs on the instructor's computer, while each student can connect to it with their user interface as a viewer and follow the instructor's explanation.
- The instructor is able to intervene in a simulation on one or more students' computers by causing an unexpected (and occasionally hidden) minor malfunction that the student has to recognize and try to handle.
- A future plan is to make the user interface module downloadable for our students through our web page. The calculation model would run on a server computer, while each student could connect to it from home with their downloaded user interface and run their own simulation. It would give them the opportunity to practice as much as they want.

Simulations run originally in real time, but they can be accelerated or slowed down, which is quite advantages during the analysis of a short or long transient. It is possible to make a snapshot of the current state and return to it later. This feature gives students the opportunity to retry to solve a given problem as many times as they need. Instructors can also save the data of a whole transient to a file, and replay it later for the students. A unique feature of our simulator is that this replay could also be stopped at any point and continued as a normal, interactive simulation. It gives instructors the opportunity to run and save a complicated transient in advance and let the students cope with the situation at a given point during the course.

The scope of simulation of new PC^2+ simulator is practically the same as that of old PC^2. At the same time, the new simulator has various minor model extensions and new features compared to the old program, most of which are of didactical importance:

- now the simulation can take into account the dependence of vertical power profile on the burnup;
- the neutron flux depression effect caused by the control and safety rods is modelled;
- the remnant heat power is now modelled with a more accurate scheme;
- for modelling reactivity feedbacks two, and for modelling boron worth three (more and more complex) levels can be selected.

4.3. Pedagogical techniques to utilize PC^2+ for various levels of education

In some cases, parts or functions of the simulator may be too difficult to understand for students at lower levels of education. For such cases, it is considered very important that certain functions of the simulator can be turned on or off, depending on the level of education. In this way, the instructor can adjust the amount of information to convey during the training session to the course participants.

As an example, the temperature dependence of reactivity coefficients may be mentioned. In courses/training sessions short of time, constant coefficients (in lieu of the temperature dependent ones) may be used, depending on the consideration of the instructor. If the timeframe of the simulation lab allows, students may also be given the task to design and perform "measurements" on the simulator to determine the temperature-dependence of the fuel and moderator temperature coefficients. The shapes are linear, so they need to determine a total of four parameters, while these coefficients simultaneously affect the transient.

PC^2+ is primarily used for education and not for operator training, so it was considered admissible to plan and construct a computational model that allows the user or instructor to set unrealistic values for some specific parameters. It gives them the opportunity to demonstrate important physical phenomena and security principles that would be more difficult or impossible with a full-scope simulator. An example is to set the fuel temperature coefficient to zero ("turn off" the Doppler effect) or the moderator temperature coefficient to positive. Instructors can illustrate with these settings the crucial role that the reactor's inherent self-regulating ability plays in a pressurized water reactor. Students also like the difficult challenge to raise the reactor power from 70% to 100% with the above described, unrealistic reactivity coefficients.

Another speciality of the simulator is the ability to turn off certain levels of the safety systems to study unusual nuclear power plant situations. For example, the possible consequences of a failure of the reactor shutdown system may be illustrated by disabling it. Earlier versions of PC^2 also had such capabilities, but a better thought-out, more advanced logic was built into the new PC^2+ to turn the safety systems on and off.

The above described new capabilities of the simulator can only be effectively exploited with sufficient depth and scope of documentation and user manuals. According to the replanning and recoding, the quality and details of the documentation have increased considerably. It is planned that eight diverse manuals for exercises with the new simulator will also be developed.

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EOLES Course, 4 years and going…results and experiences.

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Porto, Portugal

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University of Limoges
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Conference Key Areas: Open and online teaching and learning, Fundaments of engineering education: mathematics and physics

Keywords: E-Learning, Engineering Teaching, Remote Laboratories, Online Course

ABSTRACT

The EOLES (Electronics and Optics e-Learning for Embedded Systems) course consists of a 3rd year Bachelor degree that relies exclusively on e-learning and remote laboratories, developed as the result of an EU funded ERASMUS+ project, involving 15 institutions from four European and three North African countries and concluded in 2015. The developed course was accredited as a specialization year in most partner institutions and has been running non-stop since then, mainly with students from North African institutions. Although no longer supported by an EU project, the course is a good example of sustainability as it already had 4 effective editions with successful approval rates and always with many more candidates than available vacancies. This paper presents an overview and overall results for this initial period and a more detailed analysis of the Digital Systems Teaching Unit. The focus is on the course specific characteristics and features, student and teacher experiences and the methodologies that were applied to enhance learning results. Although being a fully online course, several synchronous activities and communication tools are included in the methodology to enhance student and teacher iteration and also to provide an impartial grading process, as required for accreditation. The course expositive material is provided as the student progresses, with progressive unlocking of content depending on each teaching unit timeline, and automatic quizzes results. In short, students are allowed and encouraged to adjust their learning rhythm within the limits allowed by time restraints and evaluation criteria.

1 INTRODUCTION

The preparation of the degree had into account the characteristics of the target students and the national priorities defined by Maghreb governments for the development of higher education in advance engineering fields. Training is entirely conducted in English, allowing students to substantially improve their English skills, a fundamental tool in technological areas where the information, being it study materials or manufacturers' data, is only available in this language. Therefore, candidate students would have to have a minimum English level evaluated through a TOEIC or a TOEFL test or equivalent, recognized by the different partners of the consortium.

The degree is fully delivered on-line using e-Learning 2.0 [1][2] synchronous and asynchronous tools, allowing students to be part of a "virtual learning community" and empowering teamwork, even if the team members are far apart. An innovative remote laboratory based on virtual experimentation and modelling and simulation platforms, and on remotely operated real instrumentation equipment installed in different universities was used by students to acquire essential practical skills.

Degree accreditation is still a major requirement for course validation and recruitment. This is a major advantage of the EOLES course and with particular interest to its main target group. The degree was recognized by the educational authorities of France, Morocco and Tunisia. As a result, all successful students receive a diploma recognized inside the European Higher Education Area (EHEA). Another important aspect was that the curriculum program should allow graduated students to later apply for postgraduate degrees in any other University. Therefore, all students from Morocco and Tunisia will receive a Joint Diploma issued by the University where they are enrolled in their own country and by the University of Limoges.

2 THE EOLES DEGREE

2.1. Organization

The program was defined in cooperation with the North African Universities participating in the project, considering the priorities defined by their countries' governments. The program's focus on electronics and optics for embedded systems responds to the current tendency for integration of hardware/software into single reconfigurable platforms and to the increase on the amount of data produced and transferred requiring high-speed optical transmission, and to the need of training highly qualified professionals able to keep their countries' pace with these new technologies. The program is divided in fourteen technical units (TUs) and in three optional units, as presented in Figure 1. The TUs are divided in two semesters and the detailed content of each one of the TUs is available in the project website [3]. The degree runs for 31 weeks, plus 3 weeks reserved for examinations – one in the end of the first semester, another one in the end of the second semester, and a last one in the final week of the course for make-up exams.

The Learning Management System (LMS) that supports TU organization, materials' access and delivering, on-line assessments, virtual and experimental lab access, tracking and reporting, forums and chats and all other course related activities was initially based on a Moodle 2.7 version platform [4], since then upgraded to version 3.5 for the 2018/19 edition.

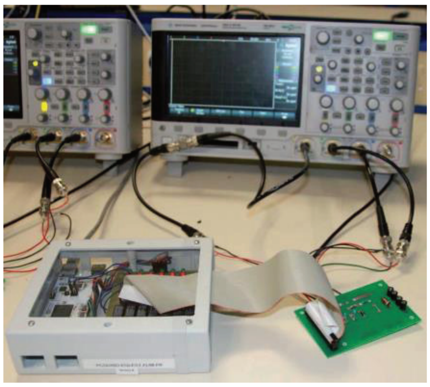
			L3-EOLES			
2017	September	18/09-24/09	Registration & Account creation			
		25/09-01/10	TU 01			SEMESTER 1
		02/10-08/10	Introduction to Virtual	Update in Electronics		
		09/10-15/10	Learning Environment	TU 02		
	October	16/10-22/10	TU 03	Mathematics and		
		23/10-29/10	Communication	Analysis Tools		
		30/10-05/11	Techniques in English	for Physics 1		
		06/11-12/11	TU 04	TU 06		
	November	13/11-19/11	Analog Electronics	Wave and		
		20/11-26/11	for	Propagation		
		27/11-03/12	Embedded Systems	for		
		04/12-10/12	TU 07	Embedded		
		11/12-17/12	Power	Systems		
	December	18/12-24/12	Electronics	TU 05		
		25/12-31/12	HOLIDAYS			
2018		01/01-07/01	HOLIDAYS			
		08/01-14/01	for	Digital Electronics		
	January	15/01-21/01	Embedded	for		
		22/01-28/01	Systems	Embedded Systems		
		29/01-04/02	Revisions			
		05/02-11/02	Exam week of the first semester			
		12/02-18/02		Update in Optics		SEMESTER 2
	February	19/02-25/02	HOLIDAYS			
		26/02-04/03	TU 09 - Mathematics and Analysis Tools for Physics		Jury S1	
		05/03-11/03	TU 10 - Signal Processing			
		12/03-18/03				
	March	19/03-25/03	TU 12 - Optics for Embedded Systems			
		26/03-01/04		TU 11		
		02/04-08/04	TU13 - Embedded Systems			
		09/04-15/04		Instrumentation		
	April	16/04-22/04				
		23/04-29/04	Revisions			
		30/04-06/05	Exam week of the second semester			
		07/05-13/05				
	May	14/05-20/05				
		21/05-27/05	Internship			
		28/05-03/06				
		04/06-10/06				
		11/06-17/06				
	June	18/06-24/06				
		25/06-01/07				
		02/07-08/07			Jury S2	
	July	09/07-15/07	Second session exam			
		16/07-22/07			Final Jury	

Fig. 1. TU listing and schedule (17/18 edition)

2.2. Remote Laboratories

An effective practical innovation of the L3-EOLES degree are the remote laboratories used to perform on-line practical works. A multi-user approach is implemented allowing a group of students to work and interact in real time over the same Practical Work (PW), guaranteeing a strong collaboration among them during the training. Each hardware setup (function generator or oscilloscope, for instance) is connected to the internet. From each TU's Moodle page students have access to the related lab's webpage and to the TUs' proposed lab works. Students are able to change the hardware configuration in real-time and have an immediate feedback of their actions, via the virtual instrument interfaces that are deployed remotely and through a high-definition camera (or another interface).

Figure 2 shows one of those lab setups using internet-controlled instrumentation and a camera and Figure 3 shows part of the user interface. This enables students to see what is going on the real lab and how the real instruments react to their remote commands. This feedback is important for students to be sure that the interface they are seeing in their own monitor is not the visible face of a virtual world but the virtual interface of a real instrument.



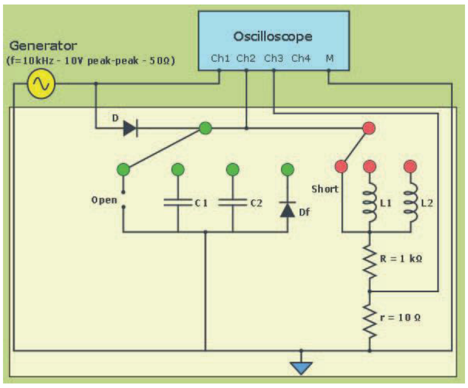


Fig. 2. Remote Laboratory Setup *Fig. 3.* Remote Laboratory Interface

The remote laboratory is expected to have a substantial learning impact as each student or group of students have the possibility of repeating the same experiment several times and trying different configurations in a controlled and safe environment. These remote laboratories are used in subjects where the real equipment is more important and were presented and demonstrated on several technical events [5][6]. In some TUs those online labs are replaced or complemented by simulator tools or remote access to advanced software tools.

2.3. Assessment and Grading

The EOLES degree follows the French university assessment system with some adaptations. Grading is made on a 0-20 scale, where 10 is the passing grade. Each student is required to have an average of 10.0 or more at the year's end for successful graduation, being possible to have less than 10 on any individual TU, although no grade can be below 5. At the end of the year, there is a final recourse exam, where each student can try to improve his grades on any specific TU in order to achieve passing results. Students that fail to graduate at years end, can repeat only part of the degree (where the failed to achieve a passing grade) on the following year. On each individual TU the grade is composed of three components, namely: (1) mandatory practical works or assignments; (2) an one-hour on-line exam held at the end of each TU; (3) a two-hour final exam held by the semester's end is worth 50% of the TU's final grade.

The on-line exam is designed to allow the students to consult any technical or pedagogical resource they deem necessary, therefore having a strict time limit and requiring students to be online and visible (through webcam) during the entire exam. The final exam is performed at a university room on a scheduled date, requiring the students to be physically on the same space and under staff supervision during the duration of the exam. A bonus between 0 and 2 points could be attributed at tutor's discretion to each student according to his/her level of participation in the synchronous sessions, forums and live chats. The specific weight of the grading components can be adjusted by each TU staff, varying between 20% and 35% for components 1 and 2 and 40% and 50% for component 3. The higher weight of the final exam being mostly due to the more controlled environment which provides a fairer grading.

3 DIGITAL ELECTRONICS TU

3.1 Organization

To better illustrate the degree, we will present and discuss the pedagogical solutions implemented on TU05-Digital Electronics for Embedded Systems. The proposed framework was similar in all TUs, but some implementation adaptations were required as the subjects and difficulty levels are considerably different in some cases.

In TU05 the lectures consist of a set of 21 pre-recorded asynchronous classes with a duration never exceeding 20 minutes, where an instructor explains the theoretical basis of a subject supported by different types of visual materials as illustrated in Figure 4. Most classes relied on PowerPoint slides presentation, recorded as online videos, with the teacher image superimposed and several visual aids (arrows, circles, etc...) used to illustrate key points. When required the classes also used external links and access to simulated equipment. The classes are interspersed with self-evaluation quizzes, composed of multiple-choice, fill-in-the-blanks, matching exercises. These are intended to keep students' interest and attention, breaking long expositive classes and have no weight on the TU grading. Additionally, these self-evaluation questions provide students with an immediate feedback about their degree of understanding of the subjects being taught. A Quiz example is presented in Figure 5.

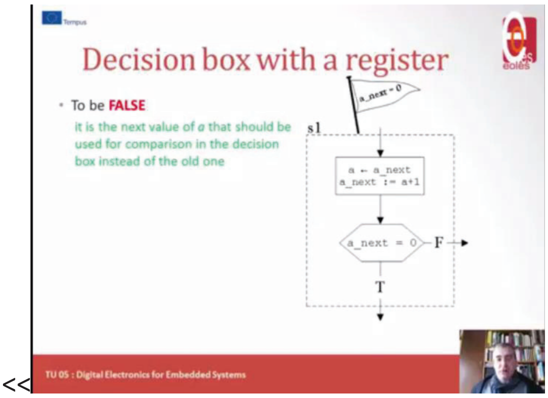


Fig. 4. Synchronous Class

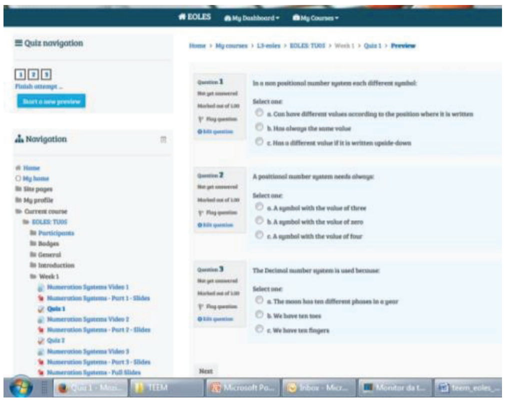


Fig. 5. Self-Assessment Quiz.

Students can progress at their own pace, viewing or reviewing this visual material anytime, any number of times, without restrictions. However, the student can only proceed to the next lecture after the successful completion of the self-evaluation questions associated to the previous one. A range of other materials is also available to support the study, including companion books freely downloadable from Internet, web links to other sites containing specialized information and other complementary data, depending on the TUs subject.Tutorial classes are synchronous classes based on the use of a web conferencing tool. Their aim is to enable students to clarify any issues and ask questions related to the content of the TUs. These classes are also recorded, and the records made available to students. During the synchronous classes tutor and students are required to have their cameras on. The aim is to have a visual feedback of the whole class making students feel part of a group and be able to interact not only with the tutor but also among each other.

4 RESULTS

4.1 EOLES Degree

The number of applicants on all degree editions largely exceeded the expectations, albeit and the number of vacancies were highly concentrated in one of the EOLES partner countries (i.e. Morocco). Each edition also included lifelong learning students that enrol already planning to take 2 years to conclude the degree and also repeat students, which try to make the remaining TUs in order to graduate. Interestingly, the last editions also included a few students with geographic origins outside the Maghreb countries (i. e. Canada and Spain) which illustrates the interest and demand for this type of courses worldwide. Table 1 presents the number of students that were enrolled in the degree, those that finished (were present at the final exam) and the approval rates, defined as the number of approved students compared with the number of students that finished the course (attended the exams) or the number originally enrolled, respectively.

Table 1. EOLES Degree Results

EDITION	ENROLLED	FINISHED	GRADUATED	APPROVAL	
14/15	25	21	11	52%	44%
15/16	32	26	21	81%	66%
16/17	37	34	26	76%	70%
17/18	27	22	19	86%	70%

The results are very satisfactory, proving that the issues present in the first edition were sorted and an adequate success rate was achieved. It should be noted the degree is deemed as challenging and requiring effort equivalent to a normal 3rd year degree in a French University, hence the adequacy of the presented success rates. Even so, failure to graduate is always analysed and three main reasons were identified, namely (1) abandonment of the degree for personal reasons (usually professional); (2) inability to complete some specific TU due to lack of previous knowledge or lack of adequate effort; and (3) language problems, albeit having prior English knowledge attested by their TOEFL certificates.

The effectiveness of the use of virtual and remote laboratories in e-engineering courses was demonstrated by an extensive study published by James Brinson [7] and by our own experience after four L3-EOLES editions [8]. As to the effectiveness of the learning environment, several non-quantitative conclusions were possible from the first years' experience, namely: (1) Students are more used to interactive classes, preferring those as an initial approach. This solution is feasible for simpler subjects; (2) Recorded classes are a much more time efficient way to deliver complex subjects, as they allow the students to study and repeat at their own pace; (3) Interactive classes are required to clarify doubts and answer questions. The use of recorded classes is not a complete solution to most students; (4) Student participation in interactive classes is very diverse, requiring the teacher to be proactive; (5) Additional asynchronous resources (forums, emails) are often preferred by some students, namely when lacking communication skills (e.g. English language)

The practical assignments were a mixed experience. In some TUs the experiments were simpler and direct, with the assignment being the best grade of the students. On others, the assignments were more complex and was frequent that some were not even executed by the students (with the negative effect on the final grade) and several works being obviously rushed by the students. There was also some need to analyse the uniqueness of the delivered reports, as the online character of the course sometimes promoted the sharing of results between students. The online exams usually present much better grades that the final exams, as was to be expected, and showing that some type of attendant assessment is still required for a fairer grading.

4.2 Digital Systems Technical Unit

In the particular case of TU05, the results were in general good, with approval rates of more than 80% every year and average grades above 12,5. The online quizzes to get access to content are a key feature of this TU and allowed some specific conclusions. Students would sometimes require several attempts to progress, some had to review the online classes after failing a quiz and others posted their doubts in forums or sent messages to the teachers. These actions were monitored using the Moodle logging functions, and show the quizzes working as intended, promoting interactivity and the need for seeking additional information.

The synchronous classes were not used to present new subjects, although several times it was necessary to clarify and repeat issues presented on recorded classes, as some doubts remained. Participation was very variable, with between 25 and 80% of students present as viewers. However, video and audio participation were limited, with a few students being responsible by the majority of questions and discussion. A very important feature was the ability to share documentation and visual aids, as several questions required the discussion and revision of available materials.

In this TU, most grades were above the 50% mark, confirming that the TU subjects were adequately delivered. The examination results were better than assignment work results, by a considerable margin in several cases, due to somewhat tough learning curve of the high-end software being used on assignments [7]. Nevertheless, this experimental work is deemed as a vital learning resource and every year the documentation and support is improved.

4.3 Degree Assessment

At the end of each EOLES edition students are asked to fill a compulsory anonymous questionnaire with 8 questions, for each individual TU, in order to assess the degree, as perceived by the students. The following figures present the questions and their answers for the last edition analysed (2017/18), with some comments to better present the results and their relationship to previous editions.

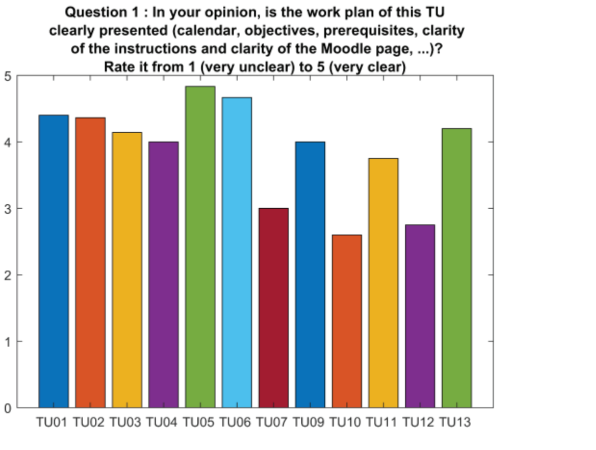


Fig. 6. Question 1

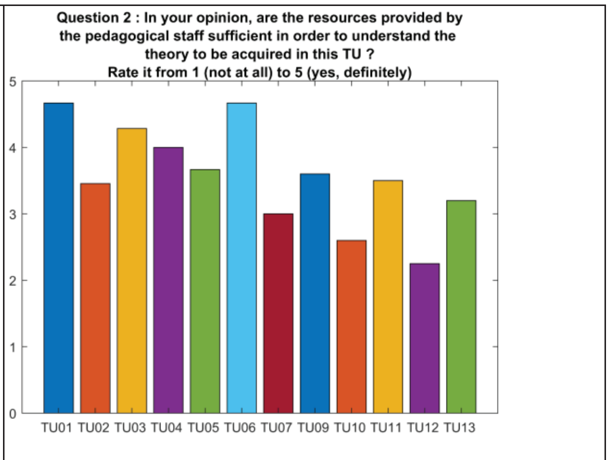


Fig. 7. Question 2

From the first 2 questions it can be derived that the overall presentation of the degree and the available resources is mostly adequate, as perceived by the students. There are a few TUs that can be improved on this regard and efforts have been made in that aspect. There is a steady improvement since the first edition, although some subjects are still difficult to convey on a format that is well accepted by the students. This type of analysis is important, and the teachers of the different units often use the comparative analysis for mutual benefit.

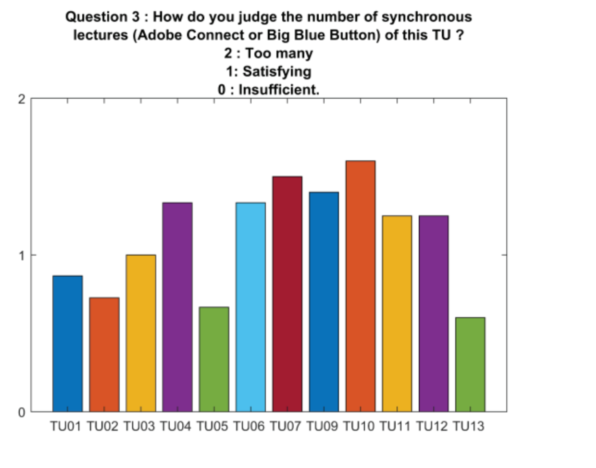


Fig. 8. Question 3

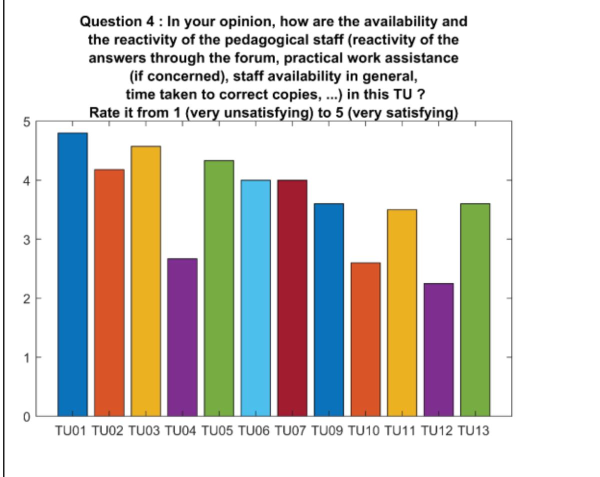


Fig. 9. Question 4

From questions 3 and 4, we can see that the number of synchronous sessions is always a reason for debate. It should be remembered that in the 2 years prior to the EOLES degree, students' study in "standard" presential university classes, and the transition to online courses takes some adaptation. In all editions of the EOLES degree it is necessary to educate the students on the remote, web-based and asynchronous formats and tools, and the need for independently consulting the available resources. Even so, the staff is rated highly in its availability and reactivity, showing that that is not the root of the problem. Students are simply used to normal classes and one year is not enough to change the paradigm. This can also be confirmed by the results from lifelong students (and partially confirmed by repeat students) that show an obvious improvement on the second year.

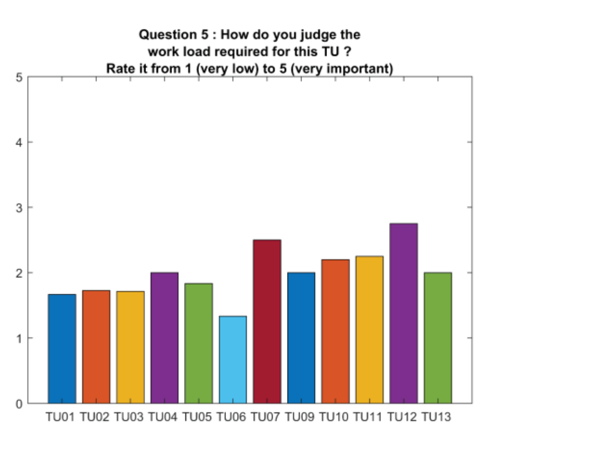


Fig. 10. Question 5

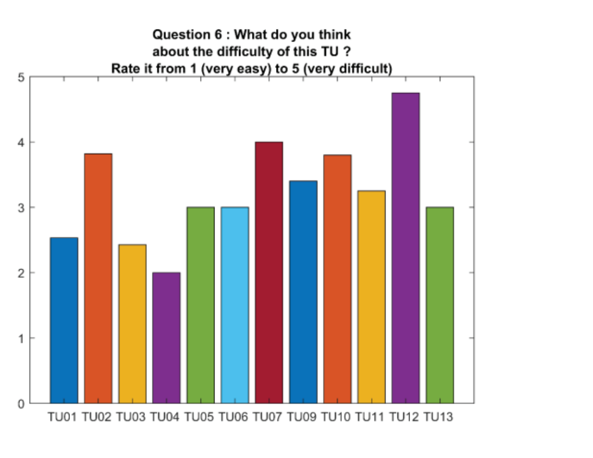


Fig. 11. Question 6

By the analysis of questions 5 and 6, the workload and difficulty of the TUs is considered adequate by the students, which usually are very candid when comparing that information with the final results. Their usual rationale is that the less good results are often due to the lack of time or effort invested by themselves, particularly on the harder TUs, with some mentioning high temporal requisites. There is an initial adaptation where the students need to realize the time, they need to invest is the same as a presential degree, but managed more autonomously, which is not always perceived adequately in due time. Most students adjust quickly during the year.

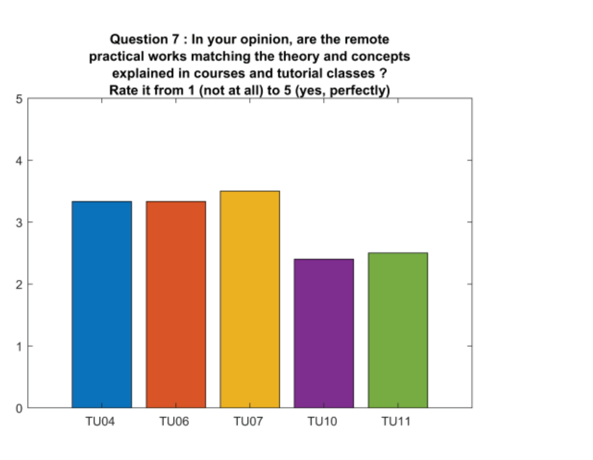


Fig. 12. Question 7

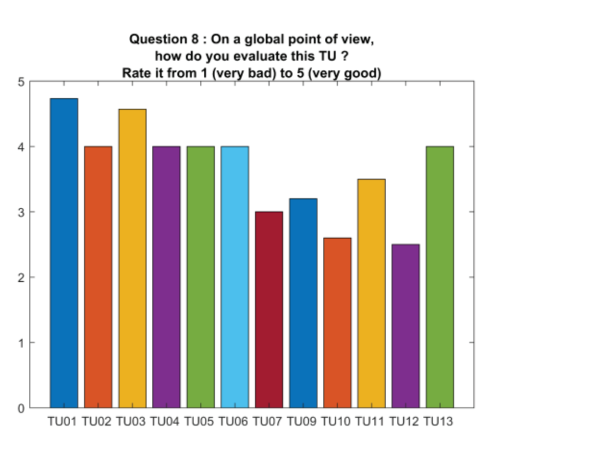


Fig. 13. Question 8

The remote experimentation results are adequate, but still show a visible difference toward the overall satisfaction. This shows that considerable work is still necessary on this area and is one where most of the improvements are planned and introduced on each EOLES edition. It is still hard to achieve remotely the same level of immersion and practical experience as possible on real labs, and the student's answers show this. Overall, the EOLES is positively assessed by the students and the retrieved data is constantly analysed in order to improve it. The evolution of student assessments (not presented in detail due to space constraints) show an overall steady improvement over time, and also some fluctuation between TUs and editions which usually relate with adjustments on the teaching resources and methodologies of each TU.

5 CONCLUSIONS

The EOLES degree is a successful example of a practical and useful outcome from an EU ERASMUS+ project. It represents a sustainable and accredited online degree that achieved a high level of maturity as a result of its 5 years of operation. The experiences and results are very interesting, and it also represents a testbed for this type of environments. The experience gained from the development of this degree is being used as a base of an ongoing ERASMUS+ project [10], where it is intended to develop a set of practices and methodologies to be used in the implementation of other online courses and laboratories in general, but with particular attention to engineering degrees. The overall experience of the teaching staff is extremely positive and allows for a permanent improvement of the teaching process. There are new challenges on each edition, and it is necessary to keep improving and evolving in order to keep up with the technological advances and the student's expectations.

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An Innovative Course In Calculus
To Motivate STEM Students in their Mathematics Studies

Benedek FORRAI
Budapest University of Technology and Economics,
Institute of Mathematics, Department of Geometry
Budapest, Hungary

Bence SIPOS
Budapest University of Technology and Economics,
Institute of Mathematics, Department of Geometry
Budapest, Hungary

Brigitta SZILÁGYI
Budapest University of Technology and Economics,
Institute of Mathematics, Department of Geometry
Budapest, Hungary

Conference Key Areas: Fundaments of Engineering Education: Mathematics and Physics; New Notions of Interdisciplinarity in Engineering Education

Keywords: Mathematics, Applied mathematics, Programming, Calculus

ABSTRACT

For STEM students, gaining an intuitive and deep understanding of mathematics is critical, because only then will they be able to successfully integrate it into their own field of study. The main obstacles of this are lack of motivation to learn mathematics, and students not being used to apply the gained knowledge. To discover solutions to overcome the presented difficulties, we developed a new program as a non-mandatory part of the Mechatronics and Energetics BSc courses at TU Budapest. Our aim is to augment the Calculus II. course in a way that accelerates the ability of application and motivates the students in gaining better understanding of mathematics. In the new course, we follow the fields taught in Calculus II., and help the students in understanding the most important concepts by looking at them from new, graphical perspectives. We also encourage them by discussing applications related to their field of interest – for example robot kinematics or neural nets. We test their knowledge by mini-quizzes, three homework assignments and one group project. The innovative course is of a great popularity – while being non-mandatory, 53 students applied, and the attendance rating is exceptional. Students complete assignments on time and are eager to work on their projects. In our concept paper, we will discuss the methodology and outcome of the course. In our experience,

applying this concept would be very beneficial for all STEM students, so we are planning to develop the equivalent of the course to augment Calculus III. as well.

1 INTRODUCTION

1.1 Challenges of Mathematics education at TU Budapest

In recent years, the students accepted into our institute tend to be very inhomogeneous in their mathematics skills. This poses a great challenge to us, as there is no opportunity of differential training or talent management in the strict timeframe of the curriculum. Furthermore, while being very varied in terms of talent, undergraduates of every skill level are harder to motivate than before - students often neglect progressing in mathematics, because they are not getting the instant gratification of building useful systems, which engineering undergraduates tend to look for. To counter this effect, our institute launched a new project in the spring of 2019, aimed at motivating the students to dig deeper into mathematics by new means of education. This was started by observing the learning environment and the feedback on our current courses.

1.2 The negative feedback on traditional education

It is a common complaint of our colleagues teaching engineering subjects that both graduates and undergraduates are having hardships applying mathematics in their field of study. The main reason for this is that students have failed to capture key concepts and abstractions of mathematics in their former studies; they only practiced the operative performance of the demonstrated exercises, and this was enough to get them through their exams. Students tend to separate their mathematics subjects into theory and practice - and they often pay little to no attention to the former, because they feel it is not practical, therefore offers no benefits for them.

1.3 Importance of solid fundamentals in mathematics

However, students thinking learning mathematics has nothing to offer them could not be further from the truth. The most important mission of our education system is to help our students gain the knowledge needed to be competent and succeed in their careers. As our environment rapidly changes, we must rethink our approach to education; in today's knowledge-based society, the individual's economic competitiveness is based on how applicable and flexible his/her knowledge is. This means that there is a lesser demand on encyclopaedic knowledge, and more on skills and know-how that can be adopted rapidly to the ever-changing work environment. Coupled with the digital revolution, which means any data can be acquired with incredible ease, it is trivial that our new work environments put such emphasis on life-long learning and self-education that is unmatched in history. However, there are skills that are incredibly hard - for even the most talented students- to learn individually: mathematics is one of them. In addition, understanding mathematics is a gatekeeper of higher engineering concepts, so in order to help our students progress in their engineering careers, we must aid them in acquiring the key abstractions in mathematics and other fundamental subjects - that even the best students have problems learning themselves - but to manage this successfully, we need to overcome their rejective attitude towards theory and mathematics in general.

1.4 Getting students involved - informal learning

Today's students tend to be less resistant to the delay of gratification; this is the main reason of them neglecting calculus and other fundamentals. In these subjects, they are not getting the confidence boost of gaining a directly applicable skill, as these are traditionally based on the concept of formal learning, which, and its informal counterpart, is described below:

- Formal learning is independent from application. It is autonomous, as it serves no purpose other than education. Formal learning was designed in order to be more efficient: which efficiency measured by how well it serves the purposes of work, life and progress [1].
- Informal learning is based on heteronomy: it has other purposes than mere education, unlike formal learning.

The approach above also states that formal and informal learning are in a symbiotic relation, and only through the latter can the former contribute to the gaining of knowledge. The traditional practice was that undergraduates undergo formal education in their first few semesters, and only then can they complete their gained skills with informal learning; but this is getting harder and harder to carry out properly, because of reasons stated before. In order to get students motivated to learn mathematics, especially calculus, formally, we must motivate them with giving them opportunities to apply their knowledge instantly. This motivation boost, paired with the informal learning done while solving practical problems, should guide our students - of all talents - to pursue learning formal mathematics with greater enthusiasm, to their great benefit, as shown above.

2 EXPECTATIONS

The vital challenges and demands of the new learning environment - raised by students, our colleagues and the industry - can be summarized as bellow. A new approach must focus more on students learning the key abstractions and concepts in mathematics, in order to make applying the learnt theories in new fields of practice easier for them.

The new course should motivate the students to dig deeper into mathematics by showing them how crucial mathematics is through practical examples taken from the industry or personal experiences.

To augment their theoretical training, students shall also acquire computing skills and techniques in the course; with which they will be able to solve problems by themselves.
Our new course should apply the concept of informal learning - "learning while doing" - in order to condition the students to apply their knowledge.

3 OUR CONCEPT

The idea of an innovative mathematics course, fulfilling the criteria stated above, was brought to life by us in '18's early autumn. The system of requirements and the vision of the course was raised by Benedek Forrai, the curriculum and methods were worked out together by the writers of the paper.

The lessons of the course shall follow Calculus II., focusing on fields that require more attention, in order to motivate constant learning, and simultaneously making it easy for students to prepare for their main course.

In the new course, the students should be presented new, and if possible, graphical ways of understanding the concepts learned in the main course. A graphical approach makes it easier to visualize problems that students would consider mundane or "not practical" before, and it also accelerates to ability to pair the engineering concepts with mathematical concepts.

The students should be presented the crucial importance of understanding mathematical theory deeply and intuitively in engineering through personal experiences or shared experiences. This would counter the ever-present criticism of our graduated students, who state that they don't understand the need for "plain, boring theory".

In order to prevent students from trying to learn everything just before the exam - as they often do with non-mandatory subjects - the students should only be obliged to do assignments and projects alone and in groups. This way, we also apply the theory of informal learning, while developing essential hard and soft skills - following their mandatory subjects, these students have had no projects in their studies before.
In their assignments, the students shall also be required to complete tasks that require self-education through the internet. This should help them realize that "why learn it, I can google it" is not always a viable answer.

4 EXECUTION

4.1 The framework of execution

Traditionally, the top of mathematics courses in TU Budapest are accredited courses dedicated to talented students, who wish to pursue mathematics further - even compete in mathematics - and take their knowledge to a higher level. These courses, just like the one introduced above, follow and augment the fields of the main, mandatory mathematics courses, and are managed by Brigitta Szilágyi. On the other hand, these courses only attract students who are very confident in their knowledge - around the upper 15-20th percentile of engineering students are interested in this way of learning. This approach leaves many students, who could profit from such a course, unmotivated to expand their mathematics skills, because they - as engineering students often think - are not interested in "pure" mathematics, they only care about building things. In the February of 2019, when one of these "traditional" augmenting courses started, we launched a parallel course with a new, innovative curriculum fitting the criteria above, named "Applications of Multivariable Calculus".

4.2 The structure of our new course

Just like it's talent management counterparts, "Applications of Multivariable Calculus" yields 3 credits, and is taught in one practice per week, for one semester. Expectations from students differ from traditional, however - because we wanted to follow the guidelines stated before - instead of taking one exam, assignments were done by the students. These assignments are listed below:

Individual assignments: students must complete 3 homework assignments, all of which require around 10-15 hours of work to complete, and require both mathematical, engineering and problem-solving skills. Students are also required to write small summaries of the most vital concepts in their own words; this hones their communication skills and also deepens their understanding. The assignments always contain a task that produces something of value, for example analysing a song or recognizing a face with a camera; this motivates students while widening their perspective further in their field of study. Each assignment is rated on a 0-20 scale, and students also receive a feedback summary - which is unprecedented in our institution.

Group assignments: students also complete a group project until the end of the semester, in groups of 3 to 5, which they present orally in the last lecture. The problem they solve in their project is chosen by them, but it needs to be relevant both to the curriculum of the course, and to their field of practice as well; this helps them in recognizing mathematical problems in engineering later.

Attendance: mandatory on the 70% of the lectures and is monitored through a small "Kahoot" quiz in the end of every lesson. The quick tests also help the students in capturing the vital concepts [2], [3], [4]. Attendance was not a question, nearly all of the 53 students who took the course attended to 90% of the lessons.

4.3 The structure of one lesson

We always start our lectures with a quick summary of what we will show the students, and we also motivate them with some applications in the beginning. After that, we follow up with deepening the mathematical foundations and describing the technical background, then we apply these theorems in practice together with the help of computers; we write small programs that solve the discussed problems, which the students follow on their own laptops. The problem solving is coupled by the sharing of our experiences, stories related to the field. This is of a great importance: in their traditional training, due to lack of time, students won't be given such examples, and are often left wondering what they will use the gained skills for. Once or twice every lesson, the guided programming sessions are intersected by "mini-tasks", smaller, easier problems that students solve individually, and the 5 fastest students are rewarded. Lectures are ended with a "Kahoot" quiz, which is a great opportunity to wrap up the session's curriculum, and is always a fun, informal ending note of our lessons - and the students to step on the "podium" are also rewarded.

4.4 Media and software used

4.4.1 Python

We use the Python 3.6 programming language with our students to develop solutions to practical problems - like image processing tasks or processing of signals for example - in order to show the importance of mathematics in application. We chose this language because it is easy to teach and learn, and students are not shown any Python in their mandatory programming classes - despite it being one of the most common languages out there, especially in fast-growing fields like data science and machine learning. Python was developed with code readability and coding speed in focus, and is best in small (<200 line) scripts, this makes it our ideal choice.

4.4.2 NumPy, SciPy

More complex matrix operations, Fourier-transformations and the like are not implemented in basic Python; in order to evade having to program these from scratch, we used the freely downloadable NumPy and SciPy libraries. These provided great "toolboxes" for us to work with and made it easier for our students to experience success. These libraries are also widespread in the industry and knowing them well is a sought-after competence.

4.4.3 Notebook environments

The Python 3.6 programs are written in notebooks, not in scripts. A notebook environment enables us to augment our programs with formatted text, LaTeX functions, links and images, greatly improving understandability and presentability. The notebook method is rapidly expanding in popularity in the engineering and scientific community.

4.4.4 YouTube channels

As stated above, we wanted to show graphical ways of understanding mathematical concepts for our students - this was inspired mostly by the great 3blue1brown channel, which we also promoted in the course. The content on this channel is of such quality and so well thought out that many students began following it themselves, to their great benefit. We were inspired by other channels too.

4.4.5 GitHub

The code written on the lessons, the homework assignments and other pieces of code of importance or interest were uploaded to a GitHub Repository. GitHub is the leading code hosting website having over 26 million public repositories. Most students won't meet this service in their mandatory lessons, but on our course, they are given an opportunity to use and master the website.

4.5 Detailed curriculum

The parallel mandatory mathematics course ("Calculus II.") has three main points in its curriculum: Linear Algebra, Function Series and Multivariable Calculus are taught to first year Energetics, Mechatronics and Industrial Design students in their second semester. We found that linear algebra requires the biggest abstractions, and is more often thought impractical by the students, so we put more emphasis on Linear Algebra and its applications in our new curriculum. In the first few weeks of the course, we paid attention to let the students pick up the pace of the course, and get familiar with Python and the environments used, so we put more emphasis on syntax, basic algorithm design, and describing Jupyter notebooks in detail. After this, we started to follow the program of the main mathematics course. We made a small by-pass too: two lectures were held in the field of Graph Theory, because this important part of mathematics could not fit into the mandatory mathematics courses. The educational program week by week is presented below:

1. Introduction: A quick Python tutorial to take the first steps, and a detailed explanation of the platforms used (Jupyter and GitHub). Mini-tasks: implementation of a signum function in Python, calculating the decimal value of bits representing floating point numbers with Python.

2. The NumPy package, basic matrix operations: a quick intro into the usage of the most commonly used Python library. Matrix and hypermatrix operations. Applications: Numerical integration and noise filtering. Mini-task: calculating the approximation of definite integral of a function with dot products.

Homework assignment I.: the basics of neural networks, calculating the output of a neural net dedicated to recognizing the numbers of the MNIST dataset with matrix operations. Calculating the distance of Bence Sipos's walk by Bence Sipos's phone's accelerometer data, by filtering and numerical integration.

3. Image processing I.: a quick summary of vision technology (from analog to digital). Importance and relevance of computer vision, with industry applications. Introduction to the OpenCV imaging library. Representation of grayscale and colour images in computers: colour spaces RGB, BGR and HSV. Cropping images in NumPy. Thresholds, colour detection. Mini-task: translation from RGB to HSV in OpenCV and Python.

4. Image processing II., Convolution and matrices: Quick revision of colour spaces with a custom GUI program written in class. Colour filtering. Handling videos in OpenCV. Convolution, as a matrix operation, and its relevance in image recognition and signal processing. Edge detection with 2D convolution. Mini-task: RGB to grayscale conversion, finding the matrix to perform edge detection.

Homework assignment II.: Face-recognition with Haar-Cascades. "Smart TV" application: play/stop a video, whether the webcam of the computer detects a face or not.

5. Matrices - an intuitive approach: Matrices as representations of linear transformations. Matrix multiplication, as composition of linear transformations. Determinant, as the constant with which areas change through a linear transformation. Instead of a "mini-tasks" a "mini-project" is done by students: forming teams of three, they develop a program that displays the famous "Game of Life" in Python, using 2D convolution.

6. Robots and matrices: the basics of industrial robots. Industrial robots and automation in Hungary. Direct and inverse kinematics, and their mathematical representations. Coordinate transformations and matrices. Nonlinear transformations and matrices: performing translation with a matrix: the Denavit-Hartenberg coordinate representation in robotics.

Projects: team selection and gathering of ideas for the students' projects.

7. Finite element method - and linear equations: presentation of Attila Kossa, the colleague of great authority of Department of Applied Mechanics, about the Finite Element Method's significance in engineering with practical examples, the brief concept of FEM, emphasizing the role linear equations play. After Attila's presentation, we showed the students the graphical intuition behind solving linear equation with Cramer's rule.

8. Graph theory I.: Main concepts and theorems of graph theory. Implementing graphs in Python in an object-oriented way. Mini-task: calculating the sum of degrees in a graph in Python.

Projects: finalization of problems (chosen by students)

9. Graph theory II.: Dijkstra's algorithm in Python. Revision of graph theory, then a 45 minute "mini-project": visualizing plane routes from online data.

10. Fourier analysis: the significance of frequencies in engineering: music, radio signal demonstration with an RTL-SDR receiver. Control systems and their oscillation. The sound of machining centres, robot vibrations. Difference between Fourier series and the Fourier transform, visualization of a Fourier-series with Python graphics. Fourier series and Fourier transforms from the linear algebra perspective. FFT. Images and FFT. Demo: online spectrogram. The role of harmonics in the sound of instruments. The working principle of the Shazam music recognizer app. Mini task: recognizing famous pieces music from spectrograms.

Homework assignment III.: Analysis of online news pages with graph theory. Programming a graphical representation of the Fourier-transform in Python, converting downloaded music to a spectrogram, then analysing it.

11. Multivariable Calculus in practice: Deep Learning applications.: presentation of [], PhD student of [institute]. The basics of feed-forward neural nets (revision). Showing the significance of multivariable calculus in backpropagation, the backbone of deep learning applications. Gradient descent methods: stochastic, batch and mini-batch. Solving the infamous XOR-problem with a Python script using NumPy.

12. Presentation of projects.: The students present their solutions in a quick pitch. They are rated by us and their classmates.

5 EXPERIENCES, RESULTS, SUMMARY

5.1 Feedback and Survey

Throughout the course, we ran an anonymous feedback system, and conducted a survey on the 12. week of the semester: we asked students studying Calculus II. 26 questions, in which we inquired about their experiences with mathematics and programming in their curriculum. Students were either attending the new course (group “A”) or not (group “B”). 61 students answered our survey, 37 from group “A” and 24 from group “B”.

According to this survey, the attending (“A”) students earned notes in Calculus I. in an even distribution, while the other group (“B”) had slightly more students in the higher percentiles. The other statistics show similarities, so we can say that the two groups had almost similar abilities and knowledge.

We asked the students rate their knowledge of Calculus II. on a scale of 10; the “A” group had a higher average by 5 percent.

We also asked them whether Calculus II. helped them in their engineering subjects, such as mechanics or mechatronics. Group “A” has given noticeably higher score for this question.

According to the collected data, the majority of the students did not have any previous programming knowledge in Python or other programming languages except C (this is mandatory for the faculty), and in group “A”, they felt that their programming skills are improved greatly throughout the course.

We also inquired if students would like to participate in a similar course the next semester: more than 54 percent of the currently non-attending students considered joining, and only 5 percent of the attending group “A” would not continue.

They also rated the “general usefulness” on a scale of 10. The distribution is shown in Fig. 1.

5.2 Summary and acknowledgements

The students’ feedback conformed our assumptions that our new course helped them in understand the concepts behind Calculus II. better, and demonstrating real word applications greatly motivated them in their studies.

The extraordinary high participation and attendance also verify the need of continuing this practice the next semester in parallel with Calculus III. and developing a course for Calculus I. as well. As an ending note, let us present some of the students’ opinions from the survey:

"...I consider this course very useful. I have been talking about it with my friends, and we would definitely like to continue this kind of learning if possible."

"You guys are great! If not for you, I would have never got the meaning behind linear algebra!"

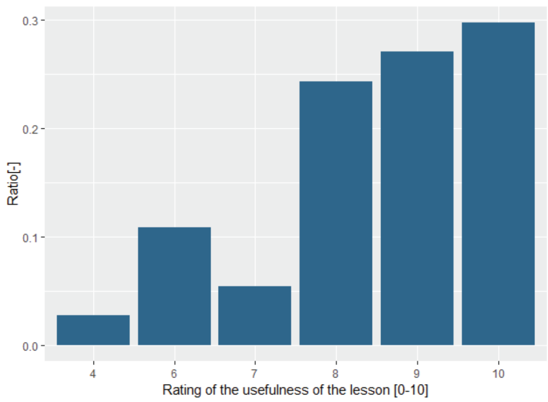

Fig. 1. The rating of the lesson's usefulness

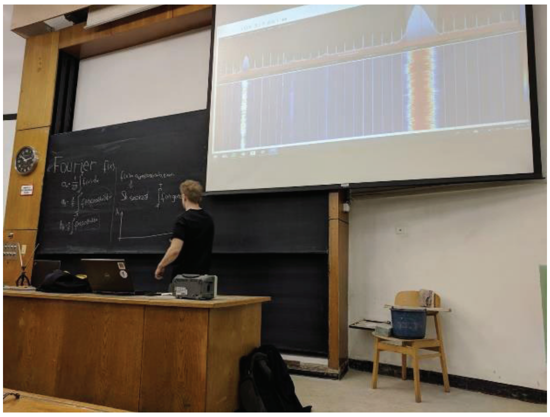

Fig. 2. Software defined radio demo

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Internationalisation and complexity:
dialogues for diversity or eradicating difference?

H. J. Foss[1]
University of Birmingham,
United Kingdom

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ABSTRACT

The concepts of internationalisation and transnational education (TNE) within Higher Education are ubiquitous phenomena for twenty-first century education. In a globalised context, this can take the form of international students and staff, internationally-delivered programmes, and internationalised content.

Drawing from experiences of working within the busy, diverse, and globally-recognised Birmingham Centre for Railway Research and Education (BCRRE), this paper explores internationalisation in engineering education. Using the themes of diversity and complexity, it considers how these intersect in teaching and learning, particularly in regards programme design and delivery.

The paper takes two case studies: a UK-delivered programme with a diverse student cohort and an internationally-delivered collaborative, transnational programme with an industry partner. Both programmes are taught by staff in one centre within a UK university and both utilise similar teaching, learning, and assessment methods. The two programmes are compared in relation to markers of internationalisation, diversity, and complexity, as well as programme design.

The data highlight not only differing levels of diversity and complexity, but also a need to adjust these faced with different contexts and examples of internationalisation. It is argued, as a result, that there is a need for ongoing, developed examination of levels of diversity and complexity for enhanced internationalisation.

1. INTRODUCTION

Internationalisation represents a key aspect within contemporary higher education, reflecting the need for fit-for-purpose teaching and learning opportunities within a globalised world. As a concept, internationalisation centres upon ‘preparing graduates to live in and contribute responsibly to a globally interconnected society’ (Higher Education Academy, 2016). This is achieved through a holistic focus encompassing all aspects of teaching and learning, including students, programmes, institutions,

[1] Corresponding author: H. J. Foss
Email address: h.j.foss@bham.ac.uk

partnerships, and beyond. Internationalisation thus refers to the integration of home and international students, staff and associates, of global projects, partnerships, and perspectives, and of de-centred, varied, and complex ways of thinking and working in research, teaching, and learning for the twenty-first century. Diversity and complexity as issues are thus of central importance within internationalised education at all levels.

1.1 Scope

This paper considers these issues of diversity and complexity within the context of internationalisation for higher education. Drawing from work and experiences within Birmingham Centre for Railway Research and Education (BCRRE), based at the University of Birmingham (UK), it explores postgraduate taught programmes in railway engineering offered in the UK and overseas. This context has been chosen due to a focus on internationalisation within the centre, primarily evident through the global reach of staff, students, projects, partnerships, and reputation. As a significant research and education centre such global spread offers key experiences of lived diversity as well as the resultant complexities faced by a large working group.

The subject matter of railway engineering, additionally contributes to the complexities under consideration. Railway engineering represents a substantial broad field of study encompassing civil, mechanical, systems, electrical and electronic engineering, as well as materials sciences, physics, design, business studies, sociology, human geography, ergonomics, and economics. Railways as a system of systems, too, are profoundly marked by complexity through dispersion, diversity, variability, and interdependence of internal and external factors.

1.2 Aims and Objectives

This paper’s central aim is to explore how higher education internationalisation is and can be informed by diversity and complexity. These matters are considered through the following objectives:

- to determine markers for diversity and complexity within higher education programmes;
- to chart these markers across two programmes, one delivered as a standard UK postgraduate programme, and one as a transnational programmes delivered via flying faculty overseas;
- to compare design and delivery of teaching, learning, and assessment across the two programmes.

By considering these aspects, questions of diversity and complexity within higher education internationalisation are raised in order to promote further examinations of teaching and learning, and assessment for twenty-first century engineering education.

1.3 Method

Two contrasting postgraduate programmes, both offered by BCRRE, University of Birmingham, have been chosen: ‘Railways Systems Engineering and Integration’, available as a PGCert, PGDip, or MSc on a full- or part-time basis in Birmingham; and ‘Urban Railway Engineering’, currently available as a PGCert based within Singapore. These two programmes have been selected in order to examine the measures that have been taken and could or should be taken in the future to engage with diversity and complexity in the context of internationalisation.

The programmes are compared in relation to programme design. This has been chosen to account for the complexities at play in examining educational programmes. Programme design includes structure and modules, teaching and learning methods, and assessment patterns, as well as learning outcomes. These are compared through the concept of constructive alignment to inform analysis. Contextual factors impacting design, such as programme team, university regulations, programme age, are also identified and taken into consideration due to how these inform programmes and the notions of diversity and complexity. Programme designs are then mapped against diversity and complexity factors for effective comparison. This comparative analysis proposes the need for profound consideration of diversity and complexity in internationalisation and argues the need for variety both between and within programmes to allow for effective learning opportunities.

1.4 Outline

The paper introduces the contexts under consideration through a background section introducing the case study programmes in more detail. A literature review is then presented to outline the pedagogical concerns relating to diversity, complexity, and internationalisation. The main body considers the case study programmes in relation to the concepts of internationalisation, diversity, and complexity. It then explores the various factors relating to programme design. The findings are discussed to propose the need for enhanced consideration of diversity and complexity in the context of internationalisation for effective learning. Recommendations and future research are provided alongside concluding remarks.

2. BACKGROUND

2.1 The University of Birmingham

The University of Birmingham (UoB) is a Russell Group institution defined by its research focus. It was established in 1900 as a ‘civic university’ in the heart of the UK’s second city, Birmingham. It boasts a student population of over 34,000, including 7,875 international students. UoB additionally has a commitment to internationalisation and transnational education through its recently established branch campus in Dubai, UAE.

The faculties of the university are divided into 5 colleges: Arts and Law; Social Sciences; Medical and Dental; Life Sciences; and Engineering and Physical Sciences (EPS). In terms of student population size, EPS, is the third largest, with a study body of 6,656; however, this includes a large international population, making it the second largest of the university, with 1,932 international students. Almost 30% of the college’s students are international, in comparison with 23% of the university’s student population overall. Each college contains a number of Schools grouping together similar subject areas, and each School contains departments and centres. In this structure, BCRRE sits within the School of Engineering.

2.2 Birmingham Centre for Railway Research and Education

BCRRE is a large research and education centre specialising in railway systems with 50 years’ experience. With over 130 members of staff and over 500 students, it is the largest railway research and education centre in Europe. BCRRE has three sections: professional and commercial services; research; and education.

Internationalisation is a central focus for BCRRE with research projects, educational programmes, and partnerships across the globe. The student and staff cohort is especially representative of such internationalisation: current postgraduate students come from Singapore, Australia, Hong Kong, Thailand, Malaysia, China, South Korea, Switzerland, Portugal, Brazil, Germany, France, USA, India, Belgium, Liberia, Syria, Egypt, Nigeria, Ghana, Iran, and more. Educational programmes in particular engender this internationalisation as students can complete postgraduate study on a full-time, part-time, distance learning international, or transnational basis, see *Table 1.* BCRRE education programmes.

Table 1. BCRRE education programmes

Programme	Study modes
Civil Engineering with Railways	BEng / MEng full-time
Electrical Engineering with Railways	BEng / MEng full-time
Railway Systems Engineering and Integration	PGCert / PGDip / MSc full-time, part-time, distance learning by attending for three week periods
Railway Safety and Control Systems	PGCert / PGDip / MSc full-time, part-time, distance learning by attending for three week periods
Railway Systems Integration	MRes full-time, part-time
Urban Railway Engineering	PGCert part-time transnational

2.3 Railway Systems Engineering and Integration

The postgraduate programmes in Railway Systems Engineering and Integration (RSEI) are the longest-running educational programmes in BCRRE. After being first offered at the University of Sheffield, the programmes were established at the University of Birmingham in 2005. Initially designed based on British Rail graduate programmes for entry into the rail sector, the programme is a global success story bolstered by exemplary reputation.

The full MSc programme covers 120 taught credits and 60 research credits. The modules encompass technical topics of control systems, rolling stock, infrastructure, and traction and non-technical subjects of railway operations, ergonomics, economics and business management, and systems engineering and integration.

Each year typically sees 25 students begin the programme full-time, and up to 40 students commencing part-time study. As a result, there are normally upwards of 100 students registered on the programme at any one time. Some 35 students graduate with an MSc each academic year.

Students enrol on the programme with two main levels of experience. Firstly, those with no or limited experience in the rail sector use the programme to start a career in rail, including those having just completed undergraduate study in engineering and those changing career. Secondly, those with experience in one aspect of the rail sector use the programme as a stepping stone to career progression, often leading to chartership and more senior-level positions.

2.4 Urban Railway Engineering

Urban Railway Engineering was recently established in 2016. It is a postgraduate collaborative programme between BCRRE and SMRT, one of the two metro operators in Singapore. The programme emerged from a successful research partnership between the two institutions. Faced with aging assets and workforce, as well as growing population and demands on the network, SMRT sought to professionalise their staff, choosing to work with BCRRE to develop a certified postgraduate programme.

The PGCert programme comprises 60 taught credits across modules covering technical and non-technical subjects. All students complete compulsory modules on railway management, basic railway technologies, asset management, and railway contexts, which covers topics such as ergonomics, economics, and operations. In addition, students take two optional modules focusing on the technical area in which they hold their day jobs, out of command and control systems, infrastructure, rolling stock, and traction and power.

The programme is predominantly designed for members of SMRT staff undertaking the company's graduate programmes as engineers. Additionally, operations staff take the first year modules. To date, a range of existing more experienced staff have also elected to study for enhanced knowledge and expertise. This has seen upwards of 80 students commence study each year.

Several key types of students enrol on the programme: developing engineers, operations staff, and experienced staff. The programme serves to develop depth of competencies within one area of railway engineering and is complemented through enhanced breadth across railway engineering technical and non-technical expertise. The programme additionally contributes to development of staff working towards professional chartership with the Institute of Engineers Singapore (IES).

3. LITERATURE REVIEW

3.1 Internationalisation

As aforementioned, internationalisation is used to refer to the need to prepare students to work in globalised contexts for the twenty-first century. This encompasses student and staff engagement, subject matter taught, methods for teaching and developing students' skills and competencies, university partnerships, and beyond. For the purpose of this paper, internationalisation is defined by students, staff, and studies, all of which are considered in the following discussion.

One component within internationalisation is transnational education. This is defined as 'the provision of a higher education degree programme leading to a […] qualification for students based in a country other than the one in which the awarding institution is located' (HEGlobal, 2016). Transnational education encompasses distance and online learning, collaborative provision with partnerships, and physical delivery overseas through branch campuses or flying faculty. Globally, the two leading national economies within transnational education are Australia and the United Kingdom (Clark, 2012). Within the UK, transnational education accounts for a significant percentage of international students and higher education institution strategies: according to Universities UK International during the academic year 2015-2016 there were 701,010 students on UK HE TNE programmes, more than the number of international students studying in the UK, alongside 82% of UK universities delivering transnational education (2018: 2) operating in all but 15 countries worldwide. Programmes cover all levels, subjects, and means of study, with student numbers growing by 17% between 2012-2013 and 2015-2016 (HEGlobal, 2016). Transnational education consequently is a significant area of growth and development within Higher Education; this is of particular importance in the present paper, given the inclusion of a transnational programme.

3.2 Diversity

The question of diversity within higher education is a long-standing subject of research and consideration. Typically associated with equality and inclusion, diversity can be said to refer to “an approach that values difference and treats each individual fairly and with dignity and respect, free from harassment and bullying” (Universities UK, 2019). This is often linked to protected characteristics and the ramifications of the 2010 Equality Act. In the context of higher education, this entails valuing and integrating difference within staff and student populations, as well as across curricula.

Considering the broad issue of equality and diversity in learning and teaching in higher education, the Equality Challenge Unit, addresses diversity with reference to matters of belonging, partnership, and embedding equality. As highlighted, this includes a focus on pedagogised norms and pedagogised others (Equality Challenge Unit, 2016) as central concerns for diversity. Similarly, C~~oleman~~ identifies the importance of examining the what, who, how, and where of diversity within higher education (2015). However, diversity is, he argues, a “dirty word” due to its eradication and obfuscation of difference, value, and definition (2015).

In the context of the engineering sector, across both industry and academia, diversity poses a further concern. In their work on diversity, Royal Academy of Engineering highlight the striking statistics that 92% of engineers are male and 94% are white (2016). RAEng’s Diversity Programme assesses the status of diversity and equality across the sector, proposes methods for improving equality and diversity, and seeks to lead the way in diversity (2016). The work produced by this group includes suggested toolkits for enhancing diversity, which begin by defining inclusion with reference to all people; the cultures, environments, and processes of an organisation; how all people feel; and an ongoing commitment and effort towards inclusion (Royal Academy of Engineering, 2015). Diversity, as the consequence of inclusion efforts, cannot be a coincidence.

Drawing from the research, the following markers for considering diversity have been identified:

- What: encompassing subject matter;
- Who: covering staff, students, and partners across gender, age, sexuality, ethnicity, religion, disability, cultural background, socio-economic class, education;
- Where: referring to spaces and places of teaching and learning opportunities;
- How: involving pedagogic practice, including normative and marginalised practices, and inclusive practice.

These are used to explore the case study programmes in the following discussion.

3.3 Complexity

Complexities are about non-linearity, indeterminism, and variety. The study of this in relation to natural sciences has been determined complexity theory, and focuses on bifurcations. Applicable to physics, mathematics, biology, and chemistry, complexity theory also holds a key role within social sciences as a way to examine organisations and social structures. For Osberg and Biesta, complexity theory goes “beyond” binaries to propose new methods for consideration (2010).

As an area of study, complexity theory has additionally been used as a lens to explore education. Kauko further considers this in the context of higher education, arguing that complexity is 'the basic condition of higher education systems' (2014). In their edited volume, Osberg and Biesta highlight how complexity theory allows for examination of both the promotion of complexity in and through education and the reduction of complexity in and through education (2010). Both matters are, they argue, a form of political intervention (Ibid.).

At its heart, complexity theory concerns valuing complexity. This seems to suggest a need for the simultaneous promotion of complexities and of new, albeit variant, orders, both engaging with the very concept of complexity itself. This theoretical positioning is used to guide the ensuing discussion.

4. FINDINGS

4.1 Internationalisation, Diversity, and Complexity markers

Both programmes can be considered forms of international higher education due to student cohort, staff, and study options, as shown in *Table 2*. Internationalisation markers. International students, well integrated across both programmes, are defined as those from outside the UK and Europe, following the University's definition for fees. Similarly, international staff are those not born and raised within the UK.

Regarding study options for markers of internationalisation, this covers patterns, topics, and methods for study. Patterns refer to part- and full-time study options, with internationalised study patterns encompassing ways of studying that allow students to join the programme and participate from a context outside the UK. This is available in the form of part-time study for both programmes, with RSEI comprising short periods of stay in the UK and URE, transnational classroom-based study in Singapore. Internationalised study topics draws from the literature to refer to the inclusion of a range of topics, contexts, theories, and approaches encompassed within teaching materials. In the context of railway education, this covers studying different technologies and their adoptions across a range of global, historical, and technical contexts and examples, as well as differing tools, companies, and business models. Similarly, methodologies concerns teaching and learning approaches designed to get students to engage with new and different ways of thinking and being. This includes group work with people of different backgrounds and experience, activities focused on critical thinking and analysis, open-ended questions where there is no single right answer.

Table 2. Internationalisation markers

Internationalisation components	Railway Systems Engineering and Integration	Urban Railway Engineering
International students	X	X
International staff	X	X
International study patterns	X	X
International study topics	X	X
Internationalised study methodologies	X	X

The identification indicated within the table shows both programmes have the same levels of internationalisation. However, further comment is required to highlight the nuanced at play. Whilst all aspects of internationalisation are present, this is at different levels, which can be unpacked further in relation to diversity.

Regarding diversity markers, the programmes show differing levels of diversity, as highlighted in *Table 3*. Diversity markers. All data are taken from academic year 2017-2018 with details regarding what, who, how, and where provided. Students refer to those registered on the programme and staff covers module leaders and any teaching fellows playing a substantial role in delivery and assessment of module.

Table 3. Diversity markers

	Railway Systems Engineering and Integration	**Urban Railway Engineering**
What	Technical and non-technical subjects covering global perspectives across range of businesses and backgrounds.	Technical and non-technical subjects covering some range of perspectives.
Who	Students male and female of a range of ages, ethnicities, educational backgrounds, career paths. Staff (n=8): majority white males (n=6), with some ethnicity and gender variation	Students predominantly male, university educated, majority of Chinese heritage working in engineering, of a range of ages. Staff (n=16): majority white males (n=9), with range of ethnicities and genders
How	Teaching delivery 9-5 lecture-based, with evening activities until 7:30. Delivery by academic staff and a broad range of guest lecturers.	Teaching delivery 8:30-5:30 mixture of lecture and activities. Delivery by academic staff.
Where	Monday-Friday 5-day Birmingham-based modules in accessible rooms with movable furniture, with further work completed independently.	Saturday-Wednesday 5-day Singapore-based modules in very large accessible rooms with majority movable furniture, taught over weekends at the request of the partner, with further work completed independently.

The diversity markers indicate differing levels across the programmes. URE demonstrates reduced diversity in terms of 'what', 'who' (students), 'how', and 'where'. This suggests the transnational programme lends itself to less diversity. For URE this is especially influenced by the collaborative nature of the programme with one company, leading to specific demands regarding content ('what') and when teaching modules can occur ('where'). The diversity of 'who' is also impacted by company demographics. In terms of methods ('how'), the reduced timeframe for teaching hours actually signals enhanced equality and inclusivity for students not having to attend during evenings (though this is mitigated by weekend teaching). Moreover, for many students on RSEI, part-time study requires staying in Birmingham for one week, not just away from work, but also from family, friends, and homes. In this respect, the part-time model that allows commuting due to the Singapore-context of URE is favourable, albeit informed by contextual factors.

Intriguingly, the core teaching team within URE represents increased diversity, which additionally intersects with internationalisation of the programme. This is in part motivated by the intensive nature of teaching for URE, which requires all 6 modules to be taught in parallel to the different student groups due to staff and student availability and thus necessitates a larger teaching team comprised of more colleagues across the wider BCRRE group. Additionally, the Birmingham-based RSEI utilises a high level of guest lecturers travelling from UK contexts, which is clearly impractical for a Singapore programme.[2] The transnational nature of URE therefore has substantial interplay with diversity markers that might be both examined further and mitigated through the notion of complexity.

For the purpose of this paper, the application of complexity theory to higher education serves as an analytical lens through which to consider difference and diversity in the context of internationalisation. If complexity concerns bifurcation and non-linearity as its essence, using complexity theory to assess the case study programmes provides a means for considering options, decentralisation, and new orders. As a line of enquiry, this highlights the politics of educational practice.

Taking bifurcation as a marker of complexity, the case study programmes promote complexity in the following manners:

- Study pathways
- Leaver destinations
- Study impetus
- Programme content

These aspects can be loosely divided into those concerning the student (pathways, destinations, and impetus) and the programme (content). Regarding the former, the presence of a range of pathways, destinations, and reasons for study not only increase complexity for the student, but also require further diversity and complexity across the programme. This is all strongly present across RSEI, demonstrating high levels of complexity. By contrast, the bespoke collaborative nature of URE limits complexity at the student level and thus requires further complexity at programme level in order to address this.

4.2 Programme Design

Markers of internationalisation, diversity, and complexity are a starting point for comparison. More detailed examination is available by considering programme design, as shown in *Table 4*. Programme design.

Table 4. Programme design

	Railway Systems Engineering and Integration	**Urban Railway Engineering**
Taught Modules	8x 10-credit 2x 20-credit	6x 10-credit
Teaching hours	5-day intensive with evening activities	5-day intensive
Teaching location	Birmingham	Singapore
Assessment	Class test, written assignment, and final exam all submitted online	Written assignment and/or final exam all submitted online

[2] In some cases guest lectures have been provided via video, however, this has not been used extensively in favour of delivery by those physically present.

Further notes		Compulsory for graduate engineers in SMRT

Programme design is limited by a number of external factors, such as the modular system of higher education and the requirement for 60 credits at PGCert level. The University of Birmingham uses 10- and 20-credit modules, additionally limiting programme design. Furthermore, the aforementioned markers of internationalisation, diversity, and complexity are built into programme design. For instance, modules delivered intensively through one week, rather than across a semester, offer more compact teaching and learning that promotes part-time study, particularly for individuals from a range of locations.

5. DISCUSSION

The data presented above highlight similarities across the two programmes. Internationalisation, diversity, and complexity markers appear throughout the case studies and the programme designs reflect consistency of pedagogical approach. At a surface level, therefore, these serve as examples of how diversity and complexity can be integrated within the context of higher education internationalisation. More broadly, the programme design also provides a demonstration of how a UK-based programme might be transposed into a different context for transnational education as part of an internationalisation strategy.

Behind this initial similarity, however, the programmes espouse difference and variety, and indicate some key concerns. The focus on diversity and complexity markers demonstrate this. Regarding diversity, the URE programme is shown to offer a smaller range of diversity across all markers, with the exception of module staff. Similarly, markers indicate limited complexity within URE. Although these aspects are likely influenced by the age, development, and bespoke nature of the programme. These results call for increased consideration of internationalisation.

Considering these factors of diversity and complexity in parallel demonstrates how different aspects of a programme could be adjusted for enhanced internationalisation. For example, reduced complexity of student factors might result in a need for developed complexity of materials and content to allow a programme to better meet the needs of internationalisation. Adjusting teaching methodologies or study patterns can therefore be prompted through analysis of the diversity/complexity markers. This suggests that such analysis can serve as a pedagogical tool for enhancing internationalisation.

Using diversity and complexity to consider URE as an example of transnational education in the context of internationalisation underscores some of the limitations around TNE as an internationalisation strategy. The data show that for the case of URE, diversity, complexity, and even internationalisation are more limited than within RSEI. Transnationalism is thus not necessarily equivalent to enhanced internationalisation. Although this result is likely influenced by limited experience within transnationalism and by the specificities of the case study programme under consideration, it is still significant to note such reductions in diversity and complexity.

This highlights a broader issue with focusing on internationalisation as a unique and coherent aspect within higher education. Indeed, this analysis emphasises the need for encompassing the ‘what’, ‘who’, ‘how’, and ‘where’ of diversity; the bifurcation possibilities of complexity; and the student, staff, and study options of internationalisation, suggesting that no one aspect can be taken in isolation.

Complexity theory particularly attends to these matters, inviting consideration of bifurcation. To return to the work of Obserg and Biesta (2010), there is a need to address the politics of complexity, in terms of both promotion and reduction. In the context of internationalisation, complexities can enhance this. Complexities can offer means for highlighting and celebrating difference as an integral part of internationalisation. They can also provide means for managing problematics of internationalisation regarding diversity. Finally, complexities put forward approaches for new persuasive pedagogies across various internationalised contexts.

6. CONCLUSION

This paper has examined the concepts of diversity and complexity within higher education internationalisation. It has taken two case study programmes, both demonstrating examples of internationalisation, and compared markers of internationalisation, diversity, and complexity, alongside programme design. It contends that, whilst programmes can appear similar on the surface, exploration of diversity and complexity invites more detailed examination of internationalisation. It uses the case study programmes to argue the methodological values of diversity and complexity analysis for pedagogy. Indeed, as demonstrated above, the presence of individual markers is not sufficient to suggest developed internationalisation. Instead, a combination of factors concerning diversity and complexity must be taken into consideration and explored in conjunction for enhanced internationalisation of higher education.

It is suggested that future study would be enhanced by a broader examination taking into consideration attainment and student and staff evaluation in order to further explore effectiveness and successes of teaching and learning within internationalisation. Such study/ies might consider programme results, alongside qualitative student evaluations and staff reflections. This range of data would allow for a more enhanced examination of diversity and complexity within internationalisation. Regardless of future analysis, internationalisation – both as context and as approach – should continue to be subject to close and careful scrutiny for educational practice.

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A Software Tool for Lifelong Learning in Engineering Education

C Fredriksson[1]
Granta Education Division, Ansys, Inc.
Cambridge, UK

M Dwek
Granta Education Division, Ansys, Inc.
Cambridge, UK

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ABSTRACT

Lifelong learning needs to be part of the solution for closing the skills-gap created by a rapid digital transition. It puts demands on educational tools for this purpose. Realistically, this requires a software platform that can be used remotely and that is relatively self-directed to provide the necessary flexibility for prospective users. Professional development and retraining are relevant examples of fertile areas for e-learning/distance learning in the lifelong perspective.

The CES EduPack software platform was specifically developed to support materials teaching at the Engineering Department of Cambridge University in the UK. It has since evolved into a widely used standard tool for areas of both higher and continued education. It is relevant in this context, since a significant number of engineering jobs for graduated students are concerned with design, manufacturing, maintenance or sales of complex technological products relying on safe high-performance materials.

In this paper, experiences from key academic institutions using this materials education tool are reported. In particular, the Open University of the UK which has a history of using the software in their courses for lifelong learning. There are also two specific examples of the software used in distance learning and professional development at other European Universities. The use of the software in these cases relied on four success-factors:

- Software licensing enabling remote use of the tool
- Extensive support-features for self-directed learning
- Embedded and online learning resources
- A number of advanced textbooks (Ashby) supplying theoretical backgrounds

[1] Corresponding Author
C FREDRIKSSON
Claes.Fredriksson@ansys.com

1 INTRODUCTION

Lifelong Learning (LLL) has been a European policy priority for more than ten years, and almost 20 years have passed since the European Commission's Working Paper, "Memorandum on Lifelong Learning". The European Parliament Resolution of 2008 on "Adult learning: It is never too late to learn" [1] urges member states to promote the acquisition of knowledge and to develop a culture of lifelong learning, designed to make adult education more attractive, more accessible and more effective [2].

When the European Council concluded and issued "A Strategic Framework for European Cooperation in Education and Training" in 2009, lifelong learning was therefore prominently featured [3]. The concept of *Lifelong Learning* was defined as "a continuous process that can last throughout a person's entire life, from quality early childhood education to post-working age. Moreover, learning also takes place outside formal learning contexts, particularly in the workplace" [2].

There is a decreasing demand for jobs requiring low qualifications leading to an increasing need for higher levels of qualifications in knowledge-based industries [2]. In addition to this, the rapid, so called, *digital transition* in industry urgently requires lifelong learning to help close a widening skills gap. For the majority of Europeans, though, lifelong learning is not a reality; obstacles include limited learning opportunities inadequately tailored to the needs of different target groups, a lack of accessible information and support systems, and *insufficiently flexible learning pathways* [2]. As pointed out by the US Department of Education: "A key enabler of continuous and lifelong learning is technology. Technology gives learners direct access to learning and to the building blocks of their knowledge—organized, indexed, and available 24/7" [4].

All of the above generate a demand for *appropriate educational tools*, which is the topic of this concept paper. Realistically, lifelong learning requires a learning platform to (i) be available remotely (distance learning), and (ii) having enough flexibility (part time, evenings, dual learning/WiL etc) for prospective users. Continuing education and retraining require (iii) ability to support professional development, particularly for engineering skills. The adult learner also relies on tools being (iv) self-directed [5], for sufficient independence, as well as (v) enabling personalised learning experiences.

Fig. 1. Relevant aspects of lifelong learning, affecting requirements on software tools

The CES EduPack software platform (referred to later as *the software*) was specifically developed to support materials teaching at the Engineering department of Cambridge University more than 30 years ago. It has since evolved into a widely used standard tool for areas of higher education and has proven suitable also for lifelong learning (see Fig. 2). Materials teaching is important since a significant number of engineering jobs for graduated students are concerned with design, manufacturing, maintenance or sales of technological products relying on safe, high-performance materials.

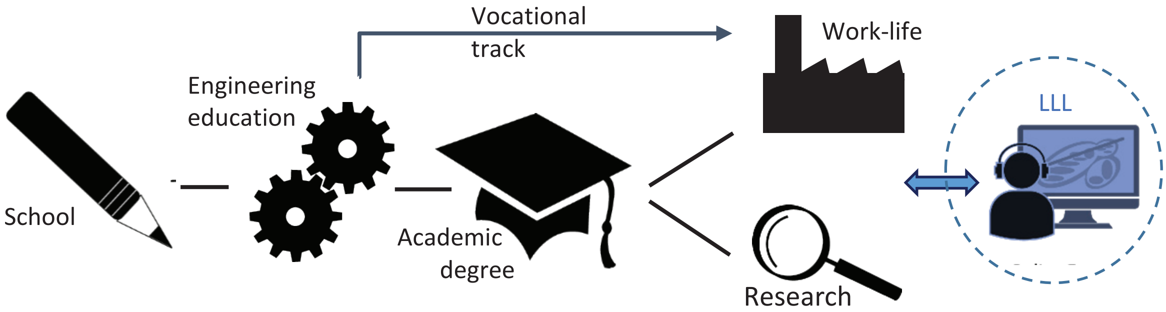

Fig. 2. The educational phases in terms of traditional engineering careers and the added feature of lifelong learning, responding to demands of the future work-life

This paper considers CES EduPack, which is part of a family of tools used for materials-related applications both in industry and research (CES Selector and Granta MI) [6]. The links and similarities between the academic and industrial applications of the software ensure that lifelong learners acquire relevant skills when using it as part of their continuing education or professional training. Academic licensing options include the possibility to equip all registered students in a controlled manner with time-limited copies of the software to install on their PC/Laptop. The visual platform for material properties (Ashby Charts), the comprehensive databases with eco- and sustainability properties, manufacturing process data with a built-in cost model and the Eco Audit tool for a lifecycle perspective, lend themselves to collaborative multi-disciplinary project work. For these reasons, it has been suggested that the software would be beneficial for, *e.g.*, Global Engineering in a product development context [7]. It does not, however, rely on internet access.

A prime example of a pioneering provider of lifelong learning using such tools is the *Open University* of the UK (OU). They are one of the largest providers of Higher Education in Europe and the UK's only university dedicated solely to distance learning. In this paper, experiences from educators using the software for lifelong learning are reported. OU, in particular, has a long history of using this and other software in their courses for lifelong learning. There are also two examples of the software being used in professional development and distance education at other European Universities.

2 METHODOLOGY

This paper reports on an exploratory qualitative survey, which represents a first step to assess the use of the software in a lifelong learning setting. It is based on the following questions, answered and elaborated freely by three key educators from academic institutions for higher education that have practised distance learning;
(i) OU, based at Milton Keynes in the UK with 100% distance operated courses
(ii) UDIMA Universidad a Distancia de Madrid, Spain, also fully distance-based
(iii) Department of Materials and Manufacturing at Jönköping University (JU), Sweden.

The responses were requested to be based on: “anonymous student comments and feedback (or stats) you might have specifically about the software”. They were summarised by the authors, in a form that facilitates comparison. There was no specific order in the questions, the answers were free format.

The questions were:

1. What relative level are the participants (beginners, advanced, experienced)?
2. How many were taking the course (per class or module)?
3. Is it a single module or a part of a full program (fully integrated, fully flexible, part time etc)?
4. Are there lectures with demos (live or recorded)?
5. Was the teaching synchronous or asynchronous (scheduled or flexible)?
6. Any group interactions (forums, Q&A, threads etc)?
7. How is support handled (on demand, emails, phone, contact hours etc)?
8. How is the CES EduPack introduced (tutorials, ppt, getting started etc)?
9. Were there specific computer labs scheduled (to learn software functionality, material selection, Eco Audit etc)?
10. Are there assignments based on this software (quiz, hand-ins etc)?
11. How is the software used in examination (if at all)?
12. What was the feedback on the software (useful, difficult, eye-opening etc)?

3 IMPLEMENTATION EXAMPLES OF LLL

The answers to the 12 questions listed in section 2 are collated below. The OU have elaborate responses, whereas UDIMA and JU have shorter answers, summarised in Tables 1-3, in their respective sections. The results are discussed in section 4.

Table 1. Summary of responses from OU

Academic Institution	Open University, based at Milton Keynes in the UK Course link: http://www.open.ac.uk/courses/modules/t271
Education	Module offered to students at OU Stage 2 of their adult studies (equivalent to UK National Level 5), 100% distance.
Students	This is the first engineering module at this stage for around 700 students on both engineering and design qualifications. However, all students on these qualifications have studied introductory engineering (with integrated maths) modules, professional skills modules and either an additional maths module (engineering qualification) or a design module (design qualification) at Stage 1. The module is a core requirement for the BEng & MEng qualifications but may also be studied as an independent unit. CES EduPack has recently been introduced, so the feedback from this initial cohort of students is tentative.
Format	CES EduPack is used in a fully distance learning context, with learning materials developed for print and online use. It is utilised as part of an active learning environment and introduced using the OU online Virtual Learning Environment (VLE) in week 2 of the module. The VLE utilises both full module and tutor-student forums for group discussions. Students are encouraged to download the software in the first week and it is put to use continually throughout the Materials part of the module (approximately 6 weeks duration) and call on it in later parts of the module. The main learning is progressive throughout the first 6 weeks of the module and parallels the students learning of materials, with guidance and activities throughout. The intention is regular exposure in small doses rather than an intensive training programme. Students are encouraged to make use of the tool to obtain materials information for other questions not specifically related to the software. Tutorials, both face-to-face and online formats, allow students to interact and they also use an online collaborative tool for group exercises.
Support	There are no lectures with demonstrations, but individual tutors may incorporate demos into tutorials based on their student's needs. The initial introduction encourages the student to make use of the inbuilt help materials within the software and other resources provided by the software supplier. Additional support is generally provided by phone or email by the student's tutor. Many tutors also use Skype and/or Adobe Connect for online demos.

Table 2. Summary of responses from UDIMA

Academic Institution	UDIMA Universidad a Distancia de Madrid, Spain Course link: https://www.udima.es/en/degree-industrial-organisation-engineering.html#plan-estudios
Education	The modules are in Spanish and 100% distance.
Students	43 students (2018/19) in the second grade of a Degree in Industrial Organisation Engineering. They are beginners in Materials Science
Format	The software is introduced via the embedded Video tutorials and some lectures and video conference. Lectures contain recorded demos. The teaching is both synchronous and asynchronous, but usually students prefer asynchronous. One activity is completely based on the software. The students have to answer a video quiz, answer some questions and submit a report with graphics. Group interaction occurs online via a '*forum of doubts'.* The software is not part of the final examination yet.
Support	A teaching assistant answers questions via a virtual laboratory classroom (Moodle LMS). Students receive support in some cases by email or phone.

Table 3. Summary of responses from JU

Academic Institution	Jönköping University, Sweden, Department of Materials and Manufacturing Course link: https://ju.se/mam
Education	Part-time Master's programme (60 ECTS), specialised in casting and given in English. It was developed in close collaboration with the Foundry Industry with intentions to contribute to professional development.
Students	Around 45 students in total with a mixed engineering background but no previous experience using the software.
Format	The software is introduced with a lecture and the embedded 'getting started' resource. The modules are in English and are mostly web-based, for example through video lectures, discussion forums and e-meetings. Meetings on Campus for laboratory work occur once or twice per module. Part-time studies (¼ speed), to enable combining studies with work. Examination is done via a report.
Support	Students get support on demand via emails or phone. Questions can also be handled during on-site Campus lab.

4 RESULTS AND DISCUSSION

The results from the survey are discussed in terms of the five components of LLL (see Fig. 1) and related to specific features in the software considered to support these.

4.1 Distance learning

All of the examples in Tables 1-3 above have been selected based on their explicit use of CES EduPack in a distance learning context. The software is delivered for installation controlled by the University on participants individual computers, enabling some online content, such as the student resources within *Learn* (see Fig. 4), to support independent learning away from a University Campus. The software is backed up by a number of textbooks by Ashby [8-9] and open resources available for any student to acquire the necessary theory.

All educational institutions (OU, JU, UDIMA) have been given access to textbooks as well as dedicated *teaching resources*, including lecture units, exercises, case studies that are being used to various degrees in their respective online learning platforms.

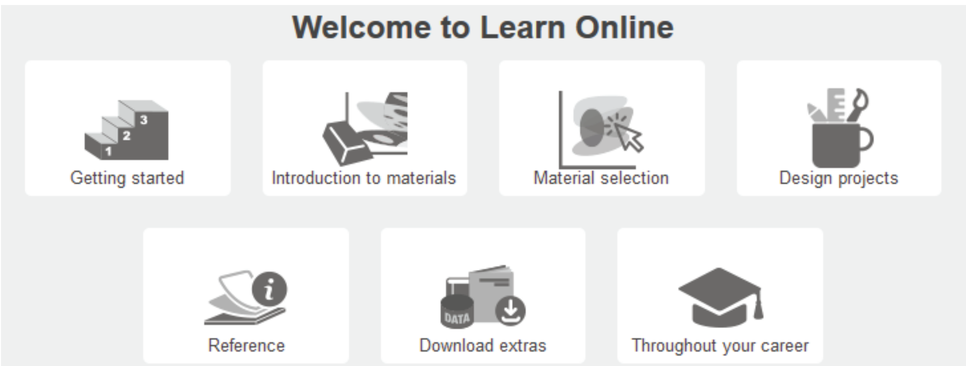

Fig. 4. The software contains both online and offline features and student learning resources to enable independent learning away from Campus.

4.2 Flexibility of use

Since the software itself does not rely on an internet connection to function, it is fully flexible to use whenever and wherever (provided power supply). Projects can be saved and retrieved at convenience. Among the educators surveyed in this paper OU report the most flexible approach while JU reports a fully scheduled, though part time, approach. UDIMA utilises both synchronous and asynchronous components. This shows viability of the software in all flexible contexts.

Extensive visual and clickable information about functionality (see Fig. 5) reduces the need for classroom or lab guidance by teaching assistants. A playlist of sequential video tutorials is available in the online mode, which allows the students to learn functions progressing at their own pace. JU uses scheduled Campus labs to ensure software proficiency whereas OU works with tutors to provide necessary instruction.

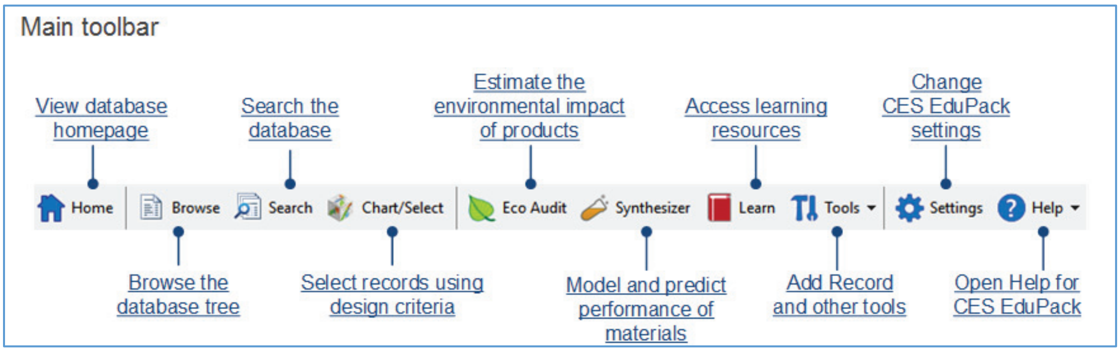

Fig. 5. Visual and clickable guidance reduces the need for classroom/lab instruction

4.3 Continuing education/professional development for engineering skills

A number of different engineering areas are covered by the available databases (see below), depending on which edition is licensed. Advanced editions (Level 3) cover Standard (mechanical) Engineering, Aerospace, Polymer and Bioengineering as well as Eco Design and Sustainability (see Fig. 6). These satisfy the needs for a wide range of areas for professional development, not only in traditional materials education. JU has demonstrated that the software can be used as part of a close and direct collaboration with the casting industry at the Master's level to promote professional development. The qualifications that can be obtained from the OU are, of course, also useful for continuing education.

Fig. 6. Relevant databases for professional development in many engineering areas

4.4 Self-directed learning, for sufficient independence

The software has been developed to support self-directed learning, both when it comes to operating the software and when it comes to learning the materials-related topics within courses. In order to understand the function and features of the tool, there is an embedded *Getting Started Guide*. In addition to this, there are short online *Video Tutorials*, containing visual demonstrations organised in sequential playlists. To support the coursework, there are extensive *Science Notes* on demand, and a comprehensive introduction to materials (see Fig. 7) for individual self-study.

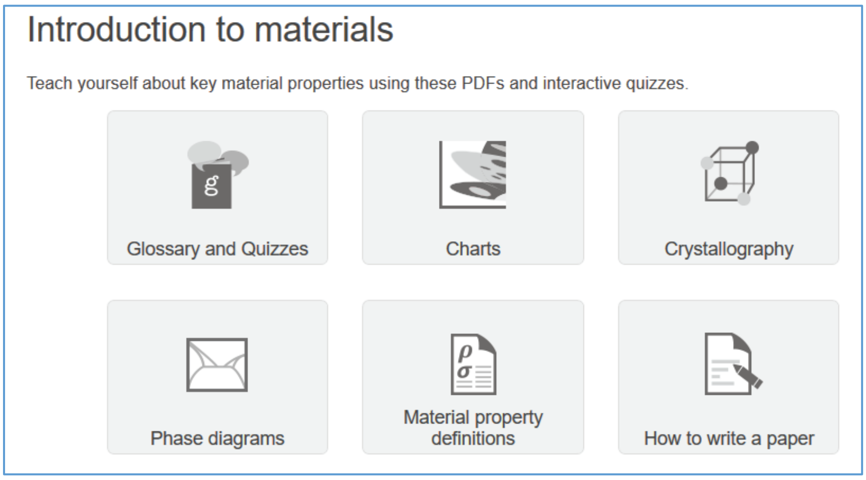

Fig. 7. Resources that enable self-directed learning, such as Teach-yourself guides

4.5 Personalised learning experiences

OU represents the use of databases for design while UDIMA utilises the Standard Engineering database for industrial engineering students. JU use the Sustainability database for, *e.g.*, environmental assessments within a manufacturing context. The software is highly versatile, as indicated in section 5.3, above. All the advanced databases contain a comprehensive set of thousands of datasheets that cover the relevant material classes (metal alloys, polymers, ceramics and hybrids/composites) as well as manufacturing processes (joining, shaping and surface treatments). This makes it possible to tailor courses and activities to many specialised areas. As many of the students in our survey are considered beginners, the streamlined, yet comprehensive databases at Level 2 are adequate (see Fig. 8). Thus, the software supports individual learning experiences both in terms of topic and complexity level.

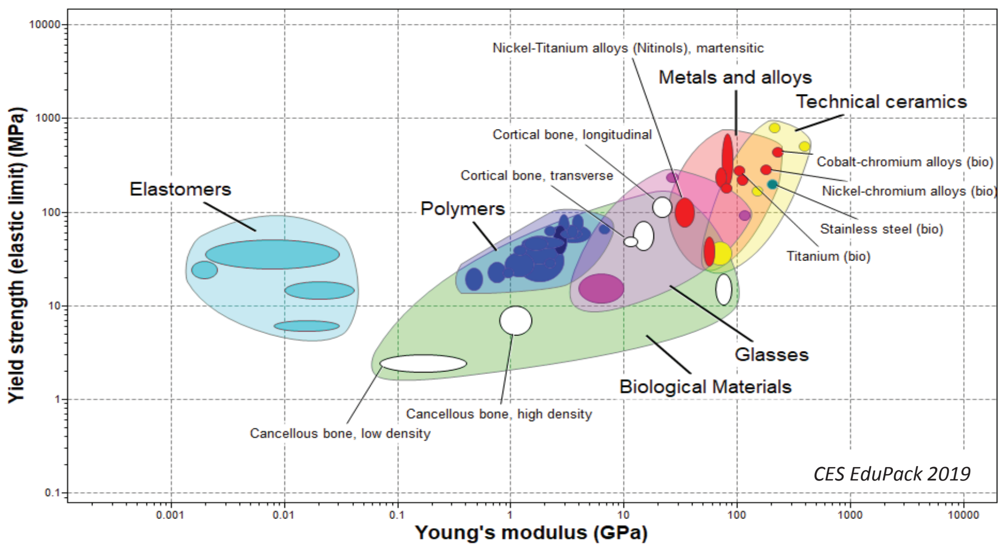

Fig. 8. Property chart at Level 2, showing both biological and engineering materials

There is also a wide range of embedded tools for individual directions in the software: visualisation tools for material properties (Ashby Charts) provide information for overview and selection which is useful for most engineers; the Eco Audit tool for a life-cycle perspective is interesting for green engineering and eco design; the built-in cost model and part cost estimator tool support manufacturing and product development. Students may also want to explore lightweighting projects with composites or structural hybrids using the Synthesizer tool.

4.6 Feedback from students and educators

First, we summarize the available student feedback given anonymously by *The Open University* who is still finalising feedback from the first cohort of students, so there are limited responses to date regarding the software and the module as a whole. The majority of students that have so far responded to questions about the software appear to consider it relatively easy to use. Very few had ever used it prior to this module. The main issue encountered appears to be a lack of a MacOS version. A couple wanted a Linux version. A couple of users encountered issues using work computers, being unable to install the software on to these. Some users wanted an option to have multiple projects/graphs open at the same time, to allow for comparisons of graphs. Many, though, expressed liking the software and the information it contained.

The Jönköping University students have been evaluated two consecutive years, 2018 and 2017 (in brackets) on a module which was heavily based on the Life-cycle tool of the software, Eco Audit. The module was: *Environmental Impact Assessment of Castings* - *TMGS27*. Various aspects of the course were assessed by students from 1 to 7, the latter being the best, with response rates of around 50%. Although the module was not purely focused on using the software, it would have affected the outcome of the questions. One relevant question in the survey was: *Possibility to achieve the intended learning outcomes (through lectures, laborations, seminars, projects, assignments, literature and other teaching aids)*. This was rated 6.5 (6.17) out of 7 by the participants, Indicating a complete absence of discontent.

The question about course material would partly reflect the provided resources and the software: *Opinion about the course material (e.g. course literature, scientific literature, recorded lectures, web quizzes, instructions for laborations)* was rated 6.83 (6.17) out of 7. On the explicit question: *The following aspects of the course were positive*, the answers mentioning the software were: “I like CES EduPack and I think it is very useful in the engineering to analyse or be aware in which phase of the life cycle a product has the highest footprint” (“It was good to learn about program that helps you understand the environmental impact like ECO Aduit” (sic)). On the question of *what is your overall opinion of the online learning design of the course*? The two answers that explicitly mentioned the software were: “Good course material and software (CES EduPack)” and “Good choice of use project works and CES software” (see Fig. 9). On the explicit issue: *Room for improvement*, the only comment was: “It was difficult to know how much to write in the assignment regarding CES EduPack”.

What is your overall opinion of the online learning design of the course?

Text answers:

competent teachers including their pedagogy.
good course material and software (CES EduPack)

The course is very professionally made. Very practical and the knowledge is transferred in a very effective way!

Good choice of use project works and CES software. The case study in the course, like examples, create more impression and sensibility.

It´s good, but it can be hard to get the time for the online meetings suite with the work.

NIce course! Eye opener for me as a Design Engineer!

Fig. 9. Text answers from one course evaluation survey at JU (n=6 students)

In the case of UDIMA, the Educator summarises the experiences from the software as: “useful, but some students have some difficulties with the language”. The Software offers Spanish and other language versions at Level 2, but some parts are only in English. Furthermore, “According to the students the most useful is the database of materials science and engineering”.

5. CONCEPT CONCLUSIONS

5.1 Summary

The concept under investigation was lifelong learning and how this is supported by the CES EduPack software. Even though the scope was limited, it provided interesting glimpses into what can be explored further. The three cases we have reported, demonstrate that the software can and is used successfully in various forms of lifelong learning. Since the platform is not online-based and current licensing enables academic institutions to distribute time-limited software to participants for the licensed period. The combination of embedded student resources, such as *Getting Started* and *Science Notes*, with online support for learning, such as *Learn* and the *Video Tutorials*, facilitates flexibility and self-directed learning, as evident in these examples.

Success factors that were identified are:

- Software licensing enabling remote use of the tool
- Extensive support for self-sufficiency
- Embedded and online learning resources
- A number of advanced textbooks (Ashby) supplying theoretical backgrounds

5.2 Future work

This work should be seen as the starting point. The use of the software in materials-related lifelong learning context should be studied further in quantitative terms and with more specific questions about functionality and benefits. It would also be interesting to explore lifelong learning from outside of the European perspective.

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What Is the Difference between a Group of Musicians and a Team of Engineering Students?

A Philosophical Approach to the Problem-Based Nature of Engineering

S. R. Frimodt-Møller[1]
Associate Professor, Department of Planning, Aalborg University
Esbjerg, Denmark

Conference Key Areas: New Notions of Interdisciplinarity in Engineering Education, Other Topic Relevant to the Conference

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ABSTRACT

Analogies between the group dynamics of a music ensemble and the general case of teamwork have been a recurring theme in management philosophy. The author of this paper has previously examined such analogies critically in connection with his own research concerning the actual patterns of decision-making in a music performance. One conclusion from this research is that these patterns are, to a large extent, generalizable to decision-making in other group contexts. At the same time, however, analogies always "hide" and "highlight" certain aspects of what they are meant to say something about (to repurpose vocabulary from George Lakoff & Mark Johnson's *Metaphors We Live By* [1]). Exploring the limits of an analogy may consequently lead to a clearer idea of the special traits of each of the two compared entities. This paper uses the critical examination of an analogy between a small music ensemble (such as a rock band) and a team of engineering students to emphasize where the two fundamentally differ in their decision-making patterns. At a first glance, the way musicians base their actions in a performance on a combination of goals (broadly construed), expectations for the actions of others, internalized routines, and prior communication with exact agreements, is very close to that of a team of engineering students. Where the two differ is especially in the way goals emerge and are negotiated in a group. Engineering processes tend to be problem-based, and problems can be discussed differently (and often more constructively) than a musical idea.

[1] Corresponding Author
S. R. Frimodt-Møller
sfm@plan.aau.dk

1 INTRODUCTION

This paper sets out to critically explore an analogy between a team of engineering students and a composing music ensemble, such as a rock band. By comparing the two types of collaboration, which, it will be argued, have many similarities, important differences between the two can be identified, and thereby lead towards a different way of explaining what distinguishes the work process of engineering teams. Critical reflection on the analogy – rather than the analogy in itself – thus provides a pedagogical tool for making engineering students understand the nature of their (coming) profession.

Engineering disciplines are typically regarded as inherently tied to problem-based work. Even if a university offering engineering programs does not explicitly brand these studies as being "problem-based", they will usually still have an emphasis on teamwork and collaborative projects revolving around a 'real-life' context (see e.g. [2] and [3]). Making engineering students understand the problem-based character of their disciplines is, however, complicated by several factors. First, there is a strong weight within the specific educations on subject-specific learning, e.g. the learning goals shared between chemical engineering and chemistry as a natural science education, between computer engineering and computer science etc. How does one make engineering students understand how their studies go beyond this type of learning goals? Second, problem-based learning is not limited to engineering (as witnessed by the fact that Aalborg University uses a PBL model throughout all of their educations [4]). So what characterizes the particular way engineers base their endeavors on problems (i.e. as opposed to the general contextualization of a topic that most educations are able to do)? On the way to answering these questions, it is worth comparing the field of engineering to another field concerned with construction or development in a general sense, but not necessarily with formulated problems. One such field is a composing music ensemble.

Analogies between the group dynamics of a music ensemble and the general case of teamwork have been a recurring theme in various fields concerned with leadership, organizational structures and management in general (witness e.g. [5] and [6] and [7])). The analogy is, however, not entirely neutral (nor are analogies in general, see section 2 below). For instance, focusing on cues for good leadership in the context of a music ensemble implies an understanding of the latter as having a specific kind of organizational structure with a leader. This is not necessarily the case, as the author of the present paper has argued in previous research [8]. There are, however, if we look at teamwork in general, several interesting things that can be generalized from the way musicians interact to group interaction in general, thus also including the interaction of a group of engineering students, and in some cases even provide an ideal for such interaction.

The way musicians base their actions in a performance on a combination of goals (broadly construed), expectations for the actions of others, internalized routines, and prior communication with exact agreements, has a detailed parallel in a team of engineering students (and graduated engineers for that matter). Furthermore, in terms of knowledge management – a booming field in management in general, but especially in relation to engineering enterprises (see e.g. [9] and [10]) – the community of musicians, whether groups, teachers, or students, demonstrate highly evolved skills in handling (communicating as well as preserving) not only explicit knowledge, but also the practical know-how sometimes referred to as “tacit knowledge” (see section 5).

Again, exactly because of the limits of any analogy, it is worth considering where the two compared entities – a music ensemble on the one hand, and a team of engineering students on the other – differ from each other. A particular difference this paper emphasizes (in section 6), relates to the way ideas (broadly construed) are negotiated in the group prior to taking action based on these ideas. In fact, this may be a crucial aspect of the work of an engineer.

The author of this paper currently works with first-year engineering students at Aalborg University Esbjerg (henceforth AAUE), as teacher of a cross-curricular PBL course on the first semester and co-supervisor of several student projects in the second semester, across 5 different engineering programs. The author has, however, previously specialized (within his career as a philosopher) in the development of theoretical models for explaining interpersonal coordination in context of music ensembles. It has therefore been a natural step to consider whether some of the insights gained via the latter research could find relevance in context of coordination processes in engineering teams.

2 ANALOGIES – A SHORT SWOT ANALYSIS

This paper uses the term “analogy” as covering explicit comparisons of two, in practice, normally unrelated entities or situations, which serve to say something about at least one of the two compared entities or situations.

Employing an analogy is of course not the only way to get a point across. In order to evaluate analogies (and the discussion thereof) as a pedagogical tool, one approach could be to identify the strengths, weaknesses, opportunities and threats of the tool – or what is popularly known as a “SWOT analysis” (a discussion of the emergence and development of SWOT analysis as a concept can be found in [11]).

The strength of analogies is the pedagogical potential: one may actually be able to get a point across more clearly via reference to a context the listener is more familiar with.

On the other hand, a weakness of analogies is the possible lack of precision: There can be a thin line between analogy and poetic metaphor, and the latter is typically meant to be ambiguous, with artistic purposes. Worse, analogies can sometimes purport to be actual models of whatever they are trying to say something about. This is problematic because analogies *highlight* certain similarities between the two compared entities, but at the same time *hide* certain differences. The terms "highlight" and "hide" are directly borrowed from George Lakoff and Mark Johnson's work on the implicit, structural metaphors underlying daily language. One of Lakoff and Johnson's examples is the metaphor "time is money", which underlies several expressions such as "spending time", "using/wasting time", "thank you for your time", "not having enough time" and so on [1]. This metaphor highlights a correlation between a certain period of time and the possibility of making money within this time, but hides the fact that time is something abstract and by its own definitions an ongoing process, beyond our direct control. Analogies, being, in a way, explicit structural metaphors, are subject to the same kind of pitfalls.

When we examine what a given analogy highlights or hides, however, there is a strong potential – an opportunity – for learning about the nature of the two compared entities. This is how we will approach the analogy presented in the next section: as an opportunity for learning about both sides of the analogy, even though we are doing so with the purpose of eventually showcasing properties of one of the two compared entities.

A threat to any analogy is that it is deemed too inaccurate to be useful, but this should be of little significance here, as we are, exactly, searching for such inaccuracies, in order to learn from them.

3 A ROCK BAND AND A TEAM OF ENGINEERING STUDENTS: INTRODUCING AN ANALOGY

Music ensembles and engineering teams come in different shapes and sizes. Apart from the number of people in a group, the limits of the interaction are also defined by the specific line of work, e.g., for music ensembles, the piece of music or genre, on which an eventual performance is based, and for an engineering team, e.g. which discipline (building and construction, chemical, electrical, computer, mechanical or other type of engineering) or specific project the team is affiliated with. Instead of fleshing out the many interesting nuances of the way music ensembles and engineering teams may work, we will consider the more specific analogy of, on the one hand, a rock band playing original material, and on the other, a project team of engineering students. The purpose of this restriction is to give the "ensemble analogy" the strongest possible presentation, in order to more clearly pinpoint where the crucial differences between musicians and engineers lie.

When we talk about a rock band playing original material, we think of a group of typically 3-6 people, playing music they have composed themselves. The task of composing may be dominated by one or more people, or done in an actual act of collaboration between band members.

By a project team of engineering students, we understand a team of engineering students in any semester, consisting, typically, of 3-6 students, working on a project of their own choice. The actual formulation and delineation of the problem, on which the project is based, conceptually, can be a more or less democratic process, but for the purposes of the analogy that follows, we assume that the members actually collaborate in this respect.

Before we turn to the central issue of creative development, whether leading to a composition or a finished engineering project, we will start by having a look at collaboration in general in the two compared cases, and how it is organized.

4 ORGANIZATION AND COORDINATION IN MUSIC ENSEMBLES AND ENGINEERING TEAMS

In previous research [8], the author has argued that the organization processes of a music ensemble may differ drastically, depending on the level of organization: At rehearsal level, an ensemble such as a symphony orchestra often has limited time to master a piece prior to a performance. In such a rehearsal, there is no time for long discussions among the musicians. Instead, a conductor or other leader manages the rehearsal in an autocratic manner. At a more general, organizational level, however, e.g. when deciding which pieces to play, which soloists to book, everyday logistics etc., even an entire symphony orchestra could potentially (and does, in many concrete cases, see e.g. [12]) take part in the discussions, thus mirroring a democratic process. At the other side of the rehearsal, the level of performance, musicians (as well as their conductors, if any) are rarely able to discuss anything (there may be various types of verbal or non-verbal signals integrated in the performance that help communicate urgent messages – see [13] for examples – but seldom an actual conversation in the traditional sense). Viewed in isolation, the music performance is almost a kind of anarchist society, where every person shares the responsibility of trying to coordinate with everyone else playing. Because, however, the rehearsal level affects the performance, and because the musicians often have a strong sense of ‘how things should be’ in relation to a piece of music or a genre, the music performance is not simply a case of unchallenged personal freedom.

The aforementioned three levels of organization have special properties in the rock band. The transition between the general, organizational level and the rehearsal level is often fluid: Because the band is a much smaller unit than e.g. a symphony orchestra, quick, ad hoc communication about other issues than the music can happen swiftly without interrupting the workflow much. Live performance has the same character for the rock band as for the symphony orchestra of being a normatively conditioned situation where everyone shares responsibility for maintaining a coherent output. Studio performance (borrowing a term from [14]) on the other hand, shaping a definitive version of a piece of music for wide distribution in recorded form, typically has a structure similar to that of a rehearsal, where the band can stop, discuss, change things and continue as they see fit. Finally, the rehearsal itself can be very different from that of a classical ensemble, small or large, in that the composition on which an eventual performance is based is not always a pre-established entity. When the band is working on new material, regardless of how many of the band members have actual input for the composition, the band is not simply learning how the piece should be played, but trying, more fundamentally, to figure out what the piece is, what it consists of, what they want it to be.

The music performance and the coordination processes taking place therein is a field of inquiry in itself (see e.g. [15]), but in general, musicians have the following ‘tools’ at hand when coordinating their actions with those of other musicians in a performance (these are in line with [16]): There are the context-specific norms taken for granted by the musician as being commonly accepted – these especially depend on verbal agreements made in advance with the other musicians (or instructions given by a conductor during rehearsal). There are the expectations the musician may have for the actions of others, expectations based e.g. on how the others have typically behaved before – how they are likely to interpret a certain kind of phrase, if they tend to play a bit too loud or too quiet, accelerate or slow down etc. Finally, there is of course also the possibility of coordinating by swiftly adjusting to the visible or audible behavior of others. Instances of all of the above can be found in the interaction of a (composing) rock band, although one might expect the musicians to be particularly proficient in coordinating according to pre-established norms understood as common knowledge in the band, given that they have built the music they are playing together.

Turning to the team of engineering students, it may be difficult to find a clear parallel to the music performance as a delineated situation. There may, however, be many situations where the students are, in practice, working together without much verbal communication, relying on what they understand as commonly accepted goals and strategies in the team. As such, daily interaction in the engineering team mirrors that of the rehearsal or studio recording process of a rock band: there can, most certainly, be agreements with respect to how work is distributed in the group, which can focus work in the team around a few types of activities at the time, but a bit of back and forth between being quietly “in flow” (to apply the popular terminology of [17]) together and having discussions about how to proceed, is unavoidable.

For both the rock band and the team of engineering students, many power structures are possible, ranging from having one, strict leader of the group, to negotiating all decisions with everyone in the group. The author’s personal experience as a teacher and co-supervisor of first year engineering students is that most student teams are hybrids, management-wise: Typically, one or more people in a group take on the role of ‘chairman’, moderating the discussions, but not necessarily monopolizing decisions – i.e. in many situations, such a group will have a democratic process, where everyone in the group is heard, before making a decision. The same type of management is possible in the rock band, but in practice, for reasons we will return to in the next two sections, democratic processes may sometimes end up feeling forced or superficial, and in the worst case, escalating into a hostile working climate. (Conversely, these scenarios could also, potentially, occur in an engineering environment.)

All in all, we may easily find parallels between a rock band and any other small collaborating team when we consider how work in general is organized, irrespective of what the work actually consists in. Once we consider the organization of the content of the work situation, however, the comparisons become less trivial, as we shall see in the next section.

5 KNOWLEDGE MANAGEMENT – TACIT AND EXPLICIT

Recent decades have seen an increased focus on knowledge management in businesses in general, prompted by a shift towards considering the knowledge e.g. a company produces, acquires or maintains (e.g. with respect to effective procedures for whatever the company does) as central to the survival of the company on the market (see e.g. [18]), rather than focusing on the – in nature, often fluctuating – sales numbers. This focus is also reflected in engineering practices (see [8] and [9]), and to some extent in engineering educations: For instance, teams of engineering students at AAUE are taught basic knowledge management tools such as formulating goals and plans for their mutual learning processes, and following up on how well they met these goals, to which extent a plan was followed etc. Where engineering practices see a major challenge, however, is in the management of so-called *tacit knowledge*, i.e. all the practical and, at least initially, non-verbalized knowhow, built by employees via experience with concrete situations.

Some approaches to tacit knowledge management (see e.g. [19]) rely on tacit knowledge eventually becoming explicit knowledge (e.g. by nudging employees to explain what they are doing), a strategy that may work for some instances, while others (see e.g. [20]) use video and other types of multimedia for essentially maintaining “watch and learn” databases, offering a digital alternative to a craft’s apprenticeship. All of these approaches still ‘early days’ in an engineering context. Engineering students in particular, typically do not have formal procedures for handling tacit knowledge, but regard it as a natural part of the practical work, a part they are not required to account for.

What is interesting, however, is that if we turn to music ensembles, and in fact, musicians in general, knowledge management (although it is rarely conceived of as such) already includes detailed practices for handling, broadly speaking, tacit knowledge: A violinist may show another violinist how a particular passage should be bowed or phrased. Sometimes there is an established vocabulary for referring to particular types of bowing or phrasing, other times it requires an illustration. A pianist may be asked to use his or her imagination in order to play something as if they were in a particular time, place or emotional situation (see e.g. the workshops described in [21] and the account of working with David Bowie in [22]). A band working on a new song may have to try something out, listen to it and make a decision about whether to change something – a process that has strongly tacit elements, but at the same time has a logical, “trial and error”-like flow that makes sure the band works towards an optimal ‘product’ or compromise (although there is no guarantee they will reach one). Many more examples could be given, but the general thing to note here is that referring to, inspiring access to or otherwise communicating tacit knowledge is a commonly accepted part of music practices.

In the author's opinion, however, one of the reasons for the tacit dimension being an accepted condition of a musician's work is that it is commonly accepted that there are parts of this work, which cannot be put into exact words. This has a downside, because, unlike in an engineering team, decisions or instructions (e.g. from a band leader, if there is one) are sometimes accepted or forced with no preceding arguments for a decision (other than e.g. some vague statement of 'visions' for the music). In a band with less democratic practices for development of a composition, it is not an atypical scenario that the musician initiating a composition process will feel the right to veto decisions in accordance with his or her ideas for what the music should sound like. And if the other musicians do not acknowledge this right, conflicts ensue that, again, can be difficult to resolve, due to the lack of a tradition for explicit arguments for different solutions.

In the next, and penultimate section, we will discuss how the (understandable) lack of tradition for arguments in relation to basic musical ideas provides slight, but important differences between the creative processes of a rock band and a team of engineering students.

6 ON CREATIVE PROCESSES AND WHY AN INITIATING PROBLEM MAKES A DIFFERENCE

Engineering teams base their work on problems they are trying to address and solve, or at least contribute to solving. At Aalborg University Esbjerg, engineering students are, among other tools for the ideation process, provided with the so-called 6W diagram, which gives them an overview of the phases a problem analysis needs to go through. The exact order of the "6 Ws" may differ, and consequently the diagram arranges these in a circle around the term "Problem", but the content remains the same:

Problem: The process begins with an initiating problem of a form such as "how can it be that…?", "how do we make X better with respect to…?", "how do we solve the problem with…?" This initiating problem, represented by the center of the diagram, is analyzed with respect to various aspects that can be summarized as answering 6 questions (all including the letter W):

What exactly constitutes the problem? In this connection, the students are encouraged to bring forth more specific details on the nature of the problem, scientific background material etc.

Why is it a problem? Here, the broader, e.g. societal relevance of the problem is investigated further.

Who are the stakeholders?

Where and **when** is the problem relevant/present? These questions should inspire the students to find concrete examples, preferably from real life.

How can the problem be solved? The student is prompted to think in terms of possible strategies. This eventually leads to a solution process, where one solution strategy is chosen and further delineated based on available resources (time, money, materials, man power etc.)

Once a solution is planned, it is carried out and evaluated, after which point further improvements can be made. The improved version can be subject to new evaluation, and the team can go through as many cycles of improvement and evaluation as they find relevant or possible within the given time frame.

If we turn to the creative process of a rock band working on a new piece of music, certain interpretations of the 6 questions above might make sense:

What is the piece of music like? Which notes, rhythms, overall structure etc.?

Why work on this particular musical idea? And why should it have a particular structure?

Who should the piece appeal to? Should any other musicians be taken onboard for a recording?

Where should the piece be played or recorded? On which platforms should it be released first?

When should it be played or released?

How is the performance or recording going to be carried out? Are there difficulties that may ensue? Things that need to be revised in the piece to make it playable for the musicians?

The major difference from the 6W diagram in engineering, however, is the absence of a formal problem initiating the creative process. In its place is, instead, something like a musical ‘idea’ or ‘gestalt’ that the musicians are trying to actualize in their performance. In some cases, it may be in the process of figuring out how to play the piece that they become aware of how its underlying ideas could be characterized – in other words, the musicians compose the piece in an act of performance similar to improvisation. In other cases, a musician has a rough idea of a composition that he or she brings to the table for the entire band to collaborate on. This situation is where things can become problematic, as hinted in section 5: If the rest of the band does not acknowledge a special connection between the initiator of a composition process and the ‘essence’ of the piece of music, conflicts will very likely take place. In other words, the musicians often lack a joint capability of evaluating their answers to the 6 W questions, because they do not necessarily share access equally to the initiating ‘vision’, against which their endeavors are being measured.

This does not necessarily mean that a music ensemble such as a rock band is necessarily less democratic than an engineering team, nor should one make a romantic claim that a democratic work process is a hindrance to the creation of great, coherent art: Musicians *could* potentially be lucky enough to be on the same page with respect to the overarching ideas for the music, and pieces composed in a manner similar to improvisation can also have great artistic value. Conversely, engineering students, may, in spite of what they have been taught, experience toxic group dynamics where one or a few people in the team take full control, without wanting to justify all of their decisions. Engineering students could also be (and are sometimes) working in a pseudo-problem-based manner, where they start from a practical solution they favor, and work their way backwards to a justification for the solution, in shape of a traditional problem analysis. If, however, we look at the conceptual pre-conditions for their creative processes, it does seem as if engineering students have a much better starting point for actual, democratic collaboration in their creative process.

7 CONCLUSION

An analogy comparing a team of engineering students to a rock band may be of help in explaining and providing nuance to a discussion of

- the many possible variations on how a unit may be organized, opening up the minds of e.g. engineering students to more than one fixed organizational structure
- how interpersonal coordination takes place – which may be useful in showing students the virtues they should strive for in order to avoid conflicts
- how knowledge management can include all aspects of the team's knowledge, including tacit ones, broadly conceived

An important limit of the analogy lies in the difference between how the creative process is typically initiated, and the consequences this has for whether informed, collaborative decisions can be made.

Incidentally, Karl Popper [23] suggested "piecemeal social engineering" as an ideal form of governmental practice, working pragmatically to find the best possible solutions to delineated problems, rather than striving to make decisions in accordance with an overarching ideology and its grand visions for the future. In continuation of this, it is interesting to note how the engineering team in itself represents a possible ideal for democratic collaboration in the way it addresses and works with problems.

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Importance Assigned by Students and Teachers to Soft Skills:
The Case of a Two-Year Technical College

A. Gero
Technion - Israel Institute of Technology
Haifa, Israel

S. Mano-Israeli[1]
Technion - Israel Institute of Technology
Haifa, Israel

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Keywords: Soft skills, electronics students, electronics teachers, two-year colleges

ABSTRACT
Soft skills play a central role in engineering and technology education, and their importance is expected to increase within the Industry 4.0 framework. However, while the literature covers the soft skills of engineering program graduates, the research focusing on the soft skills required of graduates of a two-year technical college is very limited. In view of this gap, the study described in this paper examines the importance assigned by students and teachers to soft skills required of a two-year technology program graduate. Forty-four electronics students and thirteen electronics teachers from a two-year college took part in the study, which used both quantitative and qualitative instruments. According to the findings, the importance assigned by the students to soft skills was significantly lower than the importance assigned by their teachers. It might be possible to explain the findings by the current curriculum not putting sufficient emphasis on providing relevant soft skills.

[1] Corresponding Author
A. Gero
gero@technion.ac.il

1 INTRODUCTION

"Industry 4.0" is the fourth industrial revolution, after its predecessors that were characterized by water and steam power-based mechanization (first revolution), electricity-based mass production (second revolution) and computer-based automation (third revolution). The current revolution is based on Cyber-Physical Systems, Internet of Things and Big Data [1].

The implementation of the Industry 4.0 concept requires, inter alia, to provide workers with an appropriate qualifications set that includes technical as well as soft skills [2]. Technical skills are abilities that can be taught and that are relatively easy to measure, such as the use of software. On the other hand, soft skills refer to interpersonal qualities that permit the individual to function well in society and achieve his/her goals, such as communication and self-directed learning skills [3]. It should be emphasized that soft skills play a central role in engineering and technology education even today, and their importance is expected to increase within the Industry 4.0 framework [4].

While the literature extensively deals with the soft skills of engineering program graduates, the research focusing on the soft skills required of graduates of a two-year technical college is very limited [5]. Therefore, this study investigated the importance assigned by Israeli electronics students and teachers to the soft skills required of a two-year technology program graduate. To the best of our knowledge, such an analysis was performed here for the first time. It should be noted that most of the students at Israeli two-year technical colleges are from the socioeconomic periphery or attain relatively low academic achievements [6-7].

2 SOFT SKILLS IN ENGINEERING AND TECHNOLOGY EDUCATION

As mentioned above, soft skills are a collection of interpersonal qualities that permit the individual to function well in society and achieve his/her goals [3]. These skills can be implemented in a broad context and are not limited to a particular type of activity [8]. In the engineering and technology context, soft skills include, among other things, effective teamwork and efficient oral and written communication [9].

Recognizing the necessity of soft skills, the Accreditation Board for Engineering and Technology (ABET) has updated the accreditation criteria of engineering and technology programs, so as to include soft skills alongside technical skills [9]. Consequently, leading educational institutions, such as University College London (UK) and Purdue University (US), have begun emphasizing the importance of soft skills [10]. However, it is quite difficult to find the appropriate balance in the curriculum between the weight of technical skills and soft skills, and there is still a gap between university training and the industry's requirements [11].

3 RESEARCH GOAL AND METHODOLOGY

The study characterized the importance assigned by electronics students and teachers to the soft skills required of a two-year technology program graduate. Forty-four second-year electronics students (with an average age of twenty years) and thirteen experienced electronics teachers (with an average age of fifty years) from a two-year college in Israel took part in the study.

The participants completed a closed-ended anonymous questionnaire. It was a five level Likert-like scale ranging between "very important" and "not important at all". The questionnaire covered the soft skills defined by ABET as the qualifications required of a two-year technical college graduate, i.e., (i) a commitment to continuous improvement, (ii) an ability to engage in self-directed learning, (iii) a commitment to address professional and ethical responsibilities, (iv) an ability to function effectively as a member of a technical team, and (v) an ability to apply written and oral communication in both technical and non-technical environments [9]. The questionnaire was validated by two engineering education experts and five students who did not take part in the study.

An importance index was defined as the average of the importance ratings of the five above-mentioned qualifications. This index, ranging between 1 and 5, was calculated separately for the students and their teachers.

Additionally, semi-structured interviews were held with students (five interviews) and teachers (five interviews), who had given their consent to be interviewed as part of the study. The participants were asked, inter alia, whether the current curriculum put sufficient emphasis on providing soft skills. The qualitative data underwent conventional content analysis.

4 FINDINGS

The mean value of the students' importance index was $M = 4.08$ with $SD = 0.49$, while the mean value of the teachers' index was $M = 4.43$ with $SD = 0.35$. The gap, in favor of the teachers, was statistically significant ($t(55) = 2.36$, $p < 0.05$).

In order to identify the factors leading to the above gap, *Fig. 1* displays the mean importance score of each of the five skills (students and teachers), and *Table 1* presents the corresponding effect sizes. The findings indicate a zero effect size with regard to communication skills, and medium effect sizes with regard to the remaining qualifications.

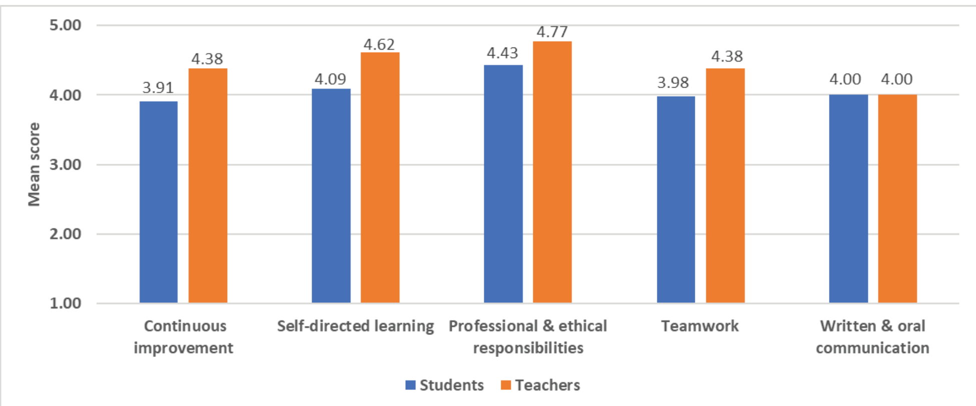

Fig. 1. Mean importance scores.

Table 1. Effect sizes.

Skill	***d***
Continuous improvement	0.55
Self-directed learning	0.56
Professional & ethical responsibilities	0.57
Teamwork	0.48
Written & oral communication	0

The qualitative information extracted from the interviews with the teachers indicates that the current curriculum does not reflect the need to provide the students with relevant soft skills:

> "*This [providing soft skills] is not built into the curriculum… It depends on each teacher and his or her method."*

A similar insight seems to be formed by the students' answers in the interviews:

> "*It can be said that [in the program] there is no focus on teamwork… There is no [focus on] independent learning, and no focus on expressive abilities either.”*

5 DISCUSSION AND CONCLUSIONS

It was found that the overall importance assigned by the students to soft skills was significantly lower than that of the teachers. Indeed, the students and their teachers agreed concerning the importance of effective written and oral communication, but the gap associated with the remaining qualifications was characterized by a medium effect size.

It might be possible to explain the findings by the current curriculum not putting sufficient emphasis on providing relevant soft skills. This fact did not permit the teachers to dedicate the necessary time to these topics that they viewed as very important, and this could have possibly affected the importance assigned to these qualifications by the students. It should be noted, however, that the above imbalance in the curriculum is characteristic of many educational institutions, and is one of the causes for the gap between the training provided by them and the industry's requirements [10-12].

In light of these results, we recommend to revise, where needed, the curriculum of two-year technical colleges so as to dedicate sufficient time to providing the students with soft skills. One of the suggested instruments for developing these qualifications is integrating "real-life" problems into the curriculum [13]. Our recommendations are validated in view of the central role played by soft skills in engineering and technology education, especially within the Industry 4.0 framework [4].

The main limitation of the study is a relatively small number of participants. Therefore, in order to increase the findings' trustworthiness, both quantitative and qualitative tools were applied. In a future study, we will considerably increase the number of participants and examine similar programs.

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New Framework for Civil Engineering Programs in Germany

B. Gigla
Technische Hochschule Lübeck

J. Weinig
Fachhochschule Bielefeld, Campus Minden

German Association of Departments of Civil Engineering and Environmental Engineering at Universities of Applied Sciences (GADCEE)

Conference Key Areas: democratic involvement in educational processes, employability as a target of engineering education

Keywords: professional civil engineering, educational standards, accreditation, reference framework, design of bachelor degree courses in civil engineering

ABSTRACT

A common European labour market requires a transparent presentation of professional standards. This is particularly important for civil engineers for three reasons: Civil engineers create products with long life cycles, important resources are bound and buildings have an impact on people, environment and society.

Who defines the prerequisites for the exercise of a profession in civil engineering - universities, state, and chambers of engineers? Due to the diversity of the courses of study, the Chambers of Engineers ultimately want to assess the professional qualification. In the case of academic training, however, teaching and research are granted free. The design of the curricula is the sole responsibility of the universities.

Therefore, to describe employability in civil engineering, a reference framework for bachelor degree courses was developed by an association of stakeholders that incorporates universities, universities of applied sciences, the construction industry, trade unions, chambers of engineers and students.

The reference framework defines learning objectives and competences. It is subdivided into the subject areas "Fundamentals of Engineering", "Planning", "Construction Design" and "Construction Management" with 135 credit points (ECTS). This ensures the necessary breadth and depth of academic education in civil engineering (Bachelor) as a basis for professional qualification. The reference framework is a compromise. The application is optional for the universities, but recommended. It ensures that the definition of professional qualifications in civil engineering programs may remain in the responsibility of the universities. In Germany, civil engineering is the first engineering discipline to succeed in such a reference framework.

1 INTRODUCTION

The entitlement to use the professional title of a civil engineer is regulated differently at international level. In North America, for example, study courses for civil engineers are accredited by professional associations such as ASCE (American Society of Civil Engineers) or Engineers Canada [1]. The intention is to guarantee the requirements for professional engineering registration in the understanding of the association.

In Europe, the European Network for the Accreditation of Engineering Education (ENAEE) has established an international, specialist accreditation network. This has not yet played a role in Germany. The European Council of Engineers Chambers surveyed the state of training of civil engineers in the countries of the European Union. Annex VI of the report suggests steps to develop "Common Training Principles for Engineers" (CTP) [2].

In Germany, the title "Civil Engineer" has been associated with the university degree "Diplom-Ingenieur" (Dipl.-Ing.) for about 150 years. Law in Germany has regulated the title since 1970. The underlying engineering laws are within the authority of 16 federal states. To avoid difficulties in mutual recognition, the engineering laws follow a coordinated "Template Engineer Act", which is drafted by the Conference of Ministers of the Federal States responsible for Economic Affairs. Previously, the study of a technical or scientific discipline with a “Diplom” (university degree Dipl.-Ing.) and a standard period of study of at least three years at a state or state-recognized academic institution were sufficient to earn the professional title "engineer". All the experts involved have so far accepted this pragmatic legal regulation as good and sufficient.

As a result of the Bologna Process and the European Professional Recognition Directive an adaptation of the engineering laws was necessary (compare: Directive 2005/36/EC amended by Directive 2013/55/EU). The replacement of Dipl.-Ing. degrees by Bachelor and Master degrees because of the Bologna reform has led to uncertainty in professional practice. Human recources departments criticized the fact that some names of degree programmes do not allow clear conclusions about the aquired competences. In reaction it was discussed to regulate required study contents by law. For this purpose, the formulation that the course of studies must be predominantly characterized by the fields of mathematics, computer science, natural sciences and technology was preferred for simplification purposes. In some federal states, the statutory chambers of engineers have also attempted to exert influence. The Chambers of Engineers proposed to combine the right to use the professional title of engineer with a membership in the chamber.

The Universities see both, legal regulations governing study content and mandatory chamber memberships for their graduates as illegitimate interference with their constitutionally guaranteed freedom of research and teaching. An association of stakeholders therefore developed the introduced reference framework for civil engineering [3]. To describe prerequisites for employability, recommendations were developed for teaching volume and obtained competences. A study programme matrix was developed to review these recommendations, enabling each university to check the course content and to make clear to what extent it deviates from the reference framework. This approach is aimed to make the description of employabilty more transparent in accreditation procedures.

2 STUDY SYSTEM IN GERMANY

2.1 Historical Development

From the middle of the 19th century to the 1960s, civil engineers in Germany were qualified at regional polytechnic academies. These gradually acquired the status of technical universities or universities of applied sciences. Due to a shortage of engineers in the 1960s, additional engineering institutions were founded in the federal states. At the beginning of the 1970s, these engineering schools were integrated into the newly founded “universities of applied sciences” nationwide.

The universities of applied sciences provide a focus of qualification oriented at the classical German dual education: Theoretical knowledge is applied in practice and practical knowledge is questioned by theory. The academic staff at universities of applied Sciences need to have a phD degree in civil engineering and is supposed to possess professional experience in leading position outside of the university.

2.2 From Diplom-Ingenieur to Bachelor of Engineering

The degrees at the universities on the one hand and at the universities of applied sciences on the other hand were titeled slightly different, either Dipl.-Ing. (Univ.) or Dipl.-Ing. (FH). The graduates of the universities of applied sciences were very well received on the labour market, especially in all tasks of planning, work preparation, construction execution and site management. Their appreciation in the construction industry in terms of salary was not inferior to that of university engineers.

In the course of the Bologna Process in the European education area, the concept of knowledge transfer changed to desribe learning outcome. Today, learning outcome is specified and extended with the concept of the mediation of competences [4]. A further objective of the Bologna Process was the differentiation of the courses offered. The aim was to respond more flexibly to the graduate needs of industry. The inclinations and talents of the students should be developed better and more precisely in these differentiated study programmes.

Today's understanding of education in Europe is based on diversity, but equivalence on academic (tertiary) education. Tertiary education no longer distinguishes between types of higher education institutions. It differentiates only in education levels. Consecutive, building on one another, i.e. in Bachelor's, Master's and doctorate degrees. Additions "Univ." and "FH" at the degree Dipl.-Ing. are therefore obsolete.

2.3 Civil engineer's responsibility in society

The "classical" civil engineers, or rather: those who perform the classical construction task, have a special responsibility for their actions. With construction measures, capital is tied up for the long term, the built environment is shaped and the energy and resource requirements are decisively determined. The state has delegated this task and responsibility to the Chambers of Engineers on a self-organising basis. In Germany, civil engineers are often self-employed and perform important public tasks.

There are 16 state chambers of engineers in Germany. The "Bundesingenieurkammer" (Federal Chamber of Engineers) is the umbrella organisation. These chambers are so-called "public corporations", i.e. they have an independent role between state and engineer, a self-organized part of society.

The professors, with the constitutional right to freedom in research and teaching, are also a special species in the German understanding of the state. The professors are civil servants for life (the German variant of the tenure track) with special duties towards state and society. Thus it is the duty and right of professors to contribute to the development of their subject area/course of study.

Collisions between the two groups resulted from this competing task of the state, on the one hand to the Chamber of Engineers and on the other hand to the professors to continue the development of civil engineering education. One solution is the introduced reference framework to describe the employability of graduates of bachelor degree courses in civil engineering.

But other regions of the world are also working on uniform standards of civil engineering education with regard to teaching content, the social responsibility of engineers and uniform ethical principles, such as in East Africa [5].

Engineers Canada has already formulated such standards [1]:

- Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest;
- Impact of engineering on society and the environment: (…). Such ability includes an understanding of the interactions that engineering has with the economic, health, safety, legal, and cultural aspects of society (…)
- Ethics and equity: An ability to apply professional ethics, accountability, and equity.

2.4 Bachelor degree: Is there a difference between the University and the University of Applied Sciences?

The university degrees are the same in the individual (federal) states, and between universities and the university of applied sciences they are of equal value, but different in orientation. The universitys of applied sciences attach particular importance to the (immediate) professional qualification of the graduates. This is achieved by the academic and practical qualification of the professors.

Research in the construction industry in Germany is low compared to other sectors (e.g. health, pharmacy, automotive) according to the classical key figures (research expenditure according to turnover). This is also due to the special structure of the construction industry in Germany. There are 760.000 employees in the main construction sector and more than 70.000 companies plus so-called self-employed individuals. This means an average of 10 employees per company. What is special about this is that these (craft) enterprises do not make any strategic considerations due to their small size. To a certain extent, craft enterprises work "on demand" by definition and not according to a marketing concept.

Innovations in the construction industry are often brought in as a result of practical research. Immediate solution concepts for a practical construction task. This is the typical business of professors before their teaching activities.

3 REFERENCE FRAMEWORK TO DESCRIBE THE EMPLOYABILITY IN CIVIL ENGINEERING

3.1 Basic Principles

The design of study programs must remain in the sole responsibility of the universities to respect the granted freedom of research and teaching. In Germany, the selected qualification goals are reviewed within the framework of accreditation procedures according to the rules of the Stiftung Akkreditierungsrat (Accreditation Council Foundation). The German accreditation system is closely related to the objectives of the study structure reform and the Bologna Process in connection with the meanwhile established European and international standards of quality assurance. These include:

- The quality responsibility of the universities;
- uniform standards with regard to qualification goals, studyability and the quality of the processes;
- freedom of research and teaching as well as the free choice of educational institution guaranteed by fundamental law;
- diversity, comparability and transparency;
- expert-centred accreditation procedure;
- stakeholder participation;
- orientation towards qualification goals and competences.

In addition to the technical aspects, the qualification goals also include scientific qualification and the ability to take up qualified employment [6].

To evaluate the employability ("Beruflichkeit") of the graduates of a study programme in the accreditation procedure, an outcome-oriented reference framework for bachelor degree course in civil engineering is required. It was developed in a voluntary association of stakeholders [3]. The participants included universities, universities of applied sciences, the construction industry, the building trade, the “Oberprüfungsamt für den höheren Technischen Verwaltungsdienst” (governmental examination board), students, chambers of engineers and other stakeholder. One reason for the project was the concern that accreditation procedures might create a predominance of individual scientific opinions in the validation of the employability.

The reference framework describes fields of competence with a volume of 135 credit points (ECTS) which should be covered within a bachelor degree course in civil engineering to ensure the necessary breadth in academic education. To describe employability, a learning objective-oriented matrix is defined in which the obtained competences in the subject areas "technical basics", "engineering design and planning", "structural design" and "engineering economics and management" can be compared with objectives across all courses. The frame of reference refers only to bachelor degree courses in civil engineering, the application is voluntary.

A very large circle of stakeholders was represented (e.g. 85.000 companies in different construction sectors), so that the reference framework received broad attention. It is also seen to be helpful that universities and universities of applied sciences have jointly agreed on the description of employability for civil engineering. The stakeholders agreed to ensure that the reference framework will be considered within all accreditation procedures for bachelor degree courses in civil engineering at universities and universities of applied sciences in Germany.

3.2 Concept of the reference framework

A main target of the stakeholders involved was to provide a well-founded and broad knowledge of civil engineering. This profile of an “allrounder” is regarded as a prerequisite for employability and basis for specializsation areas, which can be further developed within the framework of a master programme.

For this reason, the reference framework reflects sectors of competence which the stakeholders consider to be essential and which should be covered within a bachelor degree course in civil engineering. These fields of competence are summarised in *Table 1*, based on [7].

Knowledge, skills and competences are listed in the reference framework to specify the sectors of competence. These are provided as guidelines: Full implementation is not expected in every case. The selection and focus of each course will be left to the specific course design. It is assumed that the sections of competence are covered with 135 credit points (ECTS). Assuming 30 hours of workload per credit point and a total of 30 credits per semester (six month of study), this equates to 4.5 semesters of study, leaving time to set priorities in optional modules or to pursue one's own specialist interests. A total of 180 credit points are awarded for a 6-semester bachelor degree course in civil engineering. At universities of applied sciences seven semesters are standard with 210 credit points.

Table 1. Sectors of competence which should be covered within a bachelor degree course in civil engineering [3]

Sectors of competence	**Courses in civil engineering, e.g.:**
Technical basics	mathematics, computer sciences, digital building construction, building physics, engineering mechanics, structural design, building materials science, surveying, economics, laws, ecology
Structural and engineering design	Structural analysis, concrete and masonry, steel construction, wooden construction, geotechnical engineering
Water engineering	Water resources management, hydraulic engineering, urban water management
Management of resources	Waste management, recycling management
Transportation	Traffic and transport planning, road construction, public traffic systems, urban and regional planning
Construction and engineering management	Management of building projects and processes, business economics, project planning and scheduling

Until today, the construction industry has hardly complained about a lack of employability among graduates. It is regarded as usual to "familiarise" entrants with the job for a certain training period and to introduce them internally to the job requirements. At the beginning of their career, graduates are usually accompanied by a suitably qualified, experienced and responsible person.

For the first time, the introduced reference framework describes the level of competence of graduates required from the point of view of “construction practice”. Construction industry and building trade criticised the fact that so far the competencies of the graduates in the areas of technical basics and structural design have strongly predominated, compare *Fig. 1*.

On the job, a higher proportion of competences in engineering economics and management and engineering design and planning is required. Civil engineers must be able to assess the impact, consequences and economic viability of their decisions. A bachelor degree course in civil engineering has to prepare for this demand and the mandatory basic competences must be imparted. For this reason, the stakeholders are regarding the ratio shown in *Fig. 2* as necessary for the competences obtained within a bachelor degree course to guarantee employability.

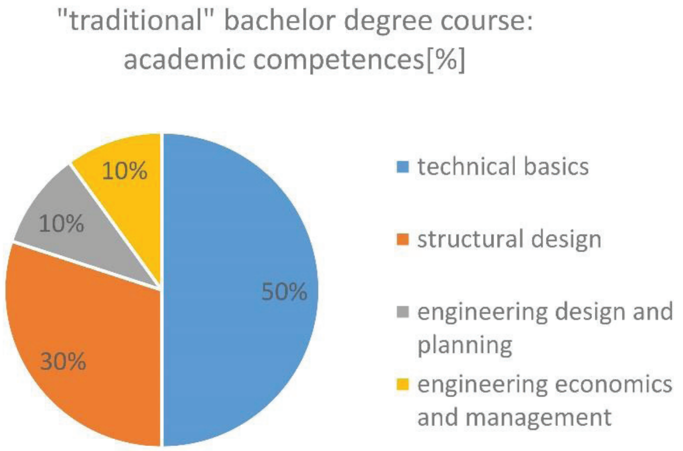

Fig. 1. Sample of the percentage distribution of competences in “traditional” bachelor degree courses in civil engineering

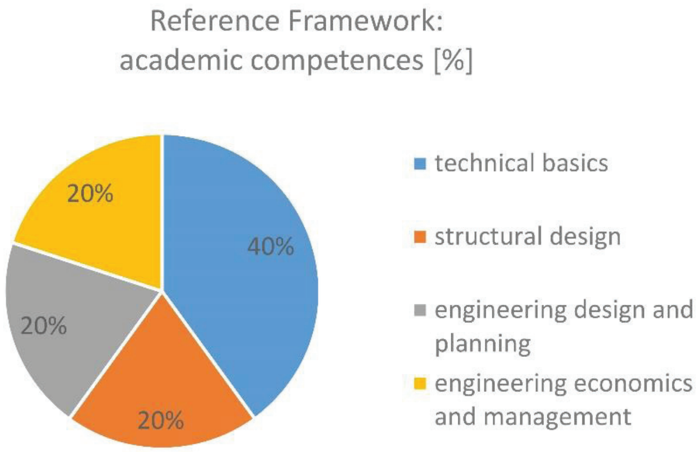

Fig. 2. Percentage distribution of competences recommended by the reference framework to fulfil requirements of professional civil engineering

In order to give the universities sufficient flexibility in designing their programmes, a new approach to review the distribution of competences has been developed: Basis are the four segments of competences in Fig. 1 and 2 (technical basics, structural design, engineering design and planning, engineering economics and management). These are referred to as “dimensions of competence”.

The stakeholders agreed not to recommend any concrete stipulations with regard to the distribution of courses. Rather, an overarching recommendation was made that 40% of the entire programme should cover the dimension of competence "technical basics" and 20% each the competence dimensions "structural design", "engineering design and planning" and "engineering economics and management". Large parts of the course will cover all four areas [3].

Since there are complaints in accreditation practice about an overweight of formal testing procedures, the criteria applied and the procedure for checking the distribution of competences should be transparent and easy to handle. For this purpose, a bachelor degree course matrix was developed with which the competence profile of a study programme or of individual study and specialisation fields can be worked out and compared with the competence distribution 40%/20%/20%/20% recommended by the reference framwork according to Fig. 2.

What is new here is the approach that the ratio of competences taught is not to be achieved on basis of the courses, but on the average of all compulsory courses, based on 135 credit points. For this purpose, the distribution of competences for each module must be determined and summarised. The procedure is explained in Table 2.

The distribution of competences depends on the individual design of the module. For example, a module such as "Structural Engineering" can contain elements from engineering planning, structural design and construction management. Individual modules may therefore cover all four competence dimensions, each in different proportions. This should at the same time emphasise the complexity of construction tasks and the job reality of engineering activities in the construction industry.

Table 2. Principle of the bachelor degree course matrix: In the compulsory area, the competence shares in the dimensions of competence "technical basics", "engineering design and planning", "structural design" and "engineering economics and management" are recorded in each module and weighted based on 135 credit points in total. The table shows an intermediate status for five example modules. The distribution of competences depends on the individual design of the module. Overall, the distribution of competencies should be 40%/20%/20%/20% as shown in Fig. 2.

Acquired competences→ Modul↓	ECTS	technical basics	engineering design and planning	structural design	engineering economics and management
Building Physics	5	70%	15%	15%	0%
Structural Masonry	5	10%	30%	50%	10%
Hydraulic Engineering	5	20%	40%	30%	10%
Management	5	0%	10%	0%	90%
Other Module	5	x	x	x	x
Subtotal	20	100%	95%	95%	110%
Mean obligatory module	135	3,7%	3,5%	3,5%	4,1%

Recommendation	135	40%	20%	20%	20%

A sample spredsheet with instructions for use is available for download to simplify processing during accreditation. The "mandatory programme" listed in the frame of reference should correspond to at least 135 credit points. The additional credit points required will be awarded within the framework of the bachelor thesis as well as with the acquisition of additional, possibly interdisciplinary competences.

Further criteria are the equipment of the university and the imparting of "soft skills". The frame of reference proposes a questionnaire for reviewing the equipment. Soft skills must be the subject of higher education, but cannot be assigned to any field of competence in terms of content. For this reason, a selection of competences is defined that should be integrated into the teaching of subject content. In addition, the reference framework recommends an internship of at least 12 weeks during the course of study.

The recommended distribution of competences 40%/20%/20%/20% should not be applied rigidly in a formalistic manner, but provides an orientation framework. However, deviations are made transparent and can be assessed in the accreditation procedure.

4 SUMMARY

The presented reference framework describes the current professional understanding in civil engineering in Germany in a transparent and outcome-oriented way. It was developed by a large circle of stakeholders and contributes to ensuring that the description of employability of graduates in all bachelor degree courses in civil engineering remains the sole responsibility of the universities. In Germany, civil engineering is the first engineering discipline to have succeeded in describing a profession in this way on an academic basis. In addition, universities and universities of applied sciences have agreed on one description of employability despite their different qualification goals.

For the first time, the reference framework takes into account the level of competence of the graduates required from the point of view of construction practice. A higher proportion of competences in engineering economics and management and in engineering design and planning are required for the practice of the profession. Civil engineers must be able to assess the implications, consequences and economic viability of decisions. In bachelor degree courses in civil engineering, the prerequisites must be defined, the mandatory basic competences have to be imparted and a corresponding awareness should be developed. The reference framework provides criteria and gives universities sufficient flexibility in designing their degree programmes without restricting the legally guaranteed freedom of research and teaching.

This paper is intended to contribute to the discussion of professionalism and occupation in accreditation practice also in an international context. The presented reference framework is a successful example for „democratic involvement in educational processes“.

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Integrating SDGs into the Bachelor's Degree in Civil Engineering

E. Gimenez-Carbo[1]
Universitat Politècnica de València
Valencia, Spain

M.E. Gómez-Martín
Universitat Politècnica de València
Valencia, Spain

I. Andrés-Doménech
Universitat Politècnica de València
Valencia, Spain

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ABSTRACT

Universities are increasingly re-thinking their role in the twenty-first century and looking to be both more responsive to societal needs and to become agents of change towards solving global challenges. As a universally agreed framework, the Sustainable Development Goals (SDGs) provide an organising structure for what this looks like for the University.

This paper develops the work undertaken by the Civil Engineering School at Universitat Politècnica de València (Spain) to adapt the Bachelor's Degree in Civil Engineering program curriculum so that SDGs will be integrated into the student outcomes. In fact, one of the targets for the SDGs announced by the United Nations in September 2015 aims to ensure that all learners acquire the knowledge and skills needed to promote sustainable development.

Civil engineering is one of the professions that most affects our environment. Indeed, infrastructures modify and shape our world to make better societies, but it is imperative engineers are aware of the consequences their decisions have. In this context, it is of paramount importance that civil engineering programs include one of the most ambitious and important global agreements related with sustainable development.

[1] Corresponding Author
E. Gimenez-Carbo
esgimen@cst.upv.es

To achieve this goal, a diagnosis of the program curriculum was developed to identify at what extent the different subjects and courses are related with the 17 SDGs. Weaknesses and non-related SDGs were identified and minimum requirements defined to be added into the program to achieve the 2030 agenda goals. In addition, a sustainable rubric is proposed, in order to analyse the ability of students to incorporate sustainability principles into their work.

1 INTRODUCTION

1.1 The Spanish 2030 Agenda

On September 25th 2015, the General Assembly of the United Nations (UN) adopted one of the most ambitious and transcendent global agreements of our time: the 2030 Agenda for Sustainable Development with the slogan "Transforming our word" [1]. The Agenda is an action plan for people, the planet and prosperity and also seeking to strengthen universal peace in larger freedom.

The Agenda proposes 17 Sustainable Development Goals (SDGs) with 169 integrated and indivisible targets aiming at addressing the most urgent global challenges: ending poverty and promoting economic prosperity, social inclusion, environmental sustainability, peace and good governance for all peoples by 2030.

In June 2018, the Spanish Government approved the "Action Plan for the 2030 Agenda Implementation" [2]. The document presents the state of the country and analyses the situation of SDGs in Spain as well as the actions to be carried out to implement the Agenda. Within the document, the University is mentioned as a key actor that must commit to the implementation of the Agenda; seven contributions from Spanish universities to the application of the 2030 Agenda are explicitly indicated [2]. Among them, we highlight:

a) *(2) A firm commitment with the inclusion of outcomes related to a sustainable and inclusive development, both necessary for the construction of a global citizenship; the commitment must involve the training of all students, the teaching and research staff and also the administration and services staff.*
b) *(3) The generation and transfer of knowledge committed to sustainable development, including knowledge needed to implement and monitor the 2030 Agenda progress.*
c) *(7) Commitment from the universities to report on impacts in terms of teaching, research and transfer, regarding the implementation of each SDG.*

Within this context, the Vice-Rectorate for Studies, Quality and Accreditation at Universitat Politècnica de València (UPV), is carrying out a teaching innovation program to adapt the graduates outcomes with SDGs, by incorporating them into the curriculum learning outcomes. First, students will have to incorporate into their Bachelor Thesis an explicit critical analysis justifying to which extent their work relates to SDGs. In addition, students will have the opportunity to enrol for specialised and specific on-line training on each SDG. In a second stage, the incorporation of SDGs into the Degree programs will be encouraged, at all levels. The work presented herein focuses on the possibilities for the Bachelor's Degree in Civil Engineering program.

1.2 Civil Engineering and SDGs

In today's societies, professional activity has a significant role and clearly influences the structure and behaviour of our social life. Therefore, it is of paramount importance that professionals know and assume SDGs in their daily tasks to ensure strongly committed societies with the 2030 Agenda.

Civil engineers have a great responsibility as agents that transform the environment; since the creation of the first Institution of Civil Engineers (ICE) in the United Kingdom, civil engineers have reflected on the work they do. In 1828, during the ICE creation, Tredgold [3] defined civil engineering as "*being the art of directing the great sources of power in nature for the use and convenience of man, as the means of production and of traffic in states, both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation, and docks, for internal intercourse and exchange; and in the construction of ports harbours, moles, breakwaters, and lighthouses, and in the art of navigation by artificial power, for the purposes of commerce; and in the construction and adaptation of machinery, and in the drainage of cities and towns".* This definition has evolved over time and in 2007 the institution rephrased it: *"civil engineering is a vital art, working with the great sources of power in nature for the wealth and well-being of the whole of society".*

Civil engineering associations worldwide define civil engineering in similar terms; for example the American Society of Civil Engineers (ASCE) of the United States says that "*civil engineers design, build, and maintain the foundation for our modern society – our roads and bridges, drinking water and energy systems, sea ports and airports, and the infrastructure for a cleaner environment*".

Following the Summit on the Future of Civil Engineering held in June 2006, ASCE published the document "The Vision for Civil Engineering in 2025", which establishes an aspirational global vision of the profession for the 21st century [4]: "*In 2025, civil engineers serve competently, collaboratively, and ethically as master*:

- a) *planners, designers, constructors, and operators of society's economic and social engine—the built environment;*
- b) *stewards of the natural environment and its resources;*
- c) *innovators and integrators of ideas and technology across the public, private, and academic sectors;*
- d) *managers of risk and uncertainty caused by natural events, accidents, and other threats; and*
- e) *leaders in discussions and decisions shaping public environmental and infrastructure policy.*

In general, all civil engineering associations in the world adopt these definitions to explain the civil engineer's tasks and their importance in shaping the environment for better societies, for instance, by establishing transportation networks or by ensuring a sustainable resources' management. All these challenges represent a great responsibility and a direct influence on the achievement of the 2030 Agenda. As a consequence, it is worthy necessary that Schools of Civil Engineering promote and educate students to achieve SDGs during their professional development.

The School of Civil Engineering at UPV, is analysing how to integrate SDGs in the Bachelor's Degree in Civil Engineering program curriculum, to ensure that graduates outcomes incorporate the main challenges of SDGs related to civil engineering.

2 HOW TO START

2.1 Methods

Many universities have incorporated sustainability into their academic programs ([5], [6], [7], [8] and [9]). These experiences are a good starting point to integrate SDGs in the Bachelor's Degree in Civil Engineering program curriculum. Different methodologies are usually used for analysis of academic programs: surveying for students, curriculum detailed analysis, interviews with academic staff or with other actors involved in the graduates' curriculum, etc.

Within this work, we have followed a methodology based on the STAUNCH tool [10] for integrating SDGs into the Bachelor's Degree in Civil Engineering program curriculum. The steps to be achieved are:

a) Selection of criteria to be analysed.
b) Information gathering; all program course syllabi are analysed, focusing on objectives, outcomes and assessment methods.
c) Information classification.
d) Program analysis and proposals.

For this purpose, it is necessary to identify the SDG-related topics that are already being taught, identifying which SDG target they contribute to. Potential courses that can contribute will also be identified as well as new needed topics. Finally, activities developed in the School will also be analysed from a SDG perspective so that students acquire from a holistic way skills and knowledge that the 2030 Agenda addresses.

The 59 courses within the academic program were analysed (*Table 1*); interviews with academic staff responsible of potential courses to include SGD-oriented topics were also held to receive their input.

Table 1. Bachelor's Degree in Civil Engineering: program curriculum.

Code	Subject	ECTS	Courses
MAT	Mathematics for civil engineering (CE)	19.5	Mathematical fundamentals of CE Mathematical methods of CE Mathematics - Extension course
MMO	Mathematical modelling	10.5	Basic programming and numerical methods Basic statistics
REP	Representation systems	12.0	Drawing Representation systems
PHY	Physics for CE	19.5	Fundamentals of physics in CE Mechanics Physics- Extension course
ECO	Economics and business	4.5	Economics, legislation and business management
GEO	Geology	6.0	Geology applied to civil works
TOP	Topography and cartography	4.5	Surveying
FBU	Fundamentals of building engineering	25.5	Chemistry for civil engineering Construction materials and their application to CE Construction procedures (I) and (II) Electrical engineering
FST	Fundamentals of structural engineering	21.0	Mechanics of deformable solids Structural analysis Structural concrete / Structural steel (I)
GTC	Geotechnics	6.0	Geotechnics and foundations
HHY	Hydraulics and hydrology	7.5	Hydraulics and hydrology
FEN	Fund. of environ. impact	4.5	Science and environmental impact of CE
BUS	Business management	4.5	Business management
RIN	Road infrastructures	10.5	Highways and airports / Railways
TRA	Transportation and land dev.	4.5	Transportation and land development
BEN	Building engineering	15.0	Industrialized construction Maritime works Risk prevention and work organization
HYD	Hydraulic infrastructures	6.0	Hydraulic infrastructures
BDG	Building	6.0	Building
LAN	Land engineering	6.0	Geotechnical eng. techniques and methods
PRO	Projects	4.5	Projects
COM	Training complements for civil engineering	31.5	Building Information Modelling Civil engineering and society Conceptual design of bridges Concrete structural elements Construction management and organization Ethics in CE Geotechnical design of foundations and ret. walls Hydraulic and energy facilities Infrastructure maintenance management Introduction to water quality Management of construction and consulting Mobility and urban transport Philosophy of structures Port facilities River basin manag., water ress. and river eng. Road safety Structural design of foundations and ret. walls Structural steel (II) Surface and groundwater hydrology Technology of concrete structures Urban history and planning Urban hydraulic facilities
THE	Bachelor thesis	12.0	Bachelor thesis

2.2 Diagnosis

Once the program curriculum analysed, we notice that, as expected, the Bachelor's Degree in Civil Engineering has great potential to integrate SDGs into the students' outcomes.

The detailed analysis of the 59 course syllabi (*Table 1*) shows that there are currently only 17 courses explicitly working with any of the 169 targets defined within the 17 SDGs. These 17 courses are directly related to 11 of the 17 SDGs. This means that in 18 of the 22 subjects within the program curriculum, some of the SDGs targets are worked on (*Table 2*).

Table 2. SDG targets developed (green) or with potential to be developed (yellow) within the program curriculum subjects.

Code	SUSTAINABLE DEVELOPMENT GOAL																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
MAT																	
MMO																	
REP																	
PHY																	
ECO					5.5			8.2 8.4 8.8		10.4		12.6					
GEO						6.6							13.3				
TOP																	
FBU			3.9			6.3	7.3		9.4			12.4 12.5					
FST									9.4			12.2					
GTC																	
HHY						6.4			9.4		11.5 11.b	12.2	13.1		15.1		
FEN					5.5	6.6		8.4 8.5			11.3 11.4 11.6		13.3		15.1 15.2 15.3 15.5 15.4 15.9		
BUS					5.5			8.3 y 8.8	9.4			12.2 12.6					17.7
RIN									9.1 9.4		11.2	12.2					
TRA			3.6			6.6			9.1 9.4		11.4 11.6 11.7		13.1				
BEN							7.2	8.8	9.4		11.5 11.b	12.2	13.1	14.1 14.2 14.7			
HYD		2.4				6.1 6.2	7.2					12.2	13.1				
BDG											11.1 11.c	12.2					
LAN												12.2					
PRO									9.4		11.b	12.2	13.1 13.3				
COM		2.4	3.6 3.9	4.7	5.5 5.c	6.1 6.2 6.3 6.4 6.5 6.6	7.2	8.3 8.8	9.1 9.2 9.4	10.2	11.1 11.2 11.3 11.4 11.5 11.b	12.2 12.6 12.7 12.8	13.1 13.3	14.1 14.4	15.1	16.7	17.7 17.14 17.17
THE	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

(*) the target will depend on the specific bachelor's thesis topic

The following SDGs must be highlighted:

a) SDG #6 “Clean water and sanitation” is developed into 6 courses within years 1, 3 and 4.
b) SDG #9 “Industry, innovation and clean energy” is developed into 4 courses within years 2 and 4.
c) SDG #11 “Sustainable cities and infrastructure” is developed into 5 courses within years 3 and 4.
d) SDG #13 “Climate action” is developed into 3 courses within years 3 and 4.

However, this analysis has shown, first, that courses already working with any of the SDGs still have potential to integrate other SDGs. Then, there are 25 courses clearly aligned with some SDGs that although they do not work them at present, they also have potential to do so, as their topics and outcomes are linked to the targets defined within the 17 SDGs. Finally, there are only 17 courses within the program curriculum where there is not an evident link to SDGs; they basically correspond to subjects of basic training in mathematics, physics and drawing.

Given the SDG targets directly related to the previously identified courses, we demonstrate that civil engineering is basically related to 5 of the 17 SDGs. These SDGs are the most related to the program curriculum so the ones with most potential to be developed in many courses within the curriculum are:

a) SDG #6 “Clean water and sanitation”: up to 10 courses.
b) SDG #9 “Industry, innovation and clean energy”: up to 25 courses.
c) SDG #11 “Sustainable cities and infrastructure”: up to 15 courses.
d) SDG #12 “Responsible production and consumption”: up to 16 courses.
e) SDG #13 “Climate action”: up to 12 courses.

The rest of SDGs can be integrated in different courses (between 1 and 9) with different depth and scope, depending on the specific case. In addition, all SDGs can be developed within other university activities that lead to ECTS credits recognition foreseen by the Spanish law (Royal Decree RD1393/2007).

Courses with the greatest potential to include SDGs, considering the number of SDGs that are integrated or have potential to, are the following:

a) Transportation and land development (year 2): 5 SDGs
b) Hydraulics and hydrology (year 3): 6 SDGs
c) Maritime works (year 3): 6 SGDs
d) Business management (year 4): 5 SDGs
e) Hydraulic infrastructures (year 4): 6 SDGs
f) Management of construction and consulting (year 4): 5 SDGs
g) Ethics in civil engineering (year 4): 8 SDGs

The year 4 course “Civil engineering for society” has a relevant importance since it is the only subject of the curriculum linked to SDG# 16 “Peace, justice and strong institutions”. In the same way, the course “Ethics in civil engineering” is the only course that develops SDG# 4. The next section develops a proposal with specific actions.

3 PROPOSAL

3.1 Actions in three levels

Continuous improvement in a degree program at Universitat Politècnica de València includes, according to the Quality Manual of the institution, actions in two areas: improvements in the University's or the School's own processes and improvements in the design of the academic program itself.

Improvements in the program design must be undertaken by the program Academic Committee, which must analyse, assess and incorporate them into the corresponding annual report of the degree. These improvements can lead to two situations:

a) The improvement proposal does not imply a modification of the program verification. In this case, after the evaluation of the UPV Quality Service, its implementation is immediate and is the responsibility of the school.
b) The improvement proposal implies a modification of the program verification. In this case, the modification process must be initiated to submit the new title proposal for verification by the National Agency for Quality Evaluation and Accreditation (ANECA). In the Spanish context, this is a long and administratively complicated procedure that can last up to two years.

Within this context, actions are proposed at three different levels to incorporate SDGs into the learning outcomes and professional profile of the Bachelor’s Degree in Civil Engineering graduates

The first level, which is immediate to apply, consists of introducing transversal activities related to the 2030 Agenda, so that all students know their extent. The most immediate way of achieving this purpose is by proposing a compulsory training activity for first-year students that can be taught within the framework of the Tutorial Action Program (PATU) [11]. This activity will explain the objectives of the 2030 Agenda, the 17 SDGs and the 169 targets. This level corresponds to the previously mentioned improvements in the own processes, in this case, of the School.

The second level will propose changes at the program subject level. Following the analysis presented in section 2, all subjects related to SDGs are known. Given this, it is proposed to hold meetings with the academic coordinators of courses within these subjects, together with experts in the 2030 Agenda, to address changes to effectively include SDGs into the students’ learning outcomes. This level corresponds to improvement proposals that do not imply a modification of the program verification. Consequently, their implementation is relatively simple and viable.

Finally, the third level corresponds to improvement proposals that imply a modification of the program verification. The room for change and the immediacy in the implementation of these proposals is very limited, as previously mentioned. However, it is also important to consider actions at this level, since they are the ones that can lead to more integrated and articulated changes throughout the program curriculum.

All the potential possibilities detected in the diagnosis can be addressed with actions at the second level, given that they would simply include specific actions in the different course syllabi. On the other hand, future revisions of the curriculum that would led to modifications in the program verification must address if courses at present elective should be compulsory within the program curriculum, for instance, “Civil Engineering for Society” or “Ethics in Civil Engineering”.

3.2 Action efficiency assessment

Besides studying how to introduce SDGs into the Bachelor's Degree in Civil Engineering program curriculum, we also had to consider how to assess that students have achieved these learning outcomes. All students must pass exams to verify that they have reached the learning outcomes, so topics related to SDGs that were introduced in each course are relatively easy to assess (of course, assessment activities must be adequately defined so that this statement is valid). In addition, it is also very important to realise that integration of these contents in the program curriculum will make them present in every work that civil engineers will develop in their professional activity.

Once the students leave the School, it is very difficult to track them from the professional perspective (it will be the responsibility of the professional associations). The last academic chance to assess them regarding at what extent their learning outcomes are aligned with the SDGs is with their Bachelor Thesis. At this point, they will develop the most similar activity to the technical work that they will carry out during their professional career.

Therefore, a rubric (a sustainable holistic rubric) has been developed to analyse the ability of students to incorporate SDGs into their work (*Table 3*). This rubric is based on that presented by Crespo et al. (2017) [12]. The rubric has been designed considering the five parts in which SDGs are grouped and four levels of achievement (A, B, C and D) to access the integration of SDGs. Two scopes, potential and assigned are considered. The adaptation of the rubric to four levels has been made to maintain the same assessment system that is carried out at UPV to evaluate the generic outcomes.

The potential score will be used to indicate whether the Bachelor Thesis has potential to include some SDGs. In this case, A means “required”; the SDG must be present and its presence is critical for the development of the Bachelor Thesis. B means “adequate”; it is advisable that the SDG is present within the work. C means “valid”; the SDG can be present within the work, although it is not necessary. Finally, D means “not applicable”; the SDG is not linked to the work.

The assigned score shows the development level of each SDG in the Bachelor Thesis. In this case A means “excellent”; there is evidence that the SDG is present in the work, and its inclusion conditioned the final result. B means “adequate”; the SDG is mentioned and applied throughout the work; C means “deficient”; the SDG is mentioned, but it is not applied or applied in an unclear or incorrect way. Finally D means "failure"; the SDG is not included within the work.

Table 3. The sustainable holistic rubric

Factors to consider	Potential	Assigned
People		
SDG #1 No poverty SDG #2 Zero hunger SDG #3 Good health and well-being SDG #4 Quality education SDG #5 Gender equality		
Planet		
SDG #6 Clean water and sanitation SDG #12 Responsible consumption and production SDG #13 Climate action SDG #14 Life below water SDG #15 Life on land		
Prosperity		
SDG #7 Affordable and clean energy SDG #8 Decent work an economic growth SDG #9 Industry, innovation and infrastructure SDG #10 Reduced inequalities SDG #11 Sustainable cities and communities		
Peace		
SDG #16 Peace, justice and strong institutions		
Partnerships		
SDG #17 Partnerships for the goals		

4 CONCLUSIONS

The analysis of the Bachelor's Degree in Civil Engineering program curriculum taught at Universitat Politècnica de València leads to the following conclusions:

a) Training of civil engineers must include SDGs into their curriculum.
b) The revision of the course syllabi within the different subjects of the program curriculum, has led to identify the presence and potential incorporation of the different SDGs into the civil engineers' training.
c) Actions at three levels have been considered to incorporate SDGs into the curriculum.
d) A rubric is proposed to assess the ability of students to incorporate SDGs into their work, at course level and at their Bachelor Thesis.

With all this information, changes will be introduced in the Bachelor's Degree in Civil Engineering program curriculum at UPV and their effectiveness will be assessed. Consequently, all graduates will know the content of the 2030 Agenda, and will be able to take into account SDGs in their future daily professional practice.

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Introducing Professional Ethics as a Soft Skill

An example in the Civil Engineering bachelor's degree program in UPV.

E. Gimenez-Carbo[1]
Universitat Politècnica de València
Valencia, Spain

M. Roig Flores
Universitat Politècnica de València
Valencia, Spain

M. J. Pelufo Carbonell
Universitat Politècnica de València
Valencia, Spain

P. Serna Ros
Universitat Politècnica de València
Valencia, Spain

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ABSTRACT

According to the Civil Engineering bachelor's degree program in Spain, students should have acquired, among others, the skill "to understand and assume the ethical and professional responsibility of the activity of the Civil Engineer". This knowledge is taught in an optative subject called "Ethics of civil engineering", and also through the transversal or soft skill "ethical, environmental and professional responsibility" that is covered in several subjects of the program. Since not all the students enrol the specific subject, learning professional ethics through the soft skills becomes of special importance.

This communication presents the methodology used in the subject "Constructions Materials" from the second year to introduce this soft skill. The approach consists on having this skill present in all the sessions in the classroom, and to obtain evidences of the steps learned by the student, a rubric is proposed, which allows the teacher to evaluate the acquisition of the competence in an agile and truthful way.

[1] Corresponding Author
E. Gimenez-Carbo
esgimen@cst.upv.es

Current situation shows that, more often than expected, civil engineering students and professionals have difficulties in identifying malpractices in the development of their profession, probably due to their high frequency. To overcome this situation, students need to be fully aware of the consequences of their decisions and the severity of their mistakes. Society needs engineers able to understand the full scope of their work, including the ethical responsibility derived from their position. Engineering Schools must dedicate strong commitment to improve the integral formation of their graduates with special emphasis on professional ethics.

1 INTRODUCTION

1.1 The beginning of the introduction of soft skills in the curriculum.

The arrival of the European Higher Education Area (EHEA) forced the redesign of Spanish university degrees to adapt to a common reference framework to make qualifications for the different EHEA countries more understandable across different systems [1]. In 2001, the Spanish Government published the Organic Law 6/2001 indicating the compromise of convergence to the EHEA [2]. From 2003, the Ministry of Education and Science published reports that talked on the objective of "providing a university education that harmoniously integrates the basic generic skills, skills related to the integral formation of persons and more specific skills that enable a professional orientation that allows graduates integration in the labour market”.

Having these frameworks as a basis, the Civil Engineering Schools of Spain began to design the new degree programs incorporating the transversal or soft skills that the students had to acquire. However, even though they were assigned to different subjects, during the first years of implementation of these new degrees’ programs, transversal skills were not systematically implemented and evaluated, which means that their acquisition was not strictly guaranteed.

For this reason, an initiative of the Vice-Rectorate for Studies, Quality and Accreditation of the Universitat Politècnica de València (UPV), supported by the strategic plan UPV 2015-2020, developed the institutional project of incorporating transversal skills in the curriculum of graduates of the UPV [3]. The fundamental objective of this action is that the students acquire and accredit the achievement of these transversal skills. Based on guidelines and national and international standards, specialized publications and taking into account the regulations or recommendations of some degree programs, the UPV defined 13 transversal competences that should be trained in all curricula (*Table 1).* Most of these skills were already being trained on a regular basis, but in most cases were not evaluated.

Table 1. Transversal skills in all degrees of the UPV.

Code	Transversal Skill
CT-01	Comprehension and integration
CT-02	Application and practical thinking
CT-03	Analysis and resolution of problems
CT-04	Innovation, creativity and entrepreneurship
CT-05	Design and project
CT-06	Teamwork and leadership
CT-07	Ethical, environmental and professional responsibility
CT-08	Effective Communication
CT-09	Critical thinking
CT-10	Knowledge of contemporary problems
CT-11	Life-long learning
CT-12	Planning and time management
CT-13	Specific instruments

To evaluate the acquisition of these soft skills, in 2015 the UPV Institute of Education Sciences (ICE), in collaboration with professors of different degrees, developed several rubrics which had to be achieved in different courses differentiating levels of skill domain: first level domain for the first and second courses of bachelor's degree, second level domain for the third and fourth courses and, third level of domain for the master's degree.

As a result of this project, the Civil Engineering School of UPV redefined the soft skills that should be included in the degree program and the assessment criteria for the achievement of the skill using the rubrics. To do this, regardless of the number of subjects that train these skills, several subjects were stablished as a checkpoint to evaluate the acquisition of the soft skills in different courses of the bachelor's degree program covering the different levels of domain. In this framework, the subject "Construction Materials" from the second year of the degree of Civil Engineering became a checkpoint of the soft skill seven (CT-07) "Ethical, environmental and professional responsibility" for the first level of domain.

1.2 The role of accreditations

At the same time as the introduction of soft skills, the Civil Engineering, B.Eng. and M.Eng programs from the Civil Engineering School of Valencia obtained the ABET accreditation on October 1st, 2015. During the current school year, they have been renovated and will remain active until the September 30th, 2024. ABET accreditation ensures that a university program meets the quality standards of the profession for which that program prepares graduates. Thus, it may help students to choose programs with quality guarantees and employers to select well-prepared graduates to exercise the profession. As a matter of fact, in Spain only two bachelor's degree programs in Civil Engineering have the ABET accreditation.

The quality criteria for accrediting bachelor level engineering programs considers eight specific criteria: 1) the students (admission, progress, evaluation...), 2) the establishment of educational objectives that the graduates will reach a few years after their graduation, 3) the competences that the students acquire throughout their studies, 4) the process of continuous improvement, 5) the curriculum, 6) the teaching staff, 7) the facilities and infrastructures available, and 8) the institutional support that guarantees the teaching of the degree.

To obtain the accreditation, the bachelor's degree program must have documented student outcomes that support the program educational objectives [4]. Among these outcomes, one covers the "ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability", and other directly refers to the "understanding of professional and ethical responsibility". These two points are directly related to the soft skill "ethical, environmental and professional responsibility". Therefore, it is not only essential to train the learning outcome, it is also necessary to obtain evidences of the outcomes to achieve the accreditation.

For this reason, it is necessary to design an activity that permits a quick and efficient evaluation of the acquisition of this competence/skill and obtaining an evidence to certify it.

2 DESIGN AND IMPLEMENTATION OF THE ACTIVITY

2.1 First implementation attempts

As a result of the concern for the introduction of soft skills in the student's curriculum, a project of innovation and educational improvement (PIME) was elaborated. The PIME tittle was "The introduction of professional responsibility in the curriculum of Civil Engineering degree" and it was developed during the course 2013-14. This project involved different subjects from different courses of the degree program, and it was previous to the strategic plan UPV2015-2020 mentioned above. From that moment, two classroom actions were carried out and their outcomes were collected as a result of the PIME project.

The first action aimed to raise students' awareness of the professional responsibility that they will assume when graduating, throughout the development of the subjects that were involved in the project. This action is based on the experiences described in the classroom by professors, who describe real experiences and decisions taken in the professional field. These experiences undoubtedly influence the training of students and transmit the responsibility that goes hand in hand with their professional work. This is the most usual way for Spanish undergraduates to become aware of the responsibility of their profession.

The second action involved the organization of two practical sessions throughout the course. In these sessions, moral dilemmas [5] were raised and the students had to discuss in small groups and then, to discuss in the whole class in a general debate. Students work and knowledge of this skill was evaluated through a rubric specifically designed for this activity. Several obstacles appeared during these sessions. One of the main difficulties was that many students were facing a moral dilemma for the first time and thus, they did not know the strategies and tools to solve them nor could they consider all the factors affecting the dilemma. Another difficulty was that the focus was made in the dilemmas directly related with the subjects in which they were taught, and they were not designed to have a progressively developing nature, which produced that in some cases younger students had to solve dilemmas of high complexity. In addition, several professors expressed their concerns over their ability to perform this type of training. To work appropriately the moral dilemmas, the professor must know and understand codes of ethics, and justify the final solution following the thinking process of moral reasoning to determine whether an idea is right or wrong. Finally, another problem detected with this methodology was the soft skill “ethical, environmental and professional responsibility” was only trained during the two sessions in which the moral dilemmas were raised, and it was not present in the rest of the sessions of the course.

Despite all the problems identified, the experience was considered as very positive since it allowed to clarify the students’ knowledge of this soft skill, as well as the a better understanding of the limitations of the professors and, thanks to this activity, a first rubric was designed to evaluate the acquisition of this soft skill.

After the publication in 2015, of several rubrics by ICE, for the different skills and differentiating levels of skill domain, we realized that the difficulty level was too high for second course students (first level domain). Using as basis all the work developed in our previous attempts and the new information provided by ICE, we designed a new activity to implement the acquisition of this soft skill in all classroom sessions using a suitable level of difficulty.

2.2 Activity development and evaluation

With the knowledge acquired in the previous experiences, and with the strong conviction that “ethical, environmental and professional responsibility” is a fundamental skill for our students to achieve professional excellence, we re-designed an activity to work and evaluate this soft skill during all classroom sessions.

The activity was planned considering that it was going to be carried out during the second course of the degree and thus, it corresponded with the first level of domain of this skill. In order to facilitate the evaluation of the activity, the rubric designed by the ICE working group was used, whose purpose is to test whether the student has reached the level required for this skill, defined as: "the student will be able to question reality and be aware of the concepts and values from which it is built". This rubric is shown in *Fig. 1*, and each indicator is evaluated using the scores from A (highest score) to D (lowest score).

INDICATORS	DESCRIPTORS			
	D-Unreached	C-Under Development	B-Good	A-Excellent
Become aware of another way of seeing and perceiving things	They have difficulty understanding that there is a plurality of ideas and people that consider and value reality in a different way	Accepts without question the judgments of other people	Explicitly and reasonably assumes the differences	Incorporate ideas from others into your own reasoning and judgment
Accept critically new perspectives	It only takes into account the perspective of those who are most involved in the course of an action and eludes the point of view of third parties	They maintain critically what has to be preserved in a dialogical positioning In a reasonable positioning	They capture and show sensitivity to the needs and interests of others, their Feelings, values, opinions and reasons	They dialogue constructively with the aim of contributing to the understanding and the solution of problems, respecting and recognizing the pretensions of validity of the other pinions
Difference facts and opinions or interpretations in the arguments of others	They do not differentiate opinions or subjective facts judgments	They question judgments or decisions based on opinions, assessments, etc.	They can difference, objective facts of opinions and evaluations	They can analyze justifiably judgments or decisions based on opinions, evaluations, etc.
Reflect on the consequences and effects that decisions and proposals have on open	There is no evidence that they are aware of the effects of the proposed decisions	They provide for the practical implications of decisions and proposals	They analyze advantages or disadvantages of the effects of the proposed decisions.	Provides ideas for improvement
Recognized the ethical and deontological concepts of the profession	Thinks that ethics belongs to the personal sphere	Expresses basic moral opinions	Expresses moral opinions about the correctness or incorrectness of an activity or action	It is able to elaborate arguments where principles and moral judgments come into play Linked to the profession

Fig. 1. Rubric UPV-CT-07. Ethical, environmental and professional responsibility.

For the activity, the students prepare a presentation to expose in the classroom news published in the press or any media, where they detected an inappropriate behaviour conducted by individuals or companies. These inappropriate behaviours may be, among others, cases of corruption, poor professional practices, poor use of resources, cause of ecological damage, etc. The main theme of the news should cover preferably (but not limited to) civil engineering problems.

This presentation can be performed either individually or in small groups, with a maximum length of five minutes. The presentation of the students should explain the facts and discuss at least the following aspects:

- Agents involved in the case
- Identification of the inappropriate action(s)
- Identification of the motivation to perform that inappropriate action(s) (economic enrichment, professional promotion, fear of reprisals, etc.)

The presentation is followed by a discussion/debate involving all the students. The professor evaluates the students using as information what happened in the classroom during the presentation and discussion stages, and using the rubric shown in *Fig. 1* as support for this evaluation. In the specific case of group work, all members of the group will obtain the same grade for the presentation but depending on their degree of participation during the debate, this grade may vary. *Fig. 2* shows some of the works presented by the students.

Fig. 2. Examples of the works presented by the students

3 ANALYSIS OF THE RESULTS

The activity presented has been carried out since 2015 in the subject “Construction Materials" and the results can be considered highly satisfactory. This type of activity presents several advantages over previous activities, including:

- The soft skill trained is present in all classroom sessions, which guarantees its presence throughout the course.
- When making presentations and oral discussion, the professor, who is present in the classroom, is able to evaluate in a fast, agile and direct way with the help of the rubric. This avoids lengthy corrective writing assignment.
- The evidences of the evaluation are the news, presented by the students in any format (.pdf, .ppt, etc.).
- The students are active during the debate incorporating diverse points of view and enriching the activity.
- The debate should be used by the professor to ensure the acquisition of the expected learning outcome.

This work explains the results obtained for this activity for three courses 2015-16 to 207-18. So far, all the students who attend the courses during the presentations of the works obtain a positive assessment in the acquisition of the expected skill level (A or B scores). *Fig. 3* shows the detailed results obtained after the evaluation of this soft skill, differentiating the score (left graph) and combining the results depending on the type of assessment (right graph), either positive (A, B) or negative (C, D).

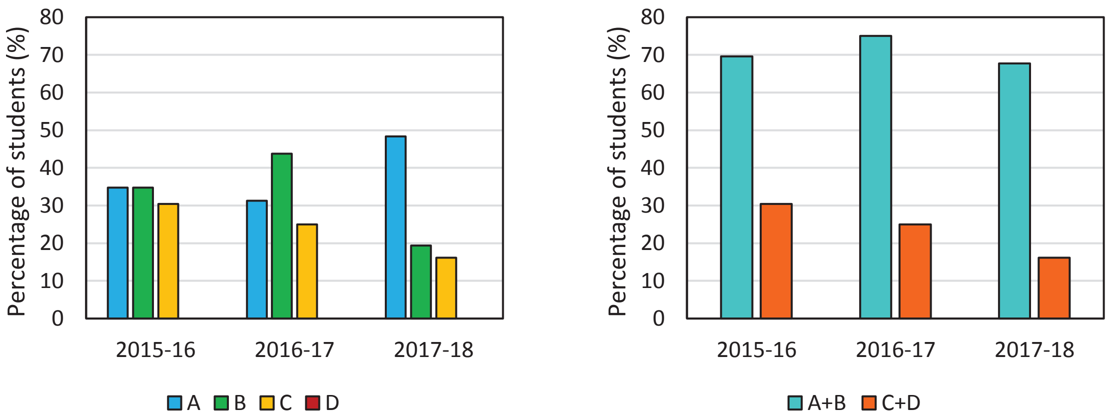

Fig. 3. Percentage of students with each score in the last three academic years.

As can be seen in *Fig. 3*, most students obtained A or B scores, and none of the students obtained D scores. However, there is still a percentage around 25% of the students who obtained C scores, which means that they did not clearly identify unethical behaviours. During the year 2017-18, there was a percentage of students that did not attend and thus, were not evaluated. Frequently, the students who obtained a C score misinterpreted the occurrence of accidents, which are facts that are impossible to anticipate, without the implication of unethical behaviour. This indicates that students should be made aware that even though many accidents can be prevented with adequate safety conditions at work, the occurrence of an accident is not necessarily caused by a lack of professional ethics.

The importance of achieving this skill related with professional ethics is highlighted in the White Books published for the Spanish Civil Engineering degrees [4], when enumerating the skills and competences that a Civil Engineer should possess. One of these skills is “to be prepared to practise the profession, having clear consciousness of its human, economic, social, legal and ethical dimensions”. In spite of that, the knowledge covered in this category is considered by this document as complementary, far from civil engineering basic subjects.

The authors consider that all students who complete their studies and aim to obtain a degree in civil engineering, should have been evaluated with a positive assessment of this soft skill, which is translated in A or B scores. With an appropriated inclusion and training of this soft skill during the whole degree program, all students should be able to obtain its competences by the end of the program. Our society cannot admit professionals who are not capable of detecting unethical behaviour.

4 CONCLUSIONS

This work has presented an activity to work and evaluate the soft skill "Ethical, environmental and professional responsibility" valid for the level of domain required for a second-year course. The activity is based on the students presenting and discussing news that show unethical behaviour. This activity allowed us to introduce the skill during the course, to directly collect the learning evidences and, to quickly evaluate the acquisition of the skill using a rubric. The experience of this activity is considered by the authors as very positive for the introduction of the soft skill.

Several degrees from UPV include specific subjects related to professional ethics. Undoubtedly, it is a question of significant importance that the students should train at different stages during the higher education programs.

In the opinion of the authors, the most appropriated approach to include professional ethics is to have specific subjects related to ethics, environmental and professional responsibility in the curriculum and, in parallel, to strengthen the skill throughout the curriculum using transversal contents. This approach would guarantee that certain skills are acquired during university studies. In fact, as stated by Prof. Cortina [6] “a society demonstrates that a subject seems essential for the formation of a professional when it explicitly includes it in its curriculum”.

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MINTgrün Robotics Lab: Programming Course for Beginners with Elements of Inquiry-Based Learning

D. Golovko[1]
Technical University of Berlin
Berlin, Germany

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Keywords: project-based learning, orientation, introductory, programming, robotics

ABSTRACT

The MINTgrün (English: STEMgreen) orientation program at the Technical University of Berlin is designed to help students who are not sure about their educational path to make an informed decision. Students enroll in the program for two semesters. In this time, they attend regular university courses from the disciplines of their potential interest as well as special MINTgrün courses. The latter include so-called project labs where students get first hands-on experiences in the subject according to the concept of inquiry-based learning. No prior knowledge is required. The robotics lab is one of about ten project labs. The objective of the robotics lab is to give students an easy access to coding and basic electronics as they build and program a simple Arduino-based robot. The projects are carried out in teams. The students come up with the topic of their projects themselves. This paper presents the structure of the robotics lab and discusses some specific challenges and considerations that arise for the instructors of this course.

1 INTRODUCTION

Didactic approaches involving active student participation such as inquiry-based learning (IBL) have been gaining popularity. They are often applied at later stages of the university curriculum. Yet their use with undergraduate students has advantages as well. The robotics lab of the MINTgrün orientation program at the Technical University of Berlin was designed for students in the first university year who have not yet decided on their degree program (major). Therefore, besides the function of teaching certain skills and competences, the robotics lab also has the function of

[1] Corresponding Author
D. Golovko
d.golovko@tu-berlin.de

introducing the students to coding, electronics and the problem-solving mindset required in engineering. In the following, we present the orientation program and the robotics lab with an emphasis on the elements of IBL.

2 MINT^{GRÜN} ORIENTATION PROGRAM

The orientation program MINT^{grün} (literally translated as "STEM^{green}", where "green" stands for a focus on sustainability issues) started at the Technical University of Berlin in 2012 and has enjoyed growing popularity [6]. In the academic year 2018/2019, 588 students are enrolled in the program [8].

The program aims at students (predominantly young high-school graduates) who are not sure about their future educational path, e.g. the choice of major or the choice of university studies vs. vocational training. The objective of the MINT^{grün} program is to assist students in making an informed decision about their career choices based on the experience they acquire attending university classes over the course of one year (two semesters). The central idea of the MINT^{grün} program is that in order to decide consciously for or against a major, one needs to try out at least some classes from that field of studies. Furthermore, some students may decide against university studies altogether and e.g. enroll for vocational training. A further objective of MINT^{grün} is the reduction of drop-out rates[2] in bachelor programs by providing students with a more realistic picture of the demands in a university STEM program and by raising the students' motivation as a result of an informed choice of their major.

Besides about 50 regular courses that students attend from the curriculum of the majors they are interested in, there are additional, MINT^{grün}-specific courses. These are two orientation courses in a lecture format and project laboratories (labs). The credits students receive during the MINT^{grün} year can be transferred to their chosen degree program, similarly to how students who change their majors do.

Depending on the semester, there are around 10 MINT^{grün} labs. They encompass various subjects, e.g. following labs are offered in the summer semester of 2019: construction of mechanical machines [2], environmental issues, mathematical modeling in sciences [1], chemistry [6], physics, robotics, mechatronics, fluid mechanics [7], science and engineering history, ethical and societal issues in engineering and sciences.

2 Drop-out rates in Germany's bachelor programs are high with 29% students quitting without a degree. Drop-out rates in sciences and mathematics are the highest at 38% [3].

3 INQUIRY-BASED LEARNING

Most of the MINT^{grün} project labs use the approach of inquiry-based learning (IBL). IBL is a broad term that implies a student-centered teaching format with open problem statements, an emphasis on 'learning to learn' and the process of knowledge acquisition rather than instruction and the knowledge itself, a participative rather than receptive student role, a high degree of students' independence and their active involvement in all stages of elaborating their own solution to the problem [4]. In German-language literature, this didactic approach can also be referred to as research-based learning (“forschendes Lernen”). The robotics lab in particular uses a variation of IBL, the project-based learning (PjBL). This variation is characterized by a learning-by-doing approach, an orientation towards an end product (e.g. a prototype) and teamwork. This learning form originated in engineering and can give students an impression of the ways how practicing engineers work [2].

4 ORGANIZATION OF THE ROBOTICS LAB

The robotics lab is a one-semester course with 6 ECTS. Students (max. 45 students per semester divided into two groups) get the assignment to build and program a simple Arduino-based robot. They work in teams of 2-4 (in rare cases 5) persons and come up with the project ideas themselves. Fig. 1 shows an example of a robot built last semester. Inspired by the film “WALL-E”, the robot can ride around the table, detect an object (a yellow or black clump) with a distance sensor, ride towards it, lift it using the arm with an electromagnet and place it into one of the boxes depending on its color.

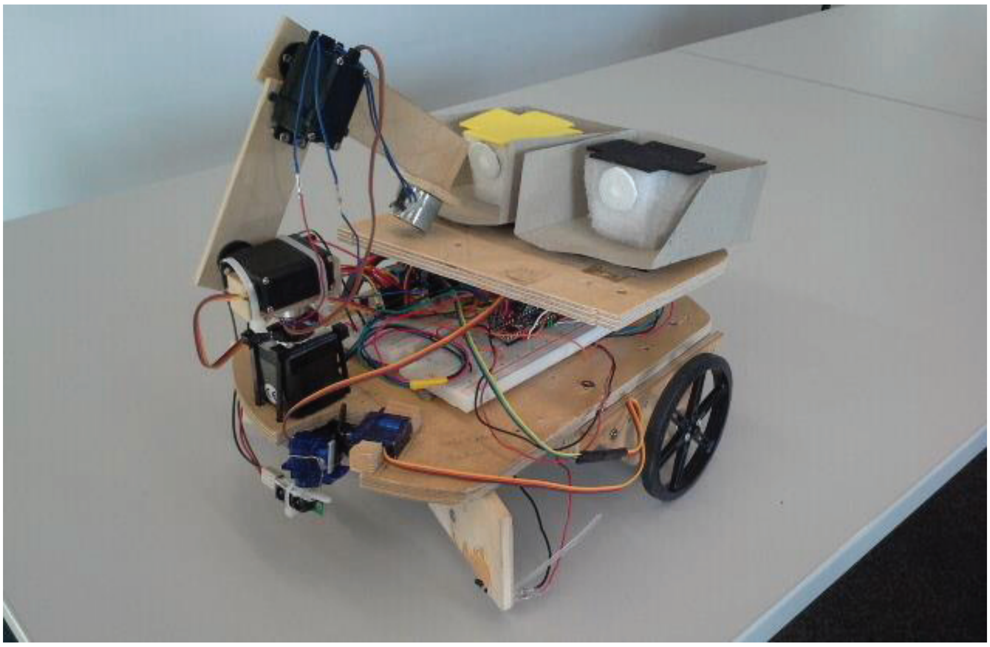

Fig. 1. Example of a project completed in the robotics lab (prototype by “WALL-E” team)

The semester in the robotics lab is divided into two parts: the introductory phase (first 4-5 weeks) and the project phase (rest of the semester). The introductory phase is a programming crash course. Students, who are assumed to be absolute beginners, need to learn the bare minimum so that they can start working on their projects. In this phase we resort to the format of frontal instruction. Students follow the teacher's instructions in assembling and programming their simple circuits. To keep attention, we have found it helpful to interrupting the lecture style with frequent questions and small practical assignments. We work in Arduino IDE, which uses a simplified version of C++, and Processing, which uses a simplified version of Java. There are weekly home assignments. Additionally, there are tutorials that focus on basic electronics. The weekly classroom presence time is 4+2 contact hours.

The project phase starts with students deciding on the project topics and planning the projects. They have to do so in writing on the course wiki page and include a Gantt chart to illustrate the project schedule. The chart is later used to compare the actual progress of the team with the plan. The project phase ends with an oral presentation and a written documentation of the project in the wiki (see Fig. 2). The latter is publicly accessible [5]. In the project phase, the teams work independently on their projects with the support of the instructors.

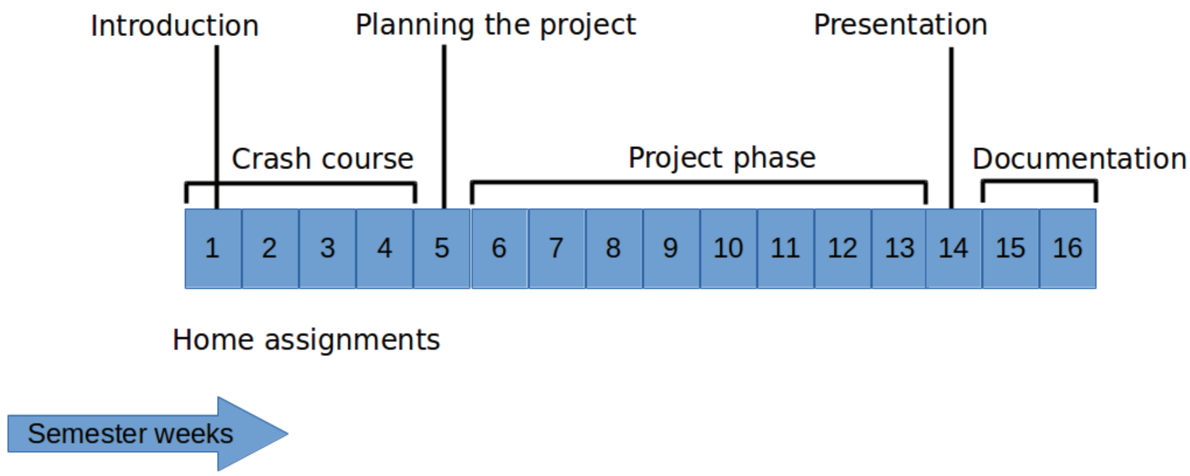

Fig. 2. Semester plan

The instructors in the robotics lab currently include a postdoc research assistant (20 hours/week) and two undergraduate student assistants (15+10 hours/week). The involvement of student assistants (tutors) is very beneficial for this interdisciplinary course because it expands the competence field of the instructors if they can join expertise from different professional areas (majors).

The capacity of the robotics lab is 45 students/semester, who are divided into two groups.

The robotics lab implements the major elements of IBL Tab. 1 gives a more detailed overview.

Table 1. Principles of Inquiry-Based Learning and Their Implementation in the Robotics Lab

Principle	Implementation
Authentic problem situations with an open outcome	Students build prototypes according to their own ideas and go through all the stages of the construction process including planning, design, coding, testing and documentation.
Learner-centered activities	Students formulate their project topics and work on them in small teams. However, the introductory phase of the course is in the format of frontal instruction.
Active participation in all stages of a research project, autonomous learning	Students formulate topics, create a project plan, carry out the project and present the results largely on their own
Instructors assume the role of facilitators	In the project phase, the instructors' primary role is answering questions and (upon request) giving tips on how to solve problems that the teams encounter. The introductory phase is teacher-centered. Sometimes more instructors' intervention is necessary, e.g. to influence the group dynamics and the temporal planning of the project.
The learning is process-centered rather than result-centered	Following a solution that eventually proves unsuccessful is not viewed negatively. Students do not receive penalties if the project remains unfinished despite sufficient effort.
Learning centers on acquiring skills and competences rather than knowledge of facts	The course aims at developing the mindset and problem-solving skills required for writing code and similar engineering tasks. Furthermore, students practice teamwork, communication, presentation skills and persistence.
Presentation of results to an interested audience	Students document their projects in a wiki that is publicly accessible. Students hold an oral presentation on their project at the last course meeting.
Critical reflection of the results	Students are required to include a “Discussion” section into their project documentation and critically discuss the project outcomes and the suitability of the chosen solutions. Reflection is welcomed at the oral presentation and during conversations with instructors within the team.

Robotics lab enjoys popularity among students, which can be explained by the fun factor (robots) and the fact that programming skills are part of many university majors and professions. Since there are usually more MINT^{grün} students willing to take the course than places available, almost all of the places are allocated to MINT^{grün} students. If students of higher semesters do take part in the course, MINT^{grün} students get the opportunity to exchange ideas and acquire more information about the majors of these older students.

In the last 4 semesters, 160 students started the course (i.e. participated in the first meeting), 129 started teamwork (i.e. stayed until the 5h week) and 110 stayed until the end. In the survey at the end of the course, over 90% of the students assess the course as "good" or "very good" and claim they would recommend it to others. It should, however, be noted that those who dropped out did not participate in the survey.

5 CHALLENGES

1. *Supervision load*. New, open-outcome project topics imply that the instructors have to obtain at least a basic idea of the methods, components etc. that can be used in the projects. This can be time-consuming since the projects are quite different each semester. However, it is often not needed that the instructors are informed about the solutions to a great detail. Instead, it makes sense that the instructors explain the students how they would proceed to solve the problem (even if they don't know if that is the right approach) rather than presenting the students with a ready answer. E.g. when it comes to bug fixing, the instructors will typically not be familiar with the individual projects to the degree of detail that allows an immediate solution, but it can be useful to point out the thought process and suggest how the problem can be narrowed down to several most likely causes and those can be identified and ruled out or corrected one by one.

This hands-on, non-frontal teaching formats requires a relatively high instructor-to-student ratio. The lab has 40-45 students in the beginning and 25-30 students in the end of the course, which results in more than 10 teams per semester. The biggest bottlenecks timewise are grading the homework, and preparing for the project supervision, i.e. researching and trying out the methods and components that can be used in the individual projects. In the course of the semester, the biggest load for the instructors is at the beginning of the project phase, when the students have selected their project topics and the homework still needs to be graded.

2. *Varying prior knowledge*. Even though the course is designed for absolute beginners, there are always a few students who have already taken programming classes or even have experience with Arduino. They can be somewhat bored during the introductory phase. One way to make them maintain interest is to interrupt the lecture teaching style with frequent questions, which they may be able to answer. For very advanced students, giving additional tasks (e.g. operating a particular component) to solve during class may be a solution. In the project phase, these

students can assume more complex tasks that challenge them. Because students do not all perform same tasks, like it is usually the case with more traditional teaching methods, this approach can accommodate the students' varying knowledge more easily.

3. Transition from introductory to project phase. Some students are overwhelmed by having to formulate the project idea, find the team and participate in the course in a much more active manner than during the frontal instruction phase. In the current semester, we try to ease the transition by making the students pick their ideas and teams early in the introductory phase. The expectation is that this way, the students have several weeks to think the idea through, to get acquainted with their team or perhaps to even change teams.

4. *Team work*. The group dynamics in the course is not always satisfactory. In some teams, students are tempted to divide the workload in the team into construction (mostly designing, cutting and assembling the robot wooden frame) and coding. Students that have some prior programming experience will typically take over the latter. If the roles do not change throughout the semester, then those who did the construction tasks will not have gained coding experience. Furthermore, the construction tasks only play an auxiliary role in the course because the robotics lab lacks both sophisticated implements and instructors' competence to teach valuable skills to students in that field. The preferred division of labor is a functional one, where students make sure certain robot functions are implemented, which involves both the construction and coding (e.g. mounting and programming a particular sensor or motor). The instructors' repeated intervention is therefore necessary for some teams. Sometimes it is hard to convince students to change the distribution of roles in the team.

Smaller teams tend to have better group dynamics and often accomplish more work than larger ones. Reasons are less organisational overhead and fewer opportunities for free-riding.

Group work may be a more suitable learning format for some students than for others depending on their personality type, communication skills, social role in the group, maturity and previous experience, etc. [2].

5. *Grading*. Fair grading is a challenge because the projects vary in their complexity and the degree of completion and the students start the course with different prior knowledge. IBL focuses on the inquiry process rather than the end result. This should be reflected in the grading procedure. It is helpful to create rubrics that evaluate aspects of students' performance that are independent of the chosen project topics. However, a lot of subjectivity remains in the grading process.

6 DISCUSSION

The challenges listed above are not unique to the robotics lab. Similar issues have been described by other authors practicing IBL or PjBL [2, 4].

Despite the interest towards active learning formats in the recent years, IBL is sometimes considered to be more suitable for students at more advanced stages of university education (e.g. master thesis). However, courses using the format of IBL work well at the initial stages too. This applies especially for topics where the necessary minimum of prior knowledge can be acquired in the short time and students can proceed to working hands-on on their projects. A programming course that uses mostly procedural programming is very suitable in this respect.

In the context of orientation studies, IBL is attractive because it lets students get a feel of hands-on work in the field without having to attend several semesters of theoretical courses on the fundamentals of the academic discipline they are interested in. Furthermore, even if the students decide against studying that discipline, the practical skills acquired during the course (e.g. coding, problem solving) can be helpful in their further lives. This goes along with the goal of the Bologna declaration to increase the students' employability.

Coding is sometimes viewed as a challenging, problematic skill that is hard to acquire but required in most STEM disciplines. If the first experiences with coding were positive, this can give the students more confidence to choose a STEM major that they are interested in but fear the complexity.

It should be noted that courses like the robotics lab are not a substitute for more theory-centered classes as well as programming classes that teach more advanced use of programming language(s) than the relatively limited Arduino IDE can foster. It can be useful to point this out to students, especially if they plan to make their decision about their further studies based on the attendance of the lab. Yet such practice-oriented courses early on in the university curriculum can give students a feel of hands-on work in the corresponding discipline and put the more advanced theoretical knowledge into a context.

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Short-term field-study programmes for developing interdisciplinary skills in engineering education

J. Gonçalves Martin

F. Graezer Bideau

E. Hoesli

M. Laperrouza

R. Tormey [1]
College of Humanities, Ecole polytechnique fédérale de Lausanne
Lausanne, CH-1015, Switzerland

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ABSTRACT

Short-term field study involves groups of students working in an off-campus (sometimes international) setting, and often involves working on realistic, open-ended problems, in interaction with a host community. Such learning experiences are intended to develop skills and knowledge needed for working across cultures and contexts and in interdisciplinary teams. One aspect of such programs which requires particular attention is their potential to take students out of their 'comfort zone', thereby enabling them to question their previously taken-for-granted assumptions. Fully exploiting such opportunities requires considering the role of social and human sciences in such programmes for engineering students. Here we analyse four case studies of short-term field study programmes in engineering education. While there are differences in location (Switzerland, China, Russia, Colombia), and in the nature of the projects, they share a methodology of mixing student disciplines and skills, interaction with people from other cultures or contexts, physically moving to a fieldwork location radically different from a classroom setting, and the use of reflection tools drawn from social and human sciences. Conclusions are drawn from this as to the possibilities, issues and challenges in short-term field studies in engineering education.

[1] Corresponding Author
R. Tormey
roland.tormey@epfl.ch

1 INTRODUCTION

1.1 Engaging engineering students with cultural differences

Engineering educators have increasingly worked to include some culturally different, often international, element as part of the training offered to engineering students. In some countries, like France for example, an obligatory international placement (either in the form of academic mobility or as an international work placement) is strongly encouraged by engineering accreditation agencies [1]. Such placements are seen as important in ensuring engineers develop an understanding of cultural diversity and of the way in which culture impacts on the work of the engineer. Although there is a growing recognition of the importance of such international placements, not all countries have normalized the practice: in the US, for example, it has been estimated that as few as 3% of engineering students study abroad (as compared to some 20% of social science and business/management students) [2].

Students who have participated in international experiences in their training have been found to have experienced a number of benefits. For example, an increase in participants' intercultural sensitivity has been found in a number of studies [3], as has a sense of ethical sensitivity (or 'global citizenship' development) [4]. There seems to be relatively few studies that look at the experience of engineering students during such international experiences, but some studies specifically with engineering students have linked such study abroad opportunities with increased capacity to work in teams as well as with increased intercultural sensitivity [5].

One important dimension of being confronted with alterity in the form of different social and cultural systems is that it can highlight that things the student may well have thought of as being 'normal', are often in fact phenomena of their own culture. Such 'decentring' experiences can be unsettling for students but also open the possibility to broaden their understanding. Some engineering educators have recently adopted the concept of 'liminality' to explain these opportunities [8]: the term 'liminal' (long used in Anthropology) derives from the Latin word for 'threshold', and indicates a sense of 'in-betweenness', of being in a process of transition in which new understandings and ways of thinking are becoming possible, and in which a new status is being socially ascribed. Liminal experiences are sometimes uncomfortable and emotionally challenging for learners as well as being potentially rewarding in terms of new learning; as such, the concept of liminality draws attention to the 'whole body' nature of the learning experience which encompasses physical and emotional experiences as well as intellectual ones.

1.2 Field studies

Central to the idea of such (dis)placements is the idea that students can learn something important from *experiencing* (as distinct to simply hearing or reading about) [6] a different cultural, social, economic and linguistic context. Indeed, it is worth noting that students may not have to engage in international travel to experience a social context radically different from their own; such differences can often be found in communities on the very doorstep of their own university.

One teaching methodology associated with this idea of experiential learning is the *field study*, defined as providing students with opportunities to learn through active involvement in "realistic" professional experiences as well as in opportunities for them to study and reflect on those experiences [7]. In social scientific disciplines like Sociology or Anthropology students often learn the analytical and research methods of the discipline through doing field research and reflecting on this experience. This practice has been translated into a signature teaching and learning strategy for professional training in disciplines which draw heavily on such social scientific disciplines, including social work and teaching. There is something to be gained in the education of engineering professionals by learning from the experiences of education in these other professional domains.

There are, however, few studies [e.g., 2] which provide insight into the issues involved in integrating into engineering education field study opportunities which involve engagement with cultural difference. This paper aims to add to this important area of study.

2 METHODOLOGY

This paper looks at the experience of introducing into engineering education short-term field studies which include an explicit focus on cultural difference and alterity. In common with other studies in this area [2] a case study approach is used. A case study is defined as an empirical enquiry that investigates a contemporary phenomenon in its real life context using multiple sources of evidence, and in which there are generally more variables of interest than data points [9]. Case studies can be thought of as akin to experiments: rather than being sampled, case studies are *selected* on the basis of particular features that make them interesting. As with multiple experiments, multiple case studies allow for cross case comparison which can rapidly increase the explanatory capacity of the study [10].

This paper is based on an analysis of four different case studies of international experiences offered to engineering students. Initial interviews were conducted with three of the four field study coordinators to explore if there was something meaningful to be gained from a comparative case study approach. Following this, data was collected from each of the four coordinators using a series of open-ended questions which were responded to either in writing (2 coordinators) or in a one-to-one interview setting (2 coordinators). Finally a group interview/discussion with three of the coordinators provided a further opportunities to tease out themes and comparisons.

3 THE CASE STUDIES

3.1 Case study descriptions

The four case studies presented here are offered by the College of Humanities in a mainland European technical university. The four field study coordinators are all social scientists.

Table 1. Overview of the Case study field studies programs

Field study location	Lausanne, Switzerland; Bengaluru, India; Shanghai, China	Greater China – Shenzhen and Hong Kong	Russian Arctic and Yamal peninsula	Amazon basin, Leticia City, Colombia
Nature of project/activity in field study location	International summer schools (academic courses and applied field visits)	Applied engineering design project with prototyping activity in China	Academic courses & Field research (e.g. oceanographic research, or civil engineering historical reconstruction)	Scientific & social research or a design project
Typical number of students per group	15-30	24	23	14
Balance between technical university students and those from other schools	75% STEM. Others from Social and Human Sciences, & Asian studies.	50% STEM. Others from Business, Industrial Design & Media Interaction Design.	50% STEM. Others from Social and Human Sciences, Environmental Sciences, Global health, & Law.	40% STEM. Others from Health, & Social and Human Sciences
Length of field study component	6 weeks	2 weeks	3-4 weeks	3 weeks
Integrated into study programme?	16 credits for courses taken when on field study (8 in Lausanne, 8 Asia).	18 credits in total for whole project, of which 4 for the field study component.	18 credits in total for whole project, of which 6 for the field study component.	4 – 6 credits for courses which prepared the project.
Years active	2009-2016	2015-present	2015-present	2018-present

The four case studies are:

- An international summer school programme in which students participated in summer schools in Europe, India and China, studying the history, political

science, anthropology, cultural studies and economics of each location, including field visits and language learning
- A hardware innovation programme, in which students design a connected device in their ‘home’ location, then travel to China to work to produce a prototype
- A Russian Arctic research program, in which students work on oceanographic, historical, and geographical research and documentation projects in the Arctic and Siberia
- An Amazon basin field study, in which students research the effect of urbanisation on indigenous people’s lives focusing on the eco-epidemiology of health or on the development of on-line tools to aid indigenous language learning.

All four have a number of similarities in structure:

- the field study is not a required part of any programme of study (three of the four are integrated into an optional minor which can be taken as part of a student’s degree programme)
- the field study involves a visit to a location which is culturally and linguistically different from their place of study
- engineering and science students participate in the field study alongside students from other disciplines, drawn from other universities
- students undertake a project (typically either an engineering design project, or a research project which involves some combination of social and natural sciences);
- while much of the project work is completed in their ‘home’ university, (either before or after the field study trip) some of the project work is completed while in the field study location
- reflective activities while in the field study location provide an important part of the learning in the field study.

A number of issues and challenges have been experienced by those responsible for the programmes. These are described below.

3.2 Embedding in a curriculum

All of the field study experiences described here involve substantial investment from students. At a minimum the students are required to invest time during the summer to travel to the field study location and to work while there. Students generally also pay a portion of the travel and accommodation costs associated with the trip. Not all of the institutions involved, however, offer the same academic credit for participation in the field study. Where the field study itself is not assigned significant credits, it seems to be regarded as being, in itself, a reward for this investment: as one of the co-ordinators put it, “*…the trip itself was viewed as the reward. The idea of the school was very much [to say to the student] ‘you get a free trip to China, so you should do the work required [by the project] for free [i.e., without getting academic credit]’*”.

In the early experiences of field study trips in the technical university, there also seemed to be a resistance on the part of the school to assign credits to the field study in the same way as they would be assigned to traditional courses. Sometimes this was explained in terms of administrative reasons – since the field study trips took place during the summer, did not fit into a spring or autumn semester and could not meet the same grading deadlines as other courses, it was assumed that academic credits could not be awarded. Although many of the students who participated at that time engaged fully with the program the lack of associated academic credit meant that some students did not approach the field study diligently. This remains the case for institutions where academic credit is not awarded, including, in at least one case, a student dropping out at the last minute, with potentially serious knock on effects on other students in the same project group. At a minimum, the ‘voluntary’ nature of the student engagement places significant additional pressure on coordinators who are left in the role of having to negotiate with students their commitment to group project activities.

Establishing the field study within a formal academic structure which involved earning academic credit was therefore an important development. This had a number of elements: first the field study needed to establish a track record which justified its inclusion. This meant that newer field studies (such as the Amazon basin program) had to establish the value of their learning by running for a number of years without significant academic credit before being accepted as ‘creditworthy’. It is notable that this is a higher bar than is set for traditional courses offered (which typically received academic approval on the basis of a short written description rather than having to be first offered without credit). Once accepted, the ECTS calculation of circa 2 credits per working week was applied to provide a ‘justifiable’ credit weighting for the field study (as in the China and Russian Arctic field studies). A solution to the ‘grading deadline’ problem was also found once the learning from the field studies had been sufficiently verified. That solutions to administrative difficulties were found suggests that it was the perceived legitimacy of the experience within student’s education which was actually at question all along.

The challenges of embedding in the curriculum are increased when multiple universities are involved. Within those field studies that are currently embedded in a curriculum (the China and Russian Arctic field studies) in the technical university, two different models of doing this emerged. In the case of the China program, each university managed the process differently, with, for example, different weights being assigned to the field study in different institutions. As a result, students were sometimes doing similar work for different credit. As noted above, this puts additional pressure on coordinators who are left in the role of having to negotiate learning activities with students. In the Russian field study, a single model for the program was developed and offered to different partner universities who either chose to ‘buy-in’ or not. Perhaps because the program was perceived as prestigious, this did not have a negative impact on student uptake.

3.3 Framing activities of the field study

The first model used for confronting students with alterity was the international summer school model. This ran for seven years and was highly valued by students. Running such a program required a very high degree of additional investment by faculty when compared to more traditional courses, and this contributed to the program being halted.

One of the features of a field study is that the students are engaged in a realistic professional activity. The China, and Russia (and later Amazon) experiences might be thought of as a shift towards a 'field study' model in that the students are involved in either a design activity, a scientific research activity, or in some mix of the two. This shift has probably made it easier to 'legitimate' the field study in that the framing activity through which students learn is more clearly an 'engineering' activity. At the same time, it also poses potential difficulties in that the practice itself becomes central to the experience and reflection on that practice runs the risk of being marginalised. This, again, requires considerable input and skill from the coordinator to ensure that the reflective activities are not lost.

4 SUMMARY AND CONCLUSIONS

It is clear that field studies can play an important role in enabling engineering students to learn through experiencing engineering and scientific practices in different social and cultural settings, and reflecting on those experiences. Such experiences can allow students to understand how disciplines are constituted in different countries, what a notion or concept means in a different setting, and what are the relations between a topic and educational policies in different settings (i.e. in a broader sense, the relations between the State and its education and research institutions). Embedding these experiences in an already crowded curriculum however, is not without its challenges.

First, the field studies discussed here differ from traditional courses. They do not follow the same timetable, or the same semester structure, and their experiential nature means that what and how students learn may be hard to describe in advance within the limitations of a taxonomy of cognitive outcomes. All of this meant that the bar to be accepted within the academic program seems higher for field studies than is the case for more traditional courses. Embedding within the formal program does, however, appear to be worthwhile, given the challenges for coordinators raised by more ad hoc solutions. Part of this embedding may involve the use of 'realistic' engineering practices as framing activities for the field study. This shift can involve risks for learning however, as retaining a focus on reflection in the field study may become a challenge.

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Sustainable Industry 4.0

A. Guerra
Aalborg University
Aalborg, Denmark

B. Nørgaard[1]
Aalborg University
Aalborg, Denmark

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ABSTRACT

Sustainability and Industry 4.0 have been dominating debates as the most pressing problems and challenges for society in general and for engineering in particular. Industry 4.0 contributes as a vision, where new technology plays a key role in the future. As sustainability is such an urgent issue, it would be expected that the vision of Industry 4.0 would include and address sustainability goals as key targets goals. However, this is not the case or at least it is not explicitly.

This paper discusses Sustainability and Industry 4.0 implications from the perspective of engineering education. The aim is to identify which needs for knowledge and competences these two concepts call for in the future to prepare engineering education. Thus, it is important to examine the relation and emergent opportunities for engineers to contribute to a Sustainable Industry 4.0.

This paper points to two major opportunities to combine Sustainability and Industry 4.0, at technological and at competence levels. Industry 4.0 core technologies enable to integrate sustainability strategies throughout the entire supply chain, through a more efficient use of resources and energy. In addition, the competences needed for Sustainability and Industry 4.0 seem to overlap, especially transversal competences such as: problem solving, communication, creativity, leadership, collaboration and lifelong learning.

1 INTRODUCTION

Sustainability and Industry 4.0 are two trends in engineering, which will irrevocably affect in which ways engineers work and are educated.

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[1] Corresponding Author
B. Nørgaard
bente@plan.aau.dk

Climate change, resources depletion, environment degradation, inequality and poverty, are some of the problems society is facing. Furthermore, societal and economic progress still relies heavily on technology and innovation. However, technological development has the possibility to provide solutions capable of solving sustainable problems locally and globally. See for example, the United Nations published the Sustainable Development Goals (SDGs), which constitute a framework for sustainable development actions towards 2030. The SDGs are a set of 17 goals and 169 targets, formulated based on previous declarations and the eight Millennium Goals not achieved for Sustainable Development (MGSDs) (2000-2015). The SDGs highlight the role of technology support and achieve the 17 goals and targets [1].

On the other hand, new ideas and technologies from Industry 4.0 will transform the entire structure of work places, world economy, communities and human identities. Technologies such as automation and internet of things (IoT) will drastically affect human, social and economic development, and as consequent, industry has to reconsider their ways of doing business to keep with rapidly technology innovation and consumers expectations [2][3].

In order to face the Sustainability challenges and Industry 4.0 demands, engineering education needs to revise their curriculum, the qualification profiles and pedagogical models. Even though curriculum changes and development of teaching methods have been taking place around the world, the process has been slow and, often, at course and programme levels. Frequently, curriculum change aims to develop the qualification profile and to make students more employable, neglecting the sustainability knowledge and competences [4]. In addition, when sustainability is integrated in engineering education, it is mainly through elective stand-alone courses and programmes, which is not enough [5]. In sum, changes are taking place, but they are still behind the needs, and rarely address both Industry 4.0 and Sustainability. Furthermore, it is claimed that engineering overcrowded curriculum constitutes a barrier for curriculum innovation and change, whereas "*for something to get in, something needs to get out*". Therefore, it is needed to investigate in which ways Industry 4.0 and Sustainability can be combined and integrated in engineering education by, for example, examining which opportunities exists for combining Sustainability and Industry 4.0. This paper discusses such issue by addressing the following research question through a literature review:

What are the opportunities to combine Sustainability and Industry 4.0?

We start by conceptualizing Industry 4.0 and the competences needed (section 2), followed by the discussion of the opportunities to combine Sustainability within Industry 4.0 context (section 3). We conclude the paper answering the research question (section 4), and briefly discussing the implications for engineering education.

2 INDUSTRY 4.0 CONCEPTUALIZATION

Most of the Industry 4.0 literature relates to the technologies that bring together the concept. In 2015, the Boston Consulting Group (BCG) [6] published a report describing nine technological trends as the building blocks of Industry 4.0. These nine technologies reflect very well the general concept of Industry 4.0. They are:

- Big Data and Analytics
- Autonomous Robots
- Simulation
- Horizontal and Vertical System Integration
- The Industrial Internet of Things
- Cyber Security
- The Cloud
- Additive Manufacturing
- Augmented Reality

Most of these new technologies are already available, although they are mainly used in other types of applications, such as within the consumer industry. However, with Industry 4.0, they will transform production into a fully integrated, automated and optimized production flow. It will lead to an increased efficiency and change traditional production conditions between suppliers, manufacturers and customers, as well as between man and machine. The implementation of Industry 4.0 will not only change the traditional relationships between man and machine, but will also place new demands on employees' competencies. Current expectations fall on employees who will increasingly focus on creative, innovative and communicative activities. Routine activities, such as monitoring tasks, are taken over entirely or partly by machines. The earlier waves of industrialization, however, showed that technological progress did not diminish overall employment rate. Although the number of production workers declined, new jobs emerged and the demand for new skills grew [7]. Today, a new workforce transformation awaits.

Industry 4.0 calls for a new qualification profile and competences. *Table 1* presents three frameworks, which define the expected competences required [8][9][10]. The three frameworks highlight the need for competences related with ICT and digitalization, transversal skills and technical expertise.

Table 1. Competence frameworks for Industry 4.0, according to [8][9][10].

Erol et al. (2016)	Hecklau et al. (2016)	Motyl et al. (2017)
• Domain competences (e.g. application of, e.g. lean thinking and methods in manufacturing; application conceptual modelling methods, e.g. data flow, material flow	• Technical competences (e.g. state-of-the-art knowledge; technical skills; process understanding; media skills; coding skills; understanding IT security)	• Hard skills (e.g. numerical and higher mathematical knowledge; problem solving; creativity and design skills; investigative and experimental skills; information

and process modelling; application of information and communication technology (ICT) for material tracking and worker tracking) • Action competences (e.g. problem analysis and structuring, solution and development; data analysis and interpretation; method, tool selection and use) • Personal Competences (e.g. solution-oriented attitude; creativity; out-of-the-box thinking) • Social competences (e.g. teamwork ability; consensus-finding ability, compromising; role taking, role-making ability)	• Methodological competences (e.g. creativity; entrepreneurial thinking; problem solving; conflict solving; decision making; analytical skills; research skills; efficiency orientation) • Personal competences (e.g. flexibility; ambiguity tolerance; motivation to learn; ability to work under pressure; sustainable mind-set; compliance) • Social competences (e.g. intercultural skills; language skills; communication skills; networking skills; ability to work in a team; ability to be compromising and cooperative; ability to transfer knowledge; leadership skills)	processing; computer programming; knowledge of specific software tools) • Digital skills (e.g. basic digital literacy skills, such as use of digital applications and ability to carry out basic internet searches; digital skills for general workforce[2] such as specific use of IT applications for workplace, developed by IT specialists and processing information; digital skills[3] for ICT professionals, such as skills linked to development of new digital technologies, products and services) • Soft skills (e.g. strong analytical thinking; communication; teamwork; leadership)

At first sight, the competences required seem quite generic, however their association and interrelation with digital technologies omen about a radically new job and competence profiles [8][9][10]. Furthermore, the role of employees will change from operators to problem-solvers and companies should make an effort concerning an enhanced interdisciplinary education in the areas of economics, engineering, informatics, and mathematics, with, e.g., educational institutions [11]. It will be necessary to introduce competence strategies and, for example, to organize work in a way that promotes learning, enabling workplace/work-based learning, i.e. lifelong learning.

Undoubtedly, Industry 4.0 arrives with promise to deeply change the industry and work places, which will also affect the way engineers are educated. However, what seems to be unchanged is the incentives (i.e. the driving forces behind) for Industry 4.0, which are still based on the mind-set of the previous waves of industrialisation, i.e. the economic growth and capitalization way of thinking. Even though two of the frameworks presented in *Table 1* refer to sustainability-related competences, such as “lean thinking methods” [8] and “sustainable mind-set” [9], in general Industry 4.0

[2]Digital skills for general workforce includes basic digital literacy skills.
[3]Digital skills for ICT professionals includes all skills from basic digital skills and digital skills for general workplace.

does not explicitly state sustainability as a goal. In fact, it seems that sustainability principles are not adapted to Industry 4.0 concept. The next section discusses the opportunities to combine sustainability and Industry 4.0.

3 OPPORTUNITIES FOR COMBINING SUSTAINABILITY AND INDUSTRY 4.0

The increase societal expectations towards decreasing the environmental impacts caused by, for example, manufacturing industry push companies not only to focus on profit and maximization, but also to develop sustainable practices and business models [12]-[15]. Literature shows that sustainability can be combined with Industry 4.0 mainly through its core technologies and the competences needed.

Industry 4.0 core technologies allow transparency in the production and organisational processes, fast in real time exchange/integration of information, which leads to an efficient allocation and use of resources in the management of production and organisational processes [12][14]. For example, intelligent scheduling of tasks and processes, processes simulations, prediction of energy consumption through smart energy systems, can optimize and reduce the energy consumption. In addition, manufacturing design "*can be improved through direct data interconnection from product usage back to design*" [12]. This allows recovering, reusing and recycling components, which decrease the use raw materials and waste, improving the product lifecycle and reducing greenhouse gas emissions [12][13].

Stock & Seliger [14] argue "*Industry 4.0 will be a step forward towards more sustainable industrial value creation*". The authors refer that the allocation and use of resources will be more efficient by the means of intelligent cross-linked value creation modules, proving opportunities for sustainable manufacturing at organizational, process and product levels. For example, at organizational level, efficient allocation of products, materials, energy and water. At process level, sustainable design by addressing the holistic resource efficiency approach. At product level, realization of close-loop life cycle for products by reusing and remanufacturing of specific products, or by applying cradle-to-cradle principles. Muller et al. [12] and Stock & Seliger [14] relate social sustainability with employees, job market, working environment, qualification and acceptance. They outline several benefits for the employees, namely "*human learning through intelligent assistance systems as well as human machines interfaces that lead to increased employee satisfaction in industrial workplaces*". Even though there is a concern of job lost due to replacement of human employees by robots or automatic systems, current literature does not provide a unified perspective. However, simple and monotonous tasks are expected to be replaced and new job profiles will be required [14]. Furthermore, Industry 4.0 vision claims to be human-centred where a "*flexible work organization will enable workers to combine their work, private lives, and continuing professional development more effectively, promoting a better work-life balance*" [16].

Sustainability can be define as complex, interdisciplinary, participatory, contextual, problem- and action-oriented. Therefore, addressing sustainable problems calls for competences aligned with sustainability principles and goals. Based on sustainability research and problem-solving frameworks, Wiek et al. [17] identify five key competences in sustainability, which are systems thinking, strategic and interpersonal competences, normative and anticipatory competences (*Table 2*).

Table 2. Competence framework for sustainability (retrieved from Wiek et al. [17])

Competence	**Definition**	**Associated terms and concepts**
Systems thinking	Ability to collectively analyse complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global and temporal), thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks.	Systemic thinking, interconnected thinking, holistic thinking, coupled human-environment; systems, social-ecological systems
Anticipatory	Ability to collectively analyse, evaluate, and craft rich ‘‘pictures’’ of the future. The ability to analyse includes being able to comprehend and articulate their structure, key components, and dynamics; the ability to evaluate refers to comparative skills that relate to the ‘‘state of the art’’; finally, the ability to craft integrates creative and constructive skills.	Anticipatory thinking, future thinking, foresighted thinking, trans-generational thinking
Normative	Normative competence is the ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets. This capacity enables, first, to collectively assess the (un-)sustainability of current and/or future states of social-ecological systems and, second, to collectively create and craft sustainability visions for these systems. This capacity is based on acquired normative knowledge	Value-focused thinking, orientation thinking/knowledge, ethical thinking

	including concepts of justice, equity, social-ecological integrity, and ethics.	
Strategic	Ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability. This capacity requires an intimate understanding of strategic concepts such as intentionality, systemic inertia, path dependencies, barriers, carriers, alliances, etc.; knowledge about viability, feasibility, effectiveness, efficiency of systemic interventions as well as potential of unintended consequences.	Linked closely to normative, anticipatory and systems thinking competences. Action-oriented competence, transformative competence, implementation skills
Interpersonal	Ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving. This capacity includes advanced skills in communicating, deliberating and negotiating, collaborating, leadership, pluralistic and trans-cultural thinking, and empathy. All of these skills are particularly important for successful stakeholder collaboration and a necessity for the majority of methods assigned to previous competencies.	Collaborative, participatory, interdisciplinary, civic competence

These five competences comprise knowledge and set of basic skills, namely interdisciplinary knowledge, critical thinking, communication, creative thinking, problem solving, collaboration, which overlap with some of competences listed in *Table 1*.

4 CONCLUSION

From the literature review, two major opportunities to combine sustainability and Industry 4.0 emerge, at technological and at competence levels.

At a technological level, Industry 4.0 enables to integrate sustainability strategies throughout the entire supply chain, allowing a more efficient use of resources (e.g. less use of raw materials, lower energy consumption, less waste and reduced greenhouse gas emissions) and energy. However, sustainability strategies need to be integrated and become explicitly part of the company's business model.

At a competence level, whereas there is an overlap of competences needed for Sustainability and Industry 4.0, especially transversal competences such as problem solving, communication, creativity, leadership, collaboration, lifelong learning (see *Table 1* and *Table 2*). Even though emphasis in given to competences, knowledge is also common to both (see for example, normative knowledge in sustainability competence framework and domain knowledge in Industry 4.0 competence framework). In addition, new competences emerge from Industry 4.0 such as the digital skills. If in the past, digital skills where more associated to specific areas of engineering, for the future they are seen as generic whereas all employees should master them.

Furthermore, competences that seems to be exclusive of Industry 4.0 and Sustainability might also be seen as transversal. For example, digital skills are closely used to technologies, which will be embedded in the future work place, such as automation and IoT. Considering that, it is through the Industry 4.0 technologies that companies can become more sustainable, digital skills also become relevant for sustainability problem solving. On the other hand, anticipatory competence might be relevant in Industry 4.0 context, whereas technological trends, costumer's needs and expectations might be anticipate.

Engineering education research community already have an awareness for change and curriculum innovation needed to cope with Industry 4.0, the competence profiles and sustainability crises however, they remain disarticulated and detached. Literature show examples of curriculum change to integrate sustainability, [18] as example, and to innovate engineering curriculum to address the companies' needs [4][19], as examples. These point out the type of curriculum and learning environment suitable to address both Sustainability challenges and Industry 4.0 demands, namely a more flexible curriculum, active and student-centred, focus on process rather than in the product, such as Problem, Project Based Learning (PBL).

Nevertheless, literature does not address Sustainability and Industry 4.0 combined. Consequently, the challenge for engineering education is to reflect in their role, foster curriculum change and innovation, and integrate adequately sustainability and Industry 4.0 as part of engineering qualification profile. What and how to educate engineers for Industry 4.0 and Sustainability are examples of questions that need empirical research and in collaboration with several stakeholders, namely other engineering education institutions and companies from private and public sectors.

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Renewing Mechanical and Mechatronics Programs using Studios

R. G. Hadgraft[1]**, B. Francis**
Learning Design Team
Faculty of Engineering and Information Technology
University of Technology Sydney
Sydney, Australia

R. Fitch, B. Halkon, T. Brown
School of Mechanical and Mechatronic Engineering
Faculty of Engineering and Information Technology
University of Technology Sydney
Sydney, Australia

Conference Key Areas: Complexity of modern society; Integrated learning environments

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ABSTRACT

In a world of rapid change, engineering programs need to adapt to be relevant. This paper addresses the renewal processes for mechanical and mechatronics engineering programs at a large university of technology. The paper sits within a wider curriculum change movement, including all engineering and IT programs at this university.

Several meetings have been held over the last 3 years with both industry panels and with academic staff and students to understand the nature of the problem. Using a design-thinking approach, we have explored: global trends, the nature of engineering work and projects, the capabilities required by engineers, and the kinds of capabilities that graduates need to operate confidently in this new world of work.

There is a clear need for graduates to be more operational as they move from study to work. Consequently, a major focus on experiential learning is emerging as the key delivery vehicle for new kinds of graduates including projects, studios, and internships. These forms of learning are supported by ready access to online materials as required. A central thread is personalisation of the student learning experience through learning contracts and portfolios.

There has been constant demand for change in engineering education for at least the last 20 years. Making change happen, however, is another matter. We are in the fortunate position at this university to have high level support from the Chancellery and the Dean to move our engineering programs to be more relevant to the future. This paper describes the process for engaging our academics, students and industry supporters in that process and will be of interest to many who are grappling with similar transitions.

[1] Corresponding author: R. G. Hadgraft: Roger.Hadgraft@UTS.edu.au

1 OVERVIEW

The 2019 SEFI conference organising committee has identified complexity and emerging technologies as key themes for this year's conference:

> ***Turbulence, interdependency and complexity*** *characterize the operating environment ...* ***Freedom, openness and creativity determine the digital economy.*** *…* ***New generation of learning technologies and networks*** *are ubiquitous and mobile which reshape access to and delivery of learning.*

This paper discusses the on-going work to prepare new programs in mechanical and mechatronics engineering at the University of Technology Sydney (UTS), taking into account complex problems on the one hand and emerging educational technologies and pedagogies on the other.

The paper serves as a roadmap for similar transformations elsewhere. In many ways, curriculum design is not the major issue. Curriculum *change* is the major issue, first for our academic staff who are used to teaching in a particular way, and second for our students, who are often comfortable with an exam-driven system that does not serve them well in the long-term. Learning the standard solutions of the past does not prepare a graduate to invent new solutions for a changing, complex future.

The paper is of obvious interest to those in related disciplines, as they make their own curriculum revisions for a world with rapidly changing industry needs. However, the paper should be of interest to those in other disciplines (not just engineering) because it signposts the *processes* we have used to explore future graduate capabilities from industry, with input from both students and academics, in the nature of the future curriculum.

A studio-based curriculum is proposed, with many examples of suitable studio projects generated by industry, academics and students, which should be of wider interest and inspiration.

2 INTRODUCTION

The 21st century is a time of great change, with job automation and offshoring now overtaking the professions, including engineering and information technology [1]. The professional jobs that are remaining are those that require creative responses to complex problems, and/or with high human contact [2]. Therefore, as university educators, we need to prepare graduates for this new world, including the ability for graduates to start and build their own organisations.

We believe that, to achieve this, learning needs to be much more experiential, based on projects and studios as well as internships, global mobility and other experiential extracurricular activities [3-6]. A studio combines project-based learning with student-led learning, enabling each student in the studio to develop themselves according to their own learning/career plan. The evidence of learning for each student will be their *learning portfolio*.

This form of collaborative learning builds competencies, teaches creativity, and how to deal with complexity. As academics, we also need to model these capabilities.

Andreas Schleicher, OECD Director for Education and Skills, reminded us that the modern world no longer rewards people just for what they know but for what they can do with what they know [7].

Researchers can attest to the value of this kind of learning in terms of educational attainment. Angela Duckworth's *grit* (combination of perseverance and passion) and Carol Dweck's *growth mindset* show causal links to improved performance [8-10].

Further, many reviews of engineering education in the last 15-20 years have urged transformation of engineering education [2, 11-17].

These international reviews recommended several issues to be addressed such as: the ability to deal with complex problems, interdisciplinarity, creativity and invention, leadership, sustainability, global ethics, and lifelong learning [18]. Curriculum changes suggested included: a professional spine, teaching for connection between topics, approximate engineering practice, use case studies, situate problems in the world. The Henley Report [17] recommended three different kinds of engineers: the technical specialist, the integrator and the change agent.

How might we achieve these recommendations, given the evidence of change over the last 15-20 years is scant? Our solution is a curriculum built around studios, borrowing from the design disciplines [19].

3 ABOUT STUDIOS

Capabilities developed in studio learning include grit, resilience, growth mindset, curiosity, collaboration, communication, creativity and sensitivity to sustainability and global concerns. Graduates need an agility of mind and transferable skills to meet future skill needs and give back to their communities.

Studio facilitators work beyond the role of imparting knowledge: they are coaches, critics and expert learners. Feedback loops are critical in studios, with students and educators providing regular feedback to one another to achieve quality learning. Education Professor, John Hattie, reminds us that the biggest effects on student learning occur when teachers become learners of their own teaching, and when students become their own teachers [20]. Students in studios have the flexibility to engage in hands-on activities.

The aim of studios is to prepare students for a lifetime of creating new solutions and thriving in a fast-changing world. Traditional subjects are complemented with real-world problems where students can apply their knowledge to collaborative problem-defining and creative problem-solving using and learning both technical rationale and professional capabilities.

3.1 Studios in FEIT

As early as 2014, studios have been used in software engineering to immerse students in real projects with industry partners [21, 22]. These studios were initially extracurricular, with students able to use work they were doing in the studios as replacement assessment tasks in their formal subjects.

From 2015, it was decided to integrate studios into all of the programs in the Faculty, both engineering and IT. The first discipline was Data Engineering, a new program that replaced the former ICT (Information and Communication Technology) Engineering program. This launched in 2017 [6, 23]. Electronic engineering followed in 2018 and electrical engineering in 2019. Mechanical and mechatronics programs will launch in 2020 with civil engineering in 2021.

3.2 Why Studios?

Engineering and Information Technologists use design processes to solve complex problems and to develop new product opportunities [24-26]. The Faculty's *Graduate*

Attributes, adapted from [27], embody the capabilities necessary for professional practice. A graduate is expected to be able to:

A. Investigate the stakeholder's *needs*,
B. Use a systematic *design process,*
C. Apply disciplinary *technical* skills,
D. *Communicate* and *coordinate tasks with co-workers,*
E. *Self-manage tasks, projects and career development,*
F. While demonstrating *social responsibility*.

Although there has been a history of project-based learning in the Faculty for many years, we are now planning to take this to the next level, shifting the emphasis from Projects to Student Learning. Studios embody that shift [6].

Studios provide students with project opportunities to develop the full range of professional capabilities. Each student defines a set of intended outcomes in a learning contract and then works on satisfying them, which they then document in a personal *e-portfolio*. Studios are graduate attribute E in action – self-management and self-learning for career development.

A challenging task requires first an understanding of its *context*, the system in which it is embedded: the client *needs* must be identified, formally recorded as the *requirements* to be delivered (point A above). These authentic project tasks are intended to be developed with industry partners.

Students use a *design* process (point B), empathising with the stakeholders to understand the problem as deeply as possible [28-30]. Is the problem clear? Are the requirements clear and deliverable?

In the process of developing a set of potential solutions and in evaluating them against the requirements, various kinds of technical (modelling) skills will be required (point C).

Engineering and IT (E&IT) rarely happens as individual activity – *teams* are required almost always. *Communication* and *coordination* are key skills (point D), likely the most important skills across a career. E&IT professionals spend around 60% of their time communicating both within the team and across team boundaries [31, 32].

Self-management (point E) is a key ingredient. Engineers and IT professionals must be able to manage their work, learning and time to become reliable and productive team members. The studios require students to maintain a reflective journal that will help them to identify strengths and weaknesses, to shape their learning across technical and non-technical capabilities.

Finally, studios will help students to see the global nature of engineering and IT practice, both in the context of problems and design opportunities but also in the nature of the teams in which they will work, blending cultural and disciplinary perspectives.

The studio is the *vehicle* for each individual's learning, as part of their overall career development at the university. Their personal e-portfolio is a record of their achievement of the graduate capabilities and of their readiness to step into the world of work. It will contain many examples that might be discussed at a job interview, demonstrating the graduate is work-ready.

4 THE UNIVERSITY BACKGROUND

This University is committed to produce graduates who [33]:

1. are equipped for **ongoing learning and inquiry** in their personal development and professional practice,

2. operate effectively with the **body of knowledge** that underpins professional practice and
3. are committed to the actions and responsibilities of a **professional and global citizen**.

To formalise these ideas, in late 2014, the University articulated the ***Learning.Futures*** model of learning comprised of [34]:

1. An integrated exposure to **professional practice** through dynamic and multifaceted modes of practice-oriented education
2. Professional practice situated in a **global workplace**, with international mobility and international and cultural engagement as centre piece
3. Learning that is **research-inspired** and integrated, providing academic rigour with cutting edge technology to equip graduates for life-long learning

Many universities have similar commitments through their learning and teaching strategies.

Learning.Futures, however, has mandated key shifts in *classroom practice*:

1. **Authentic** professional tasks with authentic assessment
2. **Flipped learning** using the best online materials (from here and elsewhere)
3. **Collaborative** learning activities, e.g. inquiry-based activities, labs, studios, projects
4. **Real-life experiences**, e.g. internships, community projects, competitions
5. **Diagnostic feedback** [34]

4.1 The Faculty Context

The Faculty of Engineering and Information Technology has a long history of engagement with practice-based learning [35]. The revised curriculum from 1998 emphasised professional formation, personal development, and academic development. The curriculum became practice-oriented and learner-centred, embodying environmental and social sustainability.

The Faculty of Engineering and IT has interpreted the University Context as:

> *To create, develop and disseminate world class technological knowledge equipped engineering and IT graduates, to contribute in a global environment, and to co-create value with industry and the community.*

Within learning and teaching, our intent is to:

1. consolidate a **flexible, practice-oriented, and inclusive learning environment** that creates graduates who are sought after and globally competitive
2. integrate and encourage **innovation and entrepreneurship** into our courses and research
3. **integrate teaching and research**
4. focus on key areas where we can make a difference to the world through **trans-disciplinary approaches** and the science of engineering

The challenge is to enact this fine rhetoric! The remainder of the paper sets out the process we have used in designing our new programs, specifically, the mechanical and mechatronics engineering programs. As Stephen Covey says: “begin with the end in mind” [36].

5 STEP 1: INDUSTRY CONSULTATION

At the November 2016 Program Advisory Board meeting, we laid the foundation for revising the mechanical and mechatronics engineering programs. Four key questions were addressed, based on some earlier work at the Royal Melbourne Institute of Technology [37]:

1. What are the *global trends* affecting your business/organisation?
2. How are these affecting the *nature of work* and *projects* in your organisation?
3. What does this mean for the kinds of *capabilities* that your people need to be successful?
4. How does this affect the kinds of *graduates* that you want to employ?

There were 18 industry representatives at the meeting, from a range of organisations, covering mechanical and mechatronics engineering as well as electrical and biomedical engineering. Ideas clustered into:

1. Technical (commercially-based, people-based, and manufacturing-based)
2. Non-technical (design tasks versus planning tasks)

There was collective agreement that skills that the university should provide include:

1. 'hard' competencies: Costing; Commercial/legal/regulatory; Designing to specification; Trade skills
2. 'soft' skills: Confidence; Critical thinking; Arguing your case; Persistence; Remote communication; Customer centricity; Teamwork and leadership; Interpersonal skills

A subsequent industry meeting on November 2017 explored project topics for future studios. Some suggestions were:

1. Design and build a sun-tracking solar panel array
2. Design and build a mechanical overspeed brake, aimed at minimising stopping distance
3. Design and fabrication of surface acoustic wave sensor (multidisciplinary)
4. Design and build a reversing linear drive
5. E-bike conversion

6 STEP 2: STUDENT INPUT

A small group of student representatives also provided input during 2017. They saw positives in the old, more traditional approach as one that's familiar, coming from high school. They recognised that the current design and build subjects were helpful (Introduction to Mechanical Engineering and Mechanical Design) with a hands-on approach in some other subjects (e.g., Manufacturing Engineering, Advanced Manufacturing).

They saw negatives in the old curriculum, which they saw as not as hands-on as students are led to believe in the promotion materials for the university. Almost every subject was textbook learning/reading, with some exceptions listed above. They believed that the final exams are stressful and lead to much learning for, and forgetting after the exam. Hands on workshop time is also lacking. Design philosophy is not well implemented in most subjects. The degree as it is, is not a realistic representation of real-world engineering.

They saw the positives of a new project-based, studio-based curriculum as modelling real-world mindset for engineering: learn the fundamentals first and develop advanced skills when necessary for completion of projects, maybe with the assistance of online modules. Academics should mentor students in the projects as required. This mentorship is what happens in engineering workplaces; why not start at university?

Eliminate exams wherever possible. This frees up focus for professional/personal development of students in engineering capacity and reduces stress and improves mental health. Alternative assessment modes will be required.

Integrate the core subjects of Project Management and Economics and Finance into the progression of projects, i.e. learn what you need as the project goes on, rather than have them as separate subjects.

Overall, students found that a new project-based curriculum would benefit students significantly more than the current system.

7 STEP 3: STAFF (FACULTY) INPUT

In January this year, a staff meeting sought to gather input from as many of the staff (academic, technical, administrative) as possible, using the themes of: Trends, Strengths, Methods, Concerns, and Opportunities. Only Trends and Strengths are reported here for space reasons.

7.1 Trends

The discussion of Trends affecting mechanical and mechatronics engineering quickly opened up the breadth of the challenges and opportunities for these disciplines. The breadth of these challenges, below, highlights the difficulty of designing mechanical and mechatronics programs to enable graduates to move into any of these fields:

Safety (all projects should include design for safety), e.g. biomedical implant design; alcohol level sensors for drivers; low noise machinery; airport silencing.

Robots for people offer many opportunities, including embedded systems; sensors and activation; predicting and monitoring; anomaly detection; people detection to track and identify harmful intentions; manufacturing systems; warehouse automation; aged care; micro/nano machines in health robotics; energy harvesting.

Energy Infrastructure (including Smart and Green) includes autonomous charging; batteries; renewable energy equipment; kinetic and thermal energy recovery; energy harvesting; generating electricity in large scales; optimisation of building management systems; efficient air conditioning systems; solar farm design; design of AC unit based on solar thermal energy; hydro dam/pumped hydro system

Autonomous Vehicles are another exciting new area, including vehicle optimisation; personal transportation; traffic coordination; electric vehicles and electric bikes; autonomous footpath delivery

Data-driven applications include: AI techniques for intelligent fault diagnosis; biomedical mechanical devices, e.g. prostheses and other aids; human factors; non-invasive measurement instrument; data driven, process monitoring and control; additive manufacturing; inspection/quality assurance; efficient and mobile vision systems

IoT includes smart materials; smart monitoring of crops; mass-customised manufacturing (CAD/CAE, measurement, ergonomics); smart home (perception, ethics, networking, programming, cybersecurity).

Environmental Sustainability includes clean water, food and resources; robotic growing and harvesting; low cost water treatment and distribution; 'Fatberg' sewer maintenance; population growth modelling with cost/benefit analysis; triple bottle line

(TBL) analysis; smart materials and structures; autonomous mining; robust reliability of mechanical systems.

7.2 Strengths

Our teaching strengths were seen to be well aligned with the proposed direction for more studio-based programs. It was felt that student interaction is already structured to provide a reason to come to campus/class/lab (maybe not in all classes). There are small group, face-to-face learning activities, supported by blended learning in a friendly environment. This is the essence of Learning.Futures (above). Academics endeavour to provide constructive feedback and offer many teamwork activities in which time management skills, critical thinking, and independent-learning is encouraged.

Graduate employability is at the forefront of curriculum intentions across the University. (This Faculty has an internship program that gives all single degree students 2 x 6-month industry placements during their degree). Industrially relevant projects and hands-on practical, active learning joins theory and practice. Nevertheless, this is not how the students saw the curriculum (above).

Teaching is usually research-inspired, with opportunities to be innovative and entrepreneurial. Many research/industry pathways and projects exist. The robotics group, for instance, has many industry-inspired consulting projects, including a bridge inspection robot.

There is encouragement for design with modelling, simulation and optimisation, including a significant infrastructure investment in additive manufacturing facilities.

Graduate employability is a central focus of our University. Academics want graduates who can work with cutting-edge industry relevant technology, who are resilient and able to evolve with changing technologies. This requires industrially relevant programs.

Practice based experience and industry connections are well established. Further, we want graduating students who can tackle global/current issues for an unknown and uncertain future.

We want to be known for good teaching, using flipped learning, to make innovative and lifelong learning graduates. We want to encourage entrepreneurial thinking and self-motivated and collaborative students.

We want to become emerging leaders in engineering education.

8 SAMPLE CURRICULUM DESIGN

The current mechanical engineering program runs over 10 semesters, including two, 6-month work placements (Figure 1). This figure has been colour-coded to indicate mathematics subjects (pink), thermofluids (green), materials (blue), management (brown), machines (grey), potential design and project subjects (yellow), and electives (white). Subject names are in **bold** and pre-requisites are in *italics*.

This University already has developed several programs using three pairs of studios: fundamentals, applications, and professional stages, initially in the data, electronics, electrical disciplines, as explained earlier [6]. Implementing this model into mechanical engineering yields Figure 2.

Note that the studio sequence has absorbed Fundamentals of Mechanical Engineering, the two Manufacturing subjects and the former Design subjects. There was a strong desire in the team to bring together design methodology with the technical (modelling) capability, as well as manufacturing considerations, including design for manufacture.

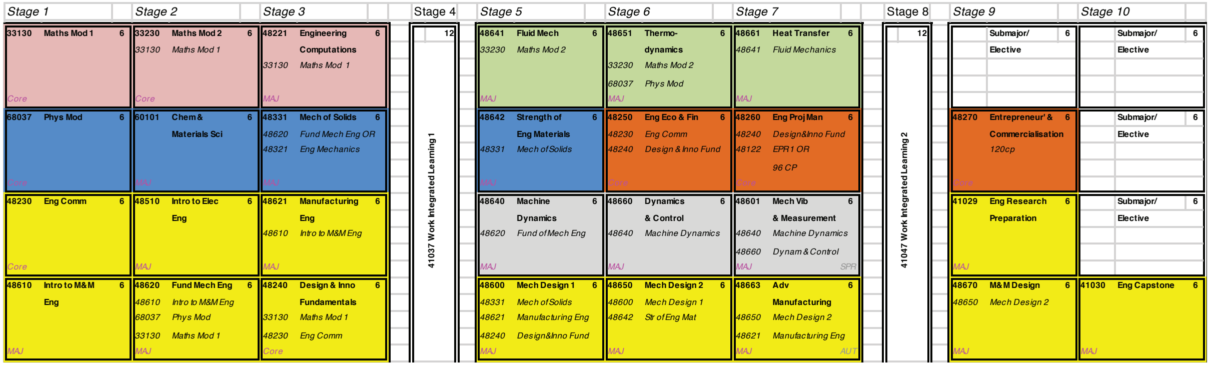

Figure 1: Current mechanical engineering program

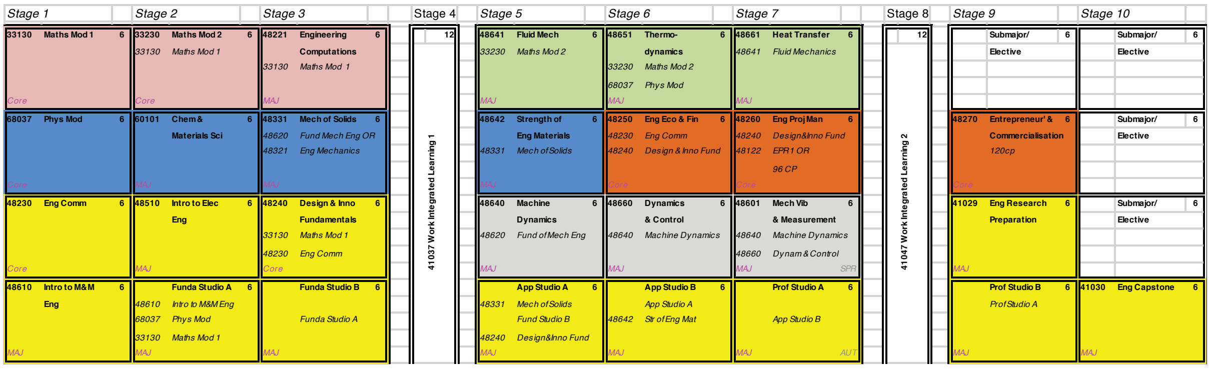

Figure 2: Proposed studio model for mechanical engineering

Figure 2 represents a soft conversion to a studio-led curriculum, one that is likely to be easy to implement with existing staff. Most of the technical subjects have been retained, while a strong, integrating design/studio thread has been established. Note that both Engineering Communication (Eng Comm) and Intro to M&M Eng (Mechanical and Mechatronic Engineering) establish the basic collaboration and design skills required for the subsequent 6 studio subjects, which then lead to the Capstone Project as an individual investigation. Thus, students begin to engineer from the first semester, gradually developing their design and investigation skills through each project/studio, documented in their portfolio.

9 CONCLUSIONS

Curriculum transformation is difficult. We have applied design thinking to the process and engaged our key stakeholders – industry friends, students and staff. Key questions for our industry supporters have included: what are the big trends affecting the discipline? How is the nature of work changing? What capabilities will graduates need in the new workplace?

We have asked our students to identify positives and negatives of our existing programs and teaching methods and also to review some proposed studio/project-driven curricula.

Our academics have also identified trends in the discipline and strengths within the existing academic team and organisation (the School and the Faculty). This process enabled them to see that we are already well-equipped to implement a project-based curriculum. The major challenges will be to provide suitable supervision, feedback and assessment in classes of 150-200. This is the next stage of our development work.

The stakeholder engagement described here is more than just collecting ideas and drafting a new curriculum. In many ways, that's the easy part of the work. The conversations and workshops have been critical in building consensus and enthusiasm for change. We have also run summer studios in the last two years as experimental opportunities for academics to test the studio concept with small numbers of students (10-25) before they embark on classes of 10 times that number. Lessons from those studios are documented elsewhere [5].

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Developing MIT's LASER -- Leadership Academy for Scientists, Engineers, and Researchers -- Program

TC Haldi [1]
Massachusetts Institute of Technology
Cambridge, MA USA

A. Bagiati
Massachusetts Institute of Technology
Cambridge, MA USA

E. Crawley
Massachusetts Institute of Technology
Cambridge, MA USA

Conference Key Areas: Lifelong Learning, New Notions of Interdisciplinarity in Engineering Education

Keywords: engineering leadership, online education, professional development

ABSTRACT

In the midst of global shifts in how professional engineers work and learn, creative and innovative new leaders are needed to step forward in their fields to tackle the world's future challenges. Today's new leaders need to be lifelong learners, continuously reflecting on the state of their field and gaining capacity to create and lead systemic change. Towards this vision, the Massachusetts Institute of Technology (MIT) is launching a new initiative, the Leadership Academy for Scientists, Engineers, and Researchers (LASER); a modular suite of online and blended educational content accompanied by on-campus opportunities, that breaks down the traditional silos between engineering and management while convening interdisciplinary approaches to leadership. LASER is by design a cross-Institute collaboration, between the Office of Open Learning, School of Engineering, Sloan School of Management, School of Architecture and Planning, Gordon Engineering Leadership Program and other programs across campus, to bring a unified MIT approach to engineering leadership.

MIT faculty from all the aforementioned schools are currently collaborating to develop and pilot 4 online courses for this new program that is expected to launch in fall 2019. This 4 course online program will lead to a professional certificate from MIT. The program is expected to provide professional engineers with the appropriate

[1] TC Haldi
thaldi@mit.edu

leadership knowledge and skills; content that is currently being underrepresented or is completely lacking from the curriculum in many traditional engineering schools.

This paper will discuss the cross disciplinary partnership between the experts from different fields as well as the implementation of the online program.

INTRODUCTION

Climate changes, water and food scarcities, a rapidly expanding population with longer life expectancies, increasing migration and displacement, looming threats of terrorism and nuclear deployment; are all posing mounting challenges for contemporary and future engineers [1-3]. Meanwhile, a Fourth Industrial Revolution is on the immediate horizon as the boundaries between the digital, physical, and biological spheres blur and intertwine. How has, and how can, engineering and science education prepare individuals with the tools and skills they need to tackle these challenges, to explore emerging frontiers, disrupt staid traditions, and develop novel, sustainable solutions for our local and global communities? What will the engineers and scientists of 2025 need to know and be able to do?

The skills for tomorrow demand both engineering expertise and leadership acumen. But, do existing engineering and science education programs prepare workers with all the skills they need? The National Academy of Engineering's 2012 forum panellists, when attempting to envision this complex education model of the future, “outlined a new vision for engineering education based on flexible, interactive, lifelong learning and the merge of activities” [4], while the World Economic Forum [5] identified ten top skills needed beyond 2020, them being: complex problem solving, critical thinking, creativity and innovation, people management, coordinating with others, emotional intelligence, judgment and decision-making, service orientation, negotiation, and cognitive flexibility. Today’s engineers and scientists possess many of the skills needed for tomorrow. They are analytical, trained in systematic problem-solving with deep technical expertise, innovative, and detail-oriented. Yet, many lack the leadership, people management, knowledge transfer, and communication skills needed to be successful, as they will be progressing into higher leadership positions in their careers. To gain these capacities, MIT suggests that lifelong leadership learning and practice must not only supplement but be woven into traditional engineering and science education.

Today, many professional organizations look to programs, assessments, and recruitment techniques to better identify and nurture employees with leadership potential. Leadership conferences, retreats, and executive education programs are profitable businesses with a flurry of new offerings each year. Yet, after decades of research, organizational management expert Morgan McCall concludes that while lots of people become leaders, few become effective in part because they fail to learn “the right lessons” from their leadership learning experiences [6]. Part of the issue may be a mismatch of one-size-fits-all leadership programs that ignore disciplinary difference, failing to grow an individual’s leadership capacity alongside their technical expertise.

Yet, integrating technical and field-specific expertise within leadership development and integrating the learning experience while on the job seems essential for leadership lessons to be meaningfully situated within these leaders' real world context and practice.

Dedicated leadership training for engineers, and others from fields in engineering, technology, and the sciences, is now an emerging area. However, while there is a burgeoning growth of "engineering leadership" programs, there are few scalable, cost-effective products or services in the market today that offer the convenience, flexibility, and variety of learning modalities in both leadership and technical expertise that these professionals need. Addressing this need, MIT aspires to develop an engineering leadership program through the LASER initiative.

1 THE PROGRAM

MIT's "Leadership Academy for Scientists, Engineers, and Researchers" (LASER) is a modular suite of online educational content that prepares engineers, scientists, and researchers in technical professions to become leaders.

LASER's content is focused on technical professionals, designed specifically for individual contributors, to first time managers, to project leads who are looking to take the next step in their career. For some, this means continuing to serve as an individual contributor, but with a better understanding of the underlying management environment in their organization. For others, this involves becoming a first time manager, or a mid-level manager of managers. LASER addresses all of these groups.

The LASER program draws from MIT's established institutions: the School of Engineering, Sloan Management, Gordon Engineering Leadership Program, and others across campus that are already addressing engineering leadership in their own way.

MIT faculty from the aforementioned schools are currently collaborating to develop and pilot four online courses for this new program that is expected to launch in fall 2019. This four course online program will lead to a professional certificate from MIT.

The program is expected to provide professional engineers with the appropriate leadership knowledge and skills; content that is currently being underrepresented or is completely lacking from the curriculum in many traditional engineering schools.

2 COURSES

2.1 Course One: Understanding Organizational Strategy and Capabilities

Course One follows the linkages from strategy to product definition, on to the design of work needed to build the products and the organization of that work in teams. The course builds an understanding of how these factors set the context and define the needs for leadership and demonstrate how one can lead people to work effectively in teams.

By the end of the course, students should be able to:

- Identify and evaluate your organization's strategy to align your ideas, products, and efforts with it.
- Prioritize products that create value for the end user.
- Decompose your product systems into individual tasks, relationships, and entities to organize and conceptualize your work.
- Develop new processes by utilizing the Four Principles of Dynamic Work Design.
- Identify the notion of capability and its impact with implementing change.
- Design knowledge work effectively by utilizing visual management.

2.2 Course Two: Negotiating and Applying Influence and Power

Course Two is about getting people to do what you want, when you want, the way you want.

By the end of the course, students should be able to:

- Understand key terms and strategies from negotiation and conflict resolution theory, theories of social influence (persuasion) and theories regarding the exercise of power within and between organizations.
- Build awareness of multicultural interactions in the workplace, particularly in regard to different perspectives on negotiation
- Demonstrate theory through multiple real-time role-play simulations followed by peer feedback.
- Identify tensions within co-working teams and understand how best to balance competing ideas and interests while finding common ground.
- Construct a personal theory of practice and the progress they have made in the course regarding their ideas about negotiation, social influence and the exercise of power inside organizations and multiparty situations.
- Develop the tools and the playbook needed to continue to learn from personal negotiation and organizational leadership efforts after completing the course.

2.3 Course Three: Leading Change in Organizations

Course Three explores three perspectives on organizations – strategic design, political, and cultural. All have important implications for performing effectively in the everyday operations of the firm as well as successfully undertaking change in organization.

By the end of the course, students should be able to:

- Introduce scientists, engineers, and researchers to a way to diagnose organizational problems and prescribe solutions based on three perspectives – strategic design, political and cultural.

- Introduce key terms and concepts from network, power and culture theories that are critical for accomplishing individual and collective goals.
- Provide ample opportunities to apply these perspectives and concepts through multiple video-enhanced cases and compact writing assignments.
- Provide participants with the practical tools available to them along with a sense of when to use such tools while attempting to lead or support a modest or extensive organizational change.

2.4 Course Four: Discovering and Implementing Your Leadership Strengths

Course Four combines an "inside out" with an "outside in" learning strategy where learners look "inside" to discover and develop their unique leadership strengths as well gain "outside" insights on how others view their strengths and how to develop them.

By the end of the course, students should be able to:

- Explain their distinctive leadership strengths grounded in personality, values, capabilities, and self-identity.
- Develop new leadership strengths.
- Define future leadership contributions and how to realize them.

3 LEARNING DESIGN

The design vision of the LASER curriculum, pedagogy, and learning environment is based in the latest neuroscience and cognitive behavioral science on learning, as well as best practices from years of MIT's work in digital learning.

LASER puts evidence-based insight into action, implementing such digital learning innovations as modular content, interleaved assessments, visualizations and simulations, and adaptive hinting. By unbundling traditional semester-long content into modular, consumable units, LASER creates a learning environment that provides learners with the knowledge they need as they need it. This program design is crucial for busy professionals working to extend their education while on the job.

MIT's founding motto mens et manus (meaning mind and hand) underwrites LASER's pedagogy with course modules and resources designed for learners to apply their knowledge and skills to real-life challenges and projects. Research on expert performance suggests that it takes 10 years or 10,000 hours of dedicated practice to become an expert in a field [7]. As leadership expert D.V. Day observes [8], leaders cannot fully develop simply through passive participation in a series of workshops, seminars, and programs. Rather, leadership is developed in experiential practice. As Day underlines, "this notion of ongoing practice through day-to-day leadership activities is where the crux of development really resides" [9]. LASER is defined with this very notion in mind – providing a platform for people to practice being leaders through modular, spaced opportunities to develop the knowledge, practice the skills and apply the learnings they need to become more effective managers and leaders in their fields.

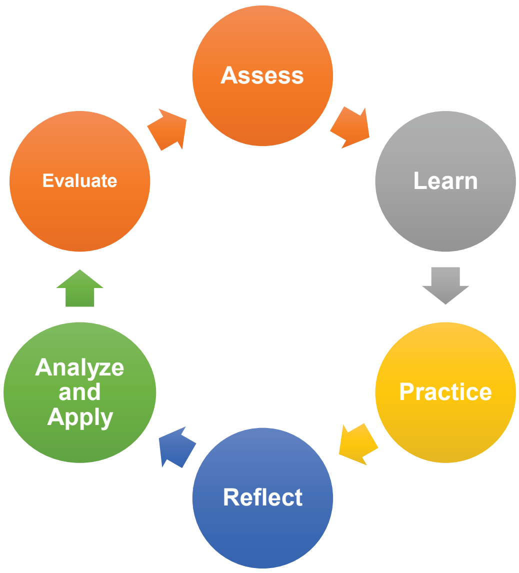

Figure 1: LASER Learning Model

The LASER learning design offers students a repeatable learning model. As illustrated in Figure 1 above, students are asked to go through a learning cycle where they will assess, learn, practice, reflect, analyze and apply, and evaluate.

- Assess: For every topic, diagnostic tools help learners assess and understand their strengths and weaknesses.
- Learn: Students learn core concepts via engaging videos and research-based readings.
- Practice: Through case studies and simulation activities, LASER creates a safe place for learners to practice and build skills.
- Reflect: Students are asked to reflect and take stock of what they have learned.
- Analyze and Apply: Via real-world projects, students learn to apply, analyze, and contextualize learnings to their current jobs.
- Evaluate: Using post-assessment instruments, LASER measures students' outcomes and evaluates their progress.

4 CURRENT STATE AND FUTURE WORK

Before launching LASER to the market in the fall of 2019, MIT is currently running a beta program with over 300 learners drawn from the following organizations: Boeing, NASA, Fidelity, Boston Scientific, and US Air Force Institute of Technology.

As ensuring customer input and industry alignment of LASER is paramount to MIT, quantitative and qualitative data covering all aspects of the program is being collected so that MIT can improve the content, learning design, and overall user experience. MIT will continue to evaluate the program with each run of the course and use findings to improve the program in its next iteration.

While MIT will not know what enrollments are for this program until later in the summer, MIT is forecasting 3,000 learners will sign up for the inaugural run. With attendees representing a large international population with different background, LASER's aspiration is to bring together bright, curious minds from around the world and create a lasting community and knowledge base for future technical leaders as well as foster new opportunities for engagement between the MIT community and the world. Finally, LASER aspires to prepare tomorrow's technical community with the leadership skills needed to tackle the globe's grand challenges.

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The creative and transdisciplinary design process in a Problem Based Learning environment

E. K. Hansen[1]
Aalborg University, Dep. of Architecture, Design and Media Technology
Copenhagen, Denmark, ORCID 0000-0001-7858-9511

L. B. Kofoed
Aalborg University, Dep. of Architecture, Design and Media Technology
Copenhagen, Denmark

J. R. Bruun-Pedersen
Aalborg University, Dep. of Architecture, Design and Media Technology
Copenhagen, Denmark

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Keywords: Creative Transdisciplinary Design Process, Problem Based Learning, Lighting Design

ABSTRACT

In higher education, transdisciplinary master programs have been developed to afford students to combine knowledge and methodologies from different fields and thereby develop an understanding of how to create new innovative solutions. An international and transdisciplinary science and engineering master programme in Lighting Design (LiD) at Aalborg University (AAU) in Copenhagen, bases its teaching on problem-based learning (PBL) and a process model "The Lighting Design Experiment" (LDE), which integrates innovation processes and design research methodologies [1] [2]. Knowledge and methods from the fields of architecture, media technology and lighting engineering are to be synthesized and applied into a problem-based semester project. To investigate to which degree students do consider creativity and innovation as integrated parts of their semester projects, a survey was carried out with 20 students from seven semester project groups, looking for aspects within two creativity components; domain relevant skills and creativity relevant processes [3] [4]. The survey indicates that the transdisciplinary approach seems to create the desired synthesis of knowledge and skills, from each academic field into the semester project despite the different knowledge areas and methodologies represented in the courses of the semester. Whereas the investigation of the creative processes points out three areas of attention for improvement; the framing of the project, the group dynamics, and tools for idea generation. The outcome has provided a better understanding of the inherent potential and barriers for creativity in the transdisciplinary design process, and how to possibly improve these in this PBL project-based design approach.

[1] Corresponding Author
E. K. Hansen
ekh@create.aau.dk

1 BACKGROUND

In Engineering and science educations, as well as on an overall level in many educational systems, there is a growing emphasis on providing students with skills and competences within innovation and entrepreneurship [5]. This emphasis comes from an a) identified need for establishment of new enterprises, b) creation of new products, and c) being able to contribute to enhanced growth [6]. Graduates combining technical and innovative backgrounds are considered to be an important key in this development, which calls for novel solutions [7]. Creativity is a prerequisite for the ability to combine present knowledge into new solutions, and widely accepted as prerequisite condition for innovation [3] [8]. Creativity and innovation are thus key components in science and engineering educations, including how collaboration and a transdisciplinary view on real life complex problems is necessary, and how it is important to focus on innovative design competences in those educations [5]. However, it is a challenge for educations, that creativity is disregarded (or killed) more often than it is supported [8] [10]. Working pedagogically with PBL and project-based group work, a challenge for both teachers and students, is to focus on the practical application of creative processes [11].

1.1 Problem-solving for innovative LiD projects; the LDE Model

In 2014, the transdisciplinary science and engineering master programme in Lighting Design (LiD) was launched at Aalborg University (AAU) in Copenhagen, as a combination of architecture, media technology and lighting engineering. The '*AAU model for problem-based learning* [9] (AAU Model) shows a strong organizational and didactic support for PBL, which for students, partly materializes through a combination of courses (for basic knowledge acquisition) and a semester project (for the application of said knowledge). The didactic method for LiD divides its three academic fields into three 5 ECTS courses, running in parallel with a 15 ECTS problem-based semester project (in which knowledge and methodologies from the courses are synthesized and expected to be applied). The AAU semester projects include a PBL process from idea generation, problem analysis, problem statement, problem solving, design, and implementing solutions [9]. These stages of the AAU PBL pedagogy are reinterpreted into a five-step, process model for LiD, called the *Lighting Design Experiment* (LDE) (see Figure 1). The LDE model was developed with reference to the innovative process model by Carlile [19], to allow the transfer of knowledge from several domains into a project, translating them into a common (shared) language, and transforming that into innovative solutions and new explicit knowledge, to be shared in new experiments [18]. The aims are to include the didactics of the AAU Model, while also synthesizing knowledge from the three LiD disciplines represented in three criteria into five design steps. Those creative processes should motivate innovative, as well as academically validated solutions in students' design projects [1].

In Figure 1, the five design steps are shown. Idea generation is formed in Step 1 (‘*imagine & ask’*), including an *imaginative research question* (IRQ). The IRQ is conventionally referred to as an *initial problem statement* in most models, but within the LDE, an emphasis is placed on imagination, to encourage a visionary and innovative project approach. The problem analysis and solution direction in Step 2 (*‘analyse & propose’*), performs the transdisciplinary translation of topic combinations for knowledge and skills, from the three fields, into a coherent framework. It is the joined understanding of these knowledge areas, which forms the foundation for creating new combinations of existing knowledge. The process includes both literature reviews, practical trials and experiments, which ultimately leads to hypothesis-formation within each of the criteria, representing the different academic fields (conventionally often framed as a final research question, or final problem statement). In step 3 (*'link & construct'*), the design is created and students are encouraged to integrate and link tools, methods and approached from the three academic fields. In step 4 (*'test & explain'*) the design is applied and hypotheses are tested, which informs a next iteration of the whole design development [1] [2]. An essential point in innovation [19] is to return new knowledge, gained in the experimental projects, back to the different discipline domains. Step 5 (*'share & learn')* puts explicit knowledge back, as a new point of initiation, whether it be feeding another iteration of the existing project, or to future projects.

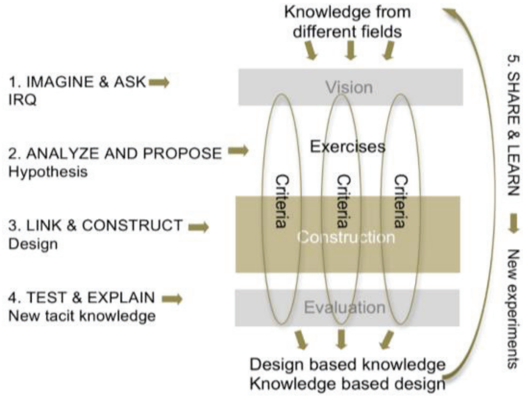

Figure 1. Model of the Lighting Design Experiment [1]

To ensure a transdisciplinary approach to combining the scientific fields, the theory of Koskinen et al. [21] is used to define how different research methods and fields can be integrated, in parallel, in the process. The three different fields in the educational programme represent tools and methodologies referring to natural science, humanities and art. These skills can be defined within the three different criteria in the process model, representing the lab, the field and the showroom - referring to Koskinen at all and their design research methodologies [21]. The iterative nature of the LDE process model is meant to encourage students to actively consider how their knowledge, expertise and technical skills from the three LiD fields, can be applied and integrated into the semester project. The question is, however; do the students experience this process as innovative and creative?

1.2 Creativity as components

The relationship between creativity and learning has been widely recognized [10] [11] [12], and a substantial amount of research in how to promote creativity in technical educations is available [13]. Some studies point out that a creative process is individual, and will often suffer in a group process [15]. Meanwhile, we also see that creative processes in groups can be very effective [11]. The componential theory of creativity Amabile states that creative influence includes three within-individual components (domain relevant skills, creativity relevant processes, and task motivation) and one outside-individual component (the surrounding environment) [3] [4]. *Domain relevant skills*, which include knowledge, expertise, technical skills, and talent, are particular domains that are represented in problem-solving work of AAU student projects. These skills are the basis upon which the individual can combine to create, during a creative process. *Creativity relevant processes* [3] include cognitive and personality processes, which according to Amabile are 'conductive' for novel thinking. Amabile highlights the most important characteristics as risk-taking, seeing new perspectives on problems, a disciplined work-style and skills in generating ideas. The personality processes include self-discipline, and a tolerance for ambiguity [4]. *Task motivation* centers especially around intrinsic motivation; from engagement in an activity purely out of interest in its process, enjoyment, or a personal sense of challenge. *The surrounding environment* (especially the social environment) includes factors which stimulate creativity, such as collaboration in groups with diverse skilled and idea focused members. Referring specifically to Amabile's *creativity-relevant processes* and *domain-relevant skills*, we have asked our students how they experience the creative and transdisciplinary process within the LDE approach, for the LiD semester project. Based on this initial case study, we will be able to contribute to the discussion of the relation between knowledge, skills and creativity, in transdisciplinary problem-based projects.

2 METHODS

Our approach is based on how 2nd semester LiD students experience *creativity relevant processes,* as part of their project work during their 1st semester, based on Amabile's first two components; *domain relevant skills* and *creativity relevant processes*. Specifically, students are asked into their experience of the previous (1st) semester's project, to make sure they refer to the holistic experience from an entire semester, including courses, project and the relations and dynamics between these. In this study, we excluded empirical focus on *task motivation* and *social environments,* to focus on students' relation to creativity relevant processes in the project. The study was a two-stage approach, as investigating creativity relevant processes requires a baseline; namely, that *domain-relevant skills* are acquired and available to the participating students.

In stage one, we therefore needed to know to what extend the students believed to have acquired the *domain-relevant skills,* provided to them through their three courses, representing the three LiD fields (lighting engineering, media technology and architecture). According to Amabile, *domain relevant skills* include factors such as 'basic knowledge' and 'technical skills'. The first part of the questionnaire asked students to rate their *domain relevant skills* for each of the individual courses, by subjective ratings of their own 'basic knowledge' (for example 'theory, subject information, etc.') as well as their opinion on how easy this was to transfer to the project. If students found the course knowledge to be useless for the project, it would not qualify as 'domain-relevant', and thus be useless in context of the study. Students were asked to rate these on scales from 0 to 6, in which 'basic knowledge' had 0 exemplified as 'not good' and 6 as 'very good'. Students were also asked to rate their technical skills (for example, methods, approaches, usage of tools, etc.), and how well they believed these transferred into the project. These were rated on scales from 0 to 6 as well, with the four ratings approaches- and questionnaire layouts being similar.

In stage two, we looked into the *creativity relevant processes,* asking students to rate Amabile's four main characteristics of the component, in relation to the semester project, using a similar scale from 0 to 6. The four main characteristics were; a) *students' willingness for risk-taking*, (for instance, in order to explore an idea, reach an academic goal or chase personal ambition), b) *the project's ability to push for novel ideas* (for instance, focusing on seeing/finding new perspectives on existing problems), c) *the degree to which the project inspires a disciplined work-style* (for instance, concentrating effort for long periods of time, not being distracted from the task), and d) *degree to which the project supports skills for generating ideas* (for instance techniques, approaches or methods). For these, we introduced an additional sub-item to each rating, where students were requested to 'place a few words on the background for the rating'. Finally, outside the scope of rating Amabile's components, the questionnaire concluded asking students to rate the education of Lighting Design, in term of being an education using/inspiring creativity, on a similar scale from 0 to

6. The analysis of students' ratings used descriptive (non-parametric) statistics, for measures on central tendencies for each question. The written responses were used for qualitative depth, supporting the quantitative ratings, and possibly allow discussion and reflection on the approach LiD has taken on creative processes until now.

3 RESULTS

The survey was carried out in April 2019 at AAU Copenhagen, with 20 participants (9 male and 11 female), all being active 2nd semester graduate students at LiD. Participants ranged between 11 nationalities, and represented 17 different undergraduate certificates, prior to their LiD graduate program admission. Distribution was carried out digitally via hyperlink. Participants were all situated in the same room, while observed by an attending author.

3.1 Domain-relevant skills

The questionnaire results of stage one, are shown in Table 1. Here, medians between 4 and 5 suggest a fairly solid impression of the *domain-relevant skills* with participants, based on both responses on basic knowledge and technical skills. Ratings for the *transfer* of

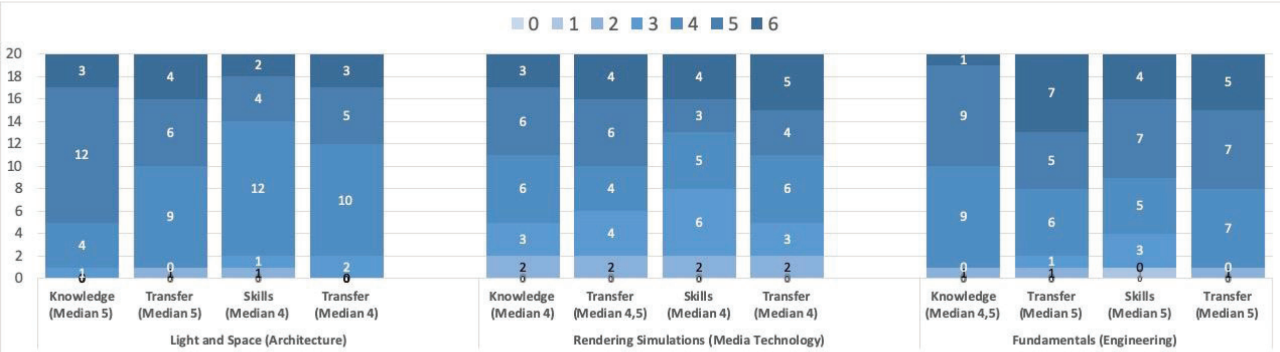

Table 1. Rating of domain-relevant skills and knowledge from each course as well as perceived ability to transfer these into the semester project.

knowledge and skills from each course into the semester project, are very consistent between three courses, and ratings are very similar to the corresponding knowledge and skills ratings of each course. It suggests that students, already in the first semester, are confident in their knowledge and skills within each academic field, despite the different academic backgrounds within the sample group *and* despite the very different knowledge areas and methodologies represented in the three courses/fields. The ratings demonstrate that the students believe in their ability to transfer and combine knowledge and methodologies, from the different fields into the semester project. It indicates that students working according to the LDE model, experience ability to work in the desired transdisciplinary problem-based context already during their first semester.

3.2 Creativity-relevant processes

Second part of the questionnaire looks at the students' experience of creativity-relevant processes in the design process. The median values in Table 2 are lower compared to Table 1, but also, here staying consistent, mostly on a median of 4. Participants also believe that LiD is a creative education to the degree of a median 4. For more insight into students' experiences and contextualization of these scores concerning creativity in the process, we will look into the qualitative responses in the questionnaires.

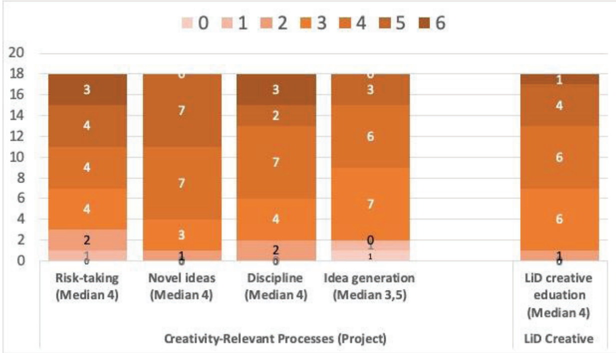

Table 2. Students rating of creativity relevant processes

3.2.1 Willingness for risk taking

Within this topic, students commented that the framing of the project could have more focus and encouragement for the willingness of risk taking. 7 of 19 students mentioned (in no particular ranking) a) the openness of the project description, b) the technical requirements, c) the format of the final scientific report, d) the examination and e) lack of time, as relevant for their willingness for risk taking. One student stated that "*it's hard to take risks if it's the only main projects we do for the finals. There are no low-stake assignments where we're encouraged to take risks and make mistakes*." Another student pointed out the technical and applied approach to the design as limiting for the willingness for risk taking. However, a student also stated: "*project requirements give a lot of freedom regarding the area we would like to work with. It is challenging but also nice to decide yourself your field of interest within the project.*" Within the project format, students experience time pressure, and the "danger" of risking, due to the lack of time; "*As long as the risk and decisions are backed up by facts, no problem. On the other hand, it might be dangerous to risk not having the time to finish the goal/ambition*." Risk-taking willingness also relates to the approach taken by facilitators/professors, specifically their role for framing the need for- and rewards of a more determined risk-taking approach. Group work dynamics can limit willingness towards risk-taking, when there are no constructive attitude or conductive consensus dynamics found within the project group. A student states that "*I would take risks to lead it to the field, I would like to work with lighting, but it is difficult when we work in groups, because we are 4 people wanting 4 different directions so I don't think it is that possible - also because the assignment on 7th semester is very specific. But I like that we have a specific frame, because we are new to everything concerning lighting*". The acquisition of new skills, knowledge areas and processes also reportedly hinder risk taking: "*The first semester we pretty much went by the book, mostly to properly learn all the new information about light we had not had from our respective bachelors. It was in that sense less interesting; however, we also learned a lot. This second semester, the "risk-taking" to explore interesting subjects will be more prevalent.*"

3.2.2 Ability to push for novel ideas

The way the assignment has been defined referring to the five steps and the integrated experiments push for novel ideas, according some students' input: "*The frame of the semester project was formed in a way that new ideas could be easily implemented on as long as the appropriate research and experimentation has been done, that could be used* *as productive argumentation during the presentation of a proposal*." "*[…] I had no experience with lighting design, it showed totally new perspective on the problem. Supporting courses played important role in the process of finding new angle to the design approach*." These statements suggest that the project can cater to creative freedom, and how domain-relevant skills paved way for a creative mindset in project work. However, the lack of fundamental knowledge on lighting and new technology from the undergraduate level, naturally limited students' ability to push hard on new ideas: "*I think it was easy to identify the weakness of the light in the space which made it also easy to come up with a solution to that problem, but I feel we lacked information on the available technology that could have been used to solve the problem.*" Here, group dynamics is also considered both a challenge and a potential, to push new ideas: "*The cross-disciplinary backgrounds of the group members helped the semester project to develop. Difference in viewpoints and experiences paved way for new ideas - although sometimes on the back of heavy discussion and disagreements.*"

3.2.3 Disciplined work-style

Distraction affect a disciplined work-style, both based on all three courses running parallel, and on different work style and experience between students: "*We had a lot of distractions with handing in (assignments for) other courses (presentations, etc.) at the beginning. Especially between two pinups. But in the end of the semester when we had a lot of free time, it was easier to concentrate on the semester project*". Meanwhile, despite their distraction from the project, some students also attribute motivational aspects for the project, from doing course work; "*The semester project required a lot of time of doing disciplined work. It is a good idea to be free from other activities or courses. However, I do not support their complete absence, since sometimes they are inspiring or maybe even help you to see things in your project in a different way*". The process model (LDE) was also mentioned as a help in structuring the work "*I personally felt not distracted when we were implementing different ways of working like idea generation sessions, experiments, readings...*". Some responses affiliated group dynamics with challenge, for the disciplined work, though not an unsolvable one: "*Coming from different backgrounds, it took time for us to get into a disciplined and structured style of working - but eventually we did and the flow felt natural.*"

3.2.4 Skills for generating ideas

A combination of (domain relevant) skills and knowledge was stated to promote idea generation: "*Being creative can be difficult when the boundaries seem very strict, but that is also where the best creative endeavors stem out from.*" Also, a perceived lack of application of skills and tools, specifically relating to idea generation knowhow, was mentioned: "*Problem solving happens in the groups but not in classes or with any supervision. It's good to be on our own in some circumstances but it would be helpful to skills for generating ideas within the context of the classes or with supervision to introduce us to the process of generating ideas.*" Group dynamics was mentioned as essential for generating ideas: *"The group dynamic is so vital for how you generate ideas through a project. In my case we had an okay process, but the idea generation for the design was totally lost."*.

3.3 Results summary

After their first semester, LiD students appeared confident in their *knowledge and skills* within their required academic fields, despite their different undergraduate backgrounds, and different knowledge areas and methodologies represented through their course work. They also believe in their ability to transfer and combine knowledge and methodologies from the three fields into the semester project. Students' experience of *creativity-relevant processes* in the design process, is rated a little lower but still ranked above average. The qualitative responses pointing towards *creativity-relevant processes,* demonstrate a potential for improvement. These improvements can be defined within three areas of attention; the framing of the project, tools for idea generation and attention on the group dynamics. The qualitative data suggest that a stronger focus on introducing specific tools for different steps of the process, would be interesting. In relation to the *project framing,* requirements should point towards a creativity-driven methodological design approach, where the constructive potential of risk-taking and making mistakes, is both inherent to the framework, and explicitly included in its presentation. Students need 'creative' support through information and guidance, on the balance of acquiring new skills and knowledge, while being willing to take risk. And how this balance can be advantageous and push for new ideas in this process. The LDE process in the semester project, integrated experiments in the design process and awareness of combining knowledge, push positivity towards novel ideas, according the students. Including explicit expectations for creativity into the project evaluation, with emphasis on the applied and implemented creative methods and approaches within the project processes (and not simply the final product), seems important to students' willingness to include risk, as well. In all four characteristics of creativity-relevant processes, *group dynamics* is mentioned by the students as a challenge or barrier, due to lack of specific shared experience in creativity management in groups. Meanwhile, group dynamics is also described as vital for generating new ideas, perhaps especially due to how LiD students come from vastly different backgrounds, which can be a creative strength, especially if managed well. Group work requires time and skills to establish a disciplined and structured work flow, but is still considered essential by many, to develop and push for new ideas, in the semester project.

4 CONCLUSION AND PERSPECTIVE

We asked Lighting Design (LiD) students at Aalborg University (AAU) about their experience of the creative and transdisciplinary process within the "Lighting Design Experiment" (LDE) approach, in their 1st LiD semester project. By structuring this investigation around Amabile's creativity components, we have been able to better understand how students experience the interplay of domain relevant skills and creativity relevant processes in such transdisciplinary context. The results illustrate that the students are confident in regard of their relevant knowledge and skills, in their semester-given LiD fields, and that these abilities transfer well into their semester project through the LDE process model. Specifically, how to combine knowledge and methodologies from the three different academic fields, and to transform this into one problem-based project. Students do experience creativity-relevant processes in the semester project, to have yet unfulfilled potential.

Three areas of attention have been identified; The framing of the project, group dynamics and tools for idea generation.

The framing of the actual semester project can support the creative processes by informing the students about how creativity can be supported through an understanding of the balance of acquiring new skills, combining different knowledge areas and processes and willingness for risk taking. These elements must be balanced in the process to support pushing for new ideas. The investigation also indicates a potential for an awareness of the curriculum defining more precise expectations for the final semester report and examination. A focus on the creative processes should here be stresses rather than the final design.

The creative processes can also be supported through introduction of specific tools for idea generation in the transdisciplinary design process. In all four characteristics of creativity-relevant processes students have pointed out that the group dynamics is vital for how to generate new ideas. This challenge and potential must have attention by the facilitators/professors.

This definition and integration of creativity aspects in the project framing, tools and group dynamics will support a more nuanced definition and understanding of the transdisciplinary creative design process. A process where there is an empathy on combining skills and knowledge from different fields and awareness of how this can be supported through an understanding of how creative processes can promote risk-taking, push for new ideas, disciplined work and idea generating results. These categories can be stressed in the different steps of a process like the LDE model through the “framing” of the assignment, introduction of idea generating tools as well as an awareness of group dynamics in the different steps of the process.

The investigation also stresses the awareness on how we should strive to integrate knowledge domains and creative processes as one collective approach, integrated in transdisciplinary and academic PBL models like the LDE. The findings from this investigation will be used to improve the curriculum and project framing, as well as sharpen the awareness on the group dynamics and introduction of specific tools for creativity for the future semesters at the LiD programme. The findings will as well be used to strengthen the creative potentials of the general LDE process model.

These initial findings will lead to further investigations integrating the two last creativity components by Amabile: task motivation and the surrounding environment.

The transdisciplinary approach through the LDE process model and PBL approach seems to create the desired synthesis of knowledge and skills from the different academic fields. But the investigation of the processes referring to Amabiles definition of creativity relevant processes, described through risk taking, new perspectives disciplined work and generating new ideas points out a general potential for combining the transdisciplinary approach with specific focus on the creative processes.

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Complexity for heterogeneous classes: teaching embedded systems using an open project approach

F. Huening[1]
Professor
Department of Electrical Engineering and Information Technology, University of Applied Science Aachen
Aachen, Germany
huening@fh-aachen.de

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ABSTRACT

Modern embedded systems are a complex mixture of hardware and software components, like for Internet of Things and Industry 4.0 applications. The technical challenges when teaching embedded systems include the basic hardware like microcontrollers, low-level software development as well as more sophisticated high-level software stacks and modules and finally complex applications. On the other hand the previous knowledge of course participants in master degree programs often differ drastically, from absolute beginners to rather experienced developers of embedded systems. Taking the technical and the non-technical challenges into account this paper presents an open project approach for heterogeneous classes taking an embedded systems course as an example. To enable an individual learning success for all participants it combines elements of typical lectures with elements of flipped classroom and project-based learning (PBL). One part of the course uses standard lectures to get every student to a defined knowledge level. In the other part students define their own projects based on a complex microcontroller system according to their prerequisites and individual focus areas. Additional teaching material is provided online for the students that can be selected according to the needs of the project. This open project approach strengthens the benefits of learning techniques like PBL and flipped classroom, increases the self-motivation of the students and encourages the students significantly to work on the project and to gain hands-on experience in developing embedded systems. The combination of modern teaching techniques with the open project is suitable for other subjects as well.

[1] F. Huening
huening@fh-aachen.de

1 INTRODUCTION

Teaching heterogeneous classes is rather challenging and many different teaching strategies were developed with different emphasis on problem or project cased learning, online and offline activities or active learning [1, 2]. The heterogeneity may be caused by different kinds of learners, different social or educational background, different mother languages, different previous knowledge and interests. For the course Electronics for Automatization, which is the base for this paper, in particular the heterogeneity with regard to different previous knowledge and the interests are the main challenges.

Problem or project based learning (both abbreviated with PBL) or cooperative learning are commonly used methods for teaching heterogeneous classes, in particular to increase the hands-on experiences and practical abilities of the students [3, 4, 5, 6]. These methods target to motivate the students to be engaged with the material, show interest in the course contents, participate in the class and collaborate with other students.

With regard to electrical engineering PBL is commonly used, both for complete curricula like in [7] or for dedicated courses. In [8] and [4] the PBL approach is described for courses in embedded systems. They are based on field-programmable gate arrays (FPGA) and microcontrollers respectively and use fixed projects for the lab work. Whereas problem based learning approaches define a specific problem to be solved by the students, project based learning relies more on self-defined projects of the students. The current work presented in this paper combines a conventional lecture style with a new approach for the project based methods for the lab. This new approach is based on the self-motivation of the students and the finding that the motivation is highest if the students can work on their own ideas and projects.

2 PROBLEM STATEMENT

The course Electronics for Automatization is part of the curriculum of the master program Electrcical Engineering at UAS Aachen [9]. Main topic of this course is teaching embedded systems and in particular microcontroller systems. The course consists of lecture (2 lessons per week), exercise (2 lessons per week) and lab with just a one lesson per week. The class is always rather heterogeneous with up to 40 students participating in this one-term-course of the master program every year. About 25 % of the students have passed their bachelor at other universities, roughly half of these at foreign universities (e.g. from India, China or Mexico). For the foreign students also the language is sometimes a problem as the course is in German. About 20 % of the participants finished their bachelor in other departments of UAS Aachen, e.g. Mechanical Engineering and Mechatronics. Even the students from Electrical Engineering department have chosen different focus areas during their bachelor. Therefore the previous knowledge of the students is very different. Some students never experienced anything with embedded systems, some already attended classes on this subject and yet others have a rather big know-how due to intensive work with embedded systems during their bachelor thesis or student jobs. In addition the interests of the students differ significantly.

This diversity in knowledge and interests is one part of the challenges during the embedded systems course. The other big challenge is the complexity of modern embedded systems that combine sophisticated hardware (HW) with several different software parts (SW), from low-level drivers to high-level application software. As most embedded systems use microcontrollers as the central device these Integrated Circuits (IC) are the major subject of the course. To cover all aspects of the development of microcontroller based embedded systems state-of-the-art microcontrollers and development environments are used, both for the lecture as well as for the lab. Initially using Renesas' RL78 16-bit microcontrollers the course switched to 32-bit microcontrollers of Renesas' Synergy platform that was launched just some years ago. The Synergy platform fits perfectly into the teaching goals of the course as it enables system development at very different levels – from just simple applications to highly-sophisticated networking and IoT (Internet of Things) applications.

Finally the goal of the course is rather simple: every student should have at least the basic theoretical background of embedded systems and microcontroller systems and in addition should gain hands-on experience with embedded systems no matter of his individual prerequisites. These goals mean that there has to be some overall theoretical part which is the same for all students and each student should be encouraged to develop his own skills further, independently of the abilities of the other students. To motivate everyone to work for the second goal the lab is setup rather individually in small groups like described below.

3 TECHNICAL CONTENT OF THE COURSE

The course is based on state-of-the-art microcontrollers from Renesas Electronics as these microcontrollers are commonly used in many different industries, from automation systems to consumer, automotive and medical applications. The microcontrollers are rather complex and provide all hardware features that are used in modern applications like IoT or Industry 4.0 applications. Initially the 16-bit RL78 microcontroller was used for the course. Besides the hardware of the microcontroller a dedicated integrated development environment (IDE, e2studio which is based on Eclipse) and additional tools like Applilet, a graphical configuration tool for the basic setup of the microcontroller, is provided as well. After the launch of the Renesas Synergy Platform the course switched to the Synergy S7G2 microcontroller [10]. This platform provides a complete ecosystem for the development of advanced applications in all fields of interest. Besides the sophisticated hardware, here the 32-bit S7G2 microcontroller with an ARM architecture, the ecosystem consists of powerful development, software and application packages. The IDE is again the eclipse based e2studio, but this time powerful software packages to simplify the configuration and programming are already implemented:

- Board Support Package (BSP) for graphical configuration
- Hardware Abstraction Layer (HAL) for direct programming of the hardware modules
- Real-Time Operating System
- Functional libraries, application frameworks and middleware for high level programming
- Connectivity modules

Taking all these features into account the Renesas Synergy platform provides everything that is needed to teach the development of modern microcontroller based embedded systems. Furthermore it allows to start with just the basic features to realize simple applications as well as the use of the complex features to develop more complex applications – again individually fitting to the prerequisites of the students.

4 CONCEPT AND REALIZATION

To reach the two goals defined above – at least same theoretical background for all students and individual enhancement of practical skills – the teaching methods for the lecture and the lab part are set up in a different way.

The lecture is conducted in a rather conventional way and starts with the introduction to embedded systems and microcontrollers at the very beginning to provide the basis for the following topics. Based on these fundamentals and on some basic programming skills software architectures and methods are introduced, like middleware and real-time operating systems (RTOS). These topics build the minimum knowledge every student should acquire during the lecture. The example systems used during the lecture are the same like the systems used during the lab. For more advanced students additional material is provided in a kind of flipped classroom approach. This material contains more detailed and comprehensive information about sophisticated topics like hardware abstraction layer (HAL), RTOS, application frameworks and connectivity. Using this additional material each student can individually select the complexity and topic that fits to both his previous knowledge and lab project.

The lab is set up in a collaborative learning style with an open project for each group of students. The formation of the groups isn't done by the lecturer but by the students. Therefore some of the groups are more homogeneous than others. According to [11] open project approach means that each group of one to four students define their very own project based on the microcontroller platform introduced in the lecture. In addition it is possible for the groups to order additional equipment if needed for the project, e.g. hardware extensions, additional components or other material. After the project was defined the groups make a timeline for their projects and directly start working on the projects right from the beginning of the course. This work includes everything from the basic setup of the systems and development environment to the hardware parts and the programming of the software including low-level drivers, RTOS and application software. The work is done more or less absolutely on their own. During official lab times there is the chance for getting support and help in case of severe problems, but in general the students are encouraged to solve all issues and problems on their own or within the group. The work is supported by dedicated teaching material like data sheets, a course book and slides covering everything that is needed. Even though this approach might cause some frustration and delays, in particular in the practical work, it prepares the students for working as an engineer finally.

At the end of the course each group prepares a final presentation of their work and project, including drawback, problems, pros and cons. As there is no final grading of the projects this approach strongly relies on the self-motivation, interest and trustworthiness of the students to realize an own project within a group. This point will be evaluated in detail below.

5 EVALUATION

The evaluation of the course and the free work approach is done in three steps:

- Standard evaluation of the course
- Review of projects developed during the free lab
- Personal feedback

At UAS Aachen each course is evaluated by a standardized evaluation process each year [12]. The evaluation is done at the end of the lecture period but before the exam. The feedback of the students is anonym and contains many questions about the content of the course, the learning atmosphere, the workload and many more. During the last five years about 160 students attended the course and the average rating on a scale from 1 (best) to 5 (worst) reveals a 1.3, for the single years ranging from 1.1 to 1.5. After the winter term 2017/2018 an additional question was added to the evaluation form: ‘In my opinion, the supervision of the practical course suited my educational needs’. The answers to this question answered by 20 students revealed an average of 2.1 (1: fully agree, 5: fully disagree) (*Table 1*).

Table 1. Student feedback to the question ‘In my opinion, the supervision of the practical course suited my educational needs’ on a scale from 1 (fully agree) to 5 (fully disagree)

Evaluation	1	2	3	4	5
Number of answers	7	8	2	1	2

Another question of the official evaluation is related to the additional workload the students spend. For this course the additional workload is mainly due to the free project work and hence is a measure for the commitment of the students to their work. The official time for the lab is just one lesson per week (45 minutes). In average the students spend about 3 additional hours for the lab which means four times the originally planned time of one lesson. Here the range is from 0 hours to more than 7 hours per week.

The last item of the official evaluation form is a free text field where the students can provide their personal feedback. Regarding the lab there were some comments very common during the 5 years, both positive and negative (*Table 2)*.

Table 2. Common comments of the official evaluation

Pros	Cons
Free project without constraints	Missing introduction to lab work
High motivation of the students	Too complex microcontroller system
Incorporation of own ideas	No final grading

Looking at the projects that were realized during the last five years it becomes obvious that the projects cover the complete range from very simple to rather complex applications like shown in the examples listed in *Table 3*.

Table 3. Examples for projects developed during the free lab, evaluation by lecturer and co-workers

Project	HW complexity	SW complexity	Previous knowledge
LED control by external buttons	Low	Low	Low
Control of a 4x4x4 LED cube	Low	Medium	Low
Radio controlled clock using the DCF77 signal	Low	Medium	Medium
Sensor cluster	Medium	Low	Medium
Sensor cluster with TCP/IP connection and LabView	High	High	High
Spacefight video game using external acceleration sensors and a display	High	High	High

Last but not least the personal feedback of the students is taken into account. This feedback is given verbally during the course and also after the course and the exams. Therefore this feedback can hardly be quantified but is a rather subjective value. The feedback is very often positive, similar to the comments of the official evaluation. In particular the possibility to work on their own without any pressure is highly appreciated by most students. They also confirm that their learning curve is high and independent of the previous knowledge. Major drawback is the starting phase of the project, i.e. the initial installation and setup of the development environment and the first step with the new system.

6 DISCUSSION

The results of the evaluation clearly reveal the pros and cons of the open project approach from student point of view. These items of the students can be matched to the expectations and assessment of the course instructor as depicted in *Table 4*.

The main positive points of the students are the freedom during the project work and the motivation to work on own projects. From instructor point of view these points are also reflected by the additional workload the students spent and the projects that were realized. Each group during the last five years finalize their project, no matter of the previous knowledge or the complexity of the project or the time they needed.

Main negative feedbacks by some students were the missing supervision of the projects, in particular in the initial phase, the complexity of the microcontroller systems and the missing grading of the project work. These feedbacks were expected by the instructor as they are related to the basic setup and approach of the course. The missing direct supervision is one of the concepts of the course. Everything they need for the project work is provided, but the students have to acquire everything they need for the realization on their own. This approach intends to prepare the students for their engineering work in their future working life – get information, extract the relevant and needed information and get the work done on your own. This approach is also related to the second drawback, the complexity of the microcontroller system some students stated. Again, using an industrial state-of-the-art system is the best preparation for real engineering life. Finally the missing final grade for the project – in particular stated by some of the students that realized really complex projects like the Spaceflight video game – was one complaint. But the missing grading is a key point to enable fully free and open project work for the students.

Table 4. Main feedback of the students compared to the expectations and assessment of the instructor

Feedback item	Judgement by students	Instructor’s expectation	Instructor’s assessment
Freedom of project work	+	Met	+: all projects were finalized
Own project	+	Met	+: large variety of projects of different

			complexity levels
Motivation	+	Met	+: high additional workload, range of complexity
Supervision of project work	Mainly +, some -	Met	+: goal of the course: find own solutions and get system running on their own, good preparation for engineering work
Complexity of microcontroller	Mainly +, some -	Mostly met	+: good preparation for industrial work as an engineer -: some students have to fight hard with the microcontroller
No final grading	Mainly +, some -	Met	+: no grading enables fully free and open work on the projects without pressure

7 SUMMARY

The open project approach is well established within the master course Electronics for Automatization at UAS Aachen. Open projects means that the students define and work on their own projects during the lab of the course. There are no restrictions regarding the size or complexity of the projects and the students are encouraged to define the projects according to their previous knowledge and interests. To avoid any external pressure there is no final grading of the projects. A rather conventional lecture about the basic theory of embedded systems supports the project work.

After five years the open project approach is evaluated by official evaluation, direct feedback by the students and a review of the projects that were realized. This evaluation reveals the major pros and cons of this approach and is matched to the instructor's expectations. Most of the feedback highly appreciates the chance to work in a free manner on an open and self-defined project. The major negative aspects of the students are clearly related to the basic concept of open projects and hence is judged to be rather fitting.

8 ACKNOWLEDGMENTS

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Comparison of the effects of the integrated learning environments between the social science and the mathematics

T. Ito [1]
Kanazawa Institute of Technology
Nonoichi, 921-8501, Japan

K. Ishii
Kanazawa Institute of Technology
Nonoichi, 921-8501, Japan

M. Nishi
Kanazawa Institute of Technology
Nonoichi, 921-8501, Japan

M. Shin
Kanazawa Institute of Technology
Nonoichi, 921-8501, Japan

K. Miyazaki
Kanazawa Institute of Technology
Nonoichi, 921-8501, Japan

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Keywords: e-learning, active learning, EdTech, flipped learning

ABSTRACT

The integration of e-learning and active learning is expected to be effective for the improvement in the digital native students' leaning. Moodle (Modular Object-Oriented Dynamic Learning Environment) is widely used as Learning Management System (LMS) in e-learning. Video streaming is also used as one of the learning contents in e-learning.

Moodle and mediasite video contents are used in the mathematics course "Statistics for Engineers" and the social sciences course "Principles of Technology

[1] Corresponding Author
T. Ito
ito@neptune.kanazawa-it.ac.jp

Management" with our university's LMS called e-Syllabus. Both courses are carried out by flipped learning and active learning.

It is expected that students' usage of e-Learning is different between the social sciences course and the mathematics course. Questionnaires about the learning effects and the validities are carried out for Mechanical Engineering students.

Both courses had video contents and good textbooks. Many students taking "Principles of Technology Management" course did preparation and review with the textbook rather than e-Learning. 60% of the students who took "Statistics for Engineers" course used Video contents.

More than half of the replies support the flipped teaching and active learning rather than the class of a lecture entity. The usefulness of the textbook was also confirmed for the digital native student.

1 INTRODUCTION

From ancient times, education has been conveying knowledge. In the ancient Confucius era, the disciples studied at word of mouth what their master said. In the Middle Ages, the learning meant reading the classical literatures. In modern ages, the textbook was invented and students wrote down on their notes the contents which a teacher wrote on a blackboard based on the textbook. The educational style in which a teacher conveyed knowledge to students has continued for a long time.

Recently, the contents which are required for education are changing. Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) focuses on developing students' active learning ability to adjust oneself to changes proactively, explore a future goal of one's own, and evaluate that goal flexibly and generally from a broad perspective [1]. The education which develops the competence to practice and apply the studied knowledge and skill is required. It is important to bring up the ability to tackle problem detection and solution. For that purpose, the effectiveness of problem-based learning and project-based learning (both abbreviated to PBL) has been accepted widely [2].

Not only the contents but also the education / learning methods are changing with progress in Information and Communication Technology (ICT). Bill Gates said" Five years from now on the Web for free you'll be able to find the best lectures in the world. It will be better than any single university." at the Techonomy conference in Lake Tahoe, CA in 2010. Although there are still many universities which give lectures in the old fashion class rooms, students' attitudes have also been changing. Mark Prensky describes "Our students have changed radically. Today's students are no longer the people our educational system was designed to teach [3-4]. "

Aiming at IoT application and realization of Society5.0, MEXT and the Ministry of Economy, Trade and Industry (METI) in Japan are advancing the measure for Active Learning and EdTech. The Education Reform Committee of MEXT considered the innovation of the education corresponding to progress of technology and the high school reform corresponding to a new era. The Committee has proposed the following to the Cabinet; aiming at collaboration learning corresponding to every person's ability and aptitude, empirical study about effective utilization of the technology like EdTech is needed by collaboration of the school, corporations, etc.

Those proposals focus on the main contents about the educational environment and the educational method corresponding to Society5.0. On the other hand, it is necessary to accumulate data on EdTech utilization suitable for the actual condition about the responses of the students who are learning by EdTech.

The authors are carrying out the classes which use e-Learning materials and textbooks in Kanazawa Institute of Technology (KIT) in Japan. Their research work on PBL was adopted by the Grant in Aid for Scientific Research in 2019.

In this paper, we firstly introduce our e-Syllabus LMS. Next, the difference of course contents between the mathematics course “Statistics for Engineers” and the social sciences course “Principles of Technology Management” will be introduced. The questionnaire survey was conducted for the student of the department of mechanical engineering. We will discuss about the questionnaire results on the integrated learning environment.

2 E-SYLLABUS SYSTEM IN KANAZAWA INSTITUTE OF TECHNOLOGY

2.1 What is e-Syllabus?

Each university shows its students the syllabus which shows the contents of learning of each course. Many syllabuses show what kind of contents students study by the class of each week. However they are only shown at the time of course introduction or the first classes.

Our university launched the e-Syllabus in 2016 [5]. The teachers who take charge of their coursework are utilizing the e-Syllabus as one of communication tools with students and as the system which is useful for students' active learning.

The procedure how students access e-Syllabus is shown in *Fig. 1*. E-Syllabus will be displayed, if a student logs in to his page from the portal site, opens his list of courses and click the course. The example of an e-Syllabus image is shown in Fig.2. E-Syllabus displays the contents of learning of weekly classes with the guide of learning targets, scholastic evaluation method, and preferred achievement, etc. The teacher in charge can upload handouts or visual contents, and carry out tests and questionnaires in the contents area of weekly learning. Moodle (Modular Object-Oriented Dynamic Learning Environment) is widely used as Learning Management System (LMS) in e-learning. Video streaming is also used as one of the learning contents in e-learning. E-Syllabus can also carry out links with these contents.

Teachers can browse not only the e-Syllabus of their own classes but also that of other classes. Teachers can share the each other's contents of classes, and the operation method through e-Syllabus.

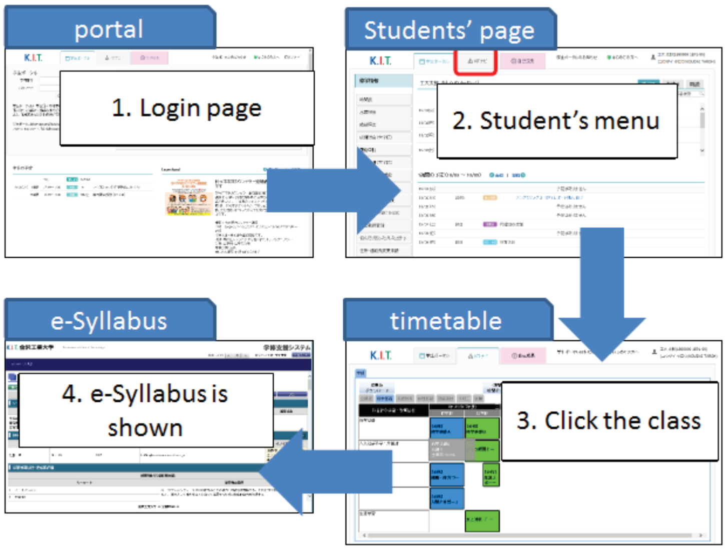

Fig. 1. e-Syllabus access procedure

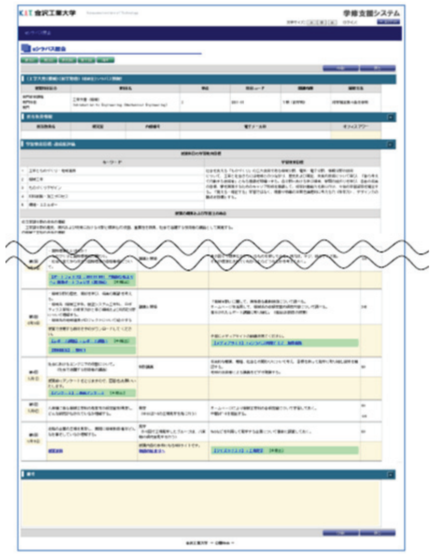

Fig. 2. Example of e-Syllabus

2.2 Flipped learning and active learning with e-Syllabus

E-Syllabus is a powerful tool when carrying out flipped learning and active learning. The teacher uploads preparation teaching materials and movies before the class, and gives assignments. Students prepare their lessons by e-Syllabus, and participate in the class. The teacher does the quiz which confirms preparation results, receives questions from students or guides discussion by students in school hours. He can carry out quiz and questionnaires by e-Syllabus in school hours, and can confirm degree of comprehension on the scene.

3 COURSE CONTENTS

Using e-Syllabus, authors conducted the classes of Statistics for Engineers, the classes of Principles of Technology Management and the classes of Project Design. The contents and the pedagogical effects of Project Design have already been reported [6-7]. In this paper, we introduce the e-Syllabus contents of Statistics for Engineers and that of Principles of Technology Management. The lectures by teachers were the main body for these courses formerly.

3.1 Statistics for Engineers

This is an elective subject for studying statistical analysis techniques and is targeting the sophomore students of all the departments. The students who choose this course are increasing in number.

The class is carried out as a flipped classroom. There are many textbooks about statistics. In this course, while using a commercial textbook, video teaching materials and preparation assignments are distributed using e-Syllabus. With video teaching materials, the teacher explains the examples of the problems of the textbook. The example of video contents is shown in *Fig.3*. In class, the teacher reviews the main contents of the text book and students solve exercise problems. The teacher explains the problem in which many students were mistaken.

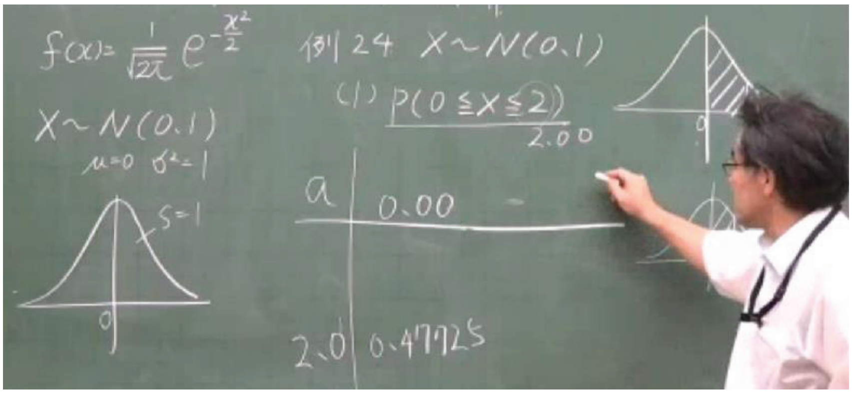

Fig. 3. The example of video contents in Statistics for Engineers e-Syllabus

3.2 Principles of Technology Management

Technology management is the scheme which develops, maintains and improves products, services, and systems making full use of technology. This program was developed by Dr Ishii and Dr Nakano as a part of the liberal arts curriculum of KIT [8-10]. The program contains 11 lecture topics and is compulsory for juniors of all the departments and aims to develop ability for students to do occupation selection.

The class is also carried out as a flipped classroom using e-Syllabus. An example of e-Syllabus of one class is shown in *Fig. 4*. Students prepare the lesson using the original textbook and mediasite contents which are PowerPoint slides with lecture voice. The degree of comprehension in preparation is confirmed in a class using e-Syllabus quiz system and through the group discussion. The teacher explains the group work based on the lecture topic and students carry out the group work. The group work functions as the training in which the leader fixed in order exercises leadership.

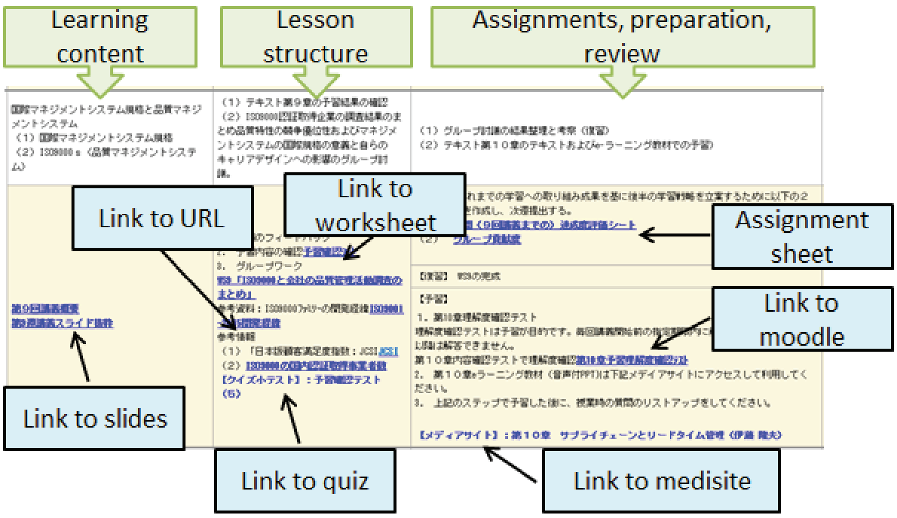

Fig. 4. The example of e-Syllabus of a Principles of Technology Management class

4 RESULTS AND DISCUSSION

4.1 Evaluation by questionnaire

The usage of e-Syllabus can be measured by access log. All students accessed e-Syllabus. However the purpose of their access or usability cannot be judged by the log. Therefore, questionnaire-based evaluation was carried out in order to measure the usage of video contents and the attitude on e-learning. The questionnaire survey was conducted using e-Syllabus for the student of the department of mechanical engineering. Ten questionnaires are designed to evaluate the usability of e-learning. They are listed on *Table 1*. They are multiple-choice questions. Those who answered (e) in Q.1 skipped Q.2 through Q.7. Each question has a field for free description.

Table 1. Questionnaires on e-learning

No.	Questions	Multiple choice
1	How many e-Learning teaching materials did you use?	(a) all, (b)2/3, (c) half, (d) 1/3, (e) less
2	What is the purpose of using e-Learning materials?	(a) prep, (b) review, (c) test prep, (d) report assignment, (e) others
3	Method of video selection	(a) each chapter/problem, (b) all in one, (c) others
4	Voice speed control	(a) X 0.5-2.0, (b) more than twice, (c) others
5	Video viewability	(a) OK, (b) not good, (c) others
6	Audio contents preference	(a) with explanation, (b) without audio,
7	Free description	
8	e-Learning and textbook usage	(a) both, (b) e-Learning, (c) textbook
9	Preference of flipped learning or normal lecture	(a) flipped, (b) normal lecture, (c) others
10	How do you change after the course?	(a) very positive, (b) positive, (c) none, (d) others

4.2 Questionnaire results and discussion

29 students in 53 successful candidates answered to the questionnaire in the Statistics for Engineers (SE) class. 53 students in 54 successful candidates answered to the questionnaire in the Principles of Technology Management (PTM).

The results are shown in *Fig.5*: SE represents Statistics for Engineers and PTM for Principles of Technology Management which are shown to be compared for each question. The result of Q1 shows 60% students of SE use e-Learning video materials and 45% students of PTM use them. As the results of Q3, Q4, Q5 and Q6 show, video and audio contents are satisfactory.

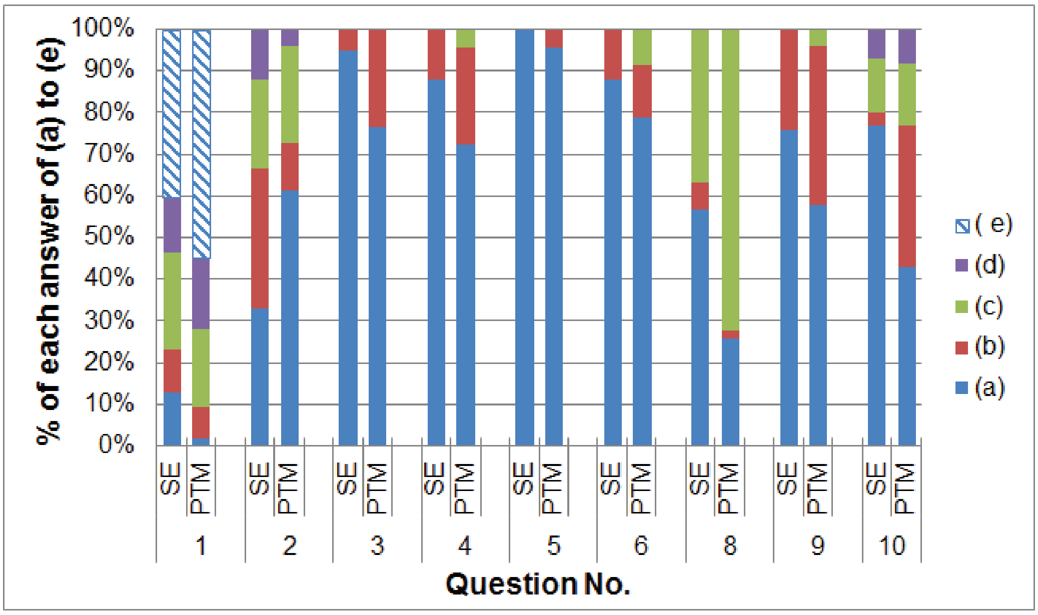

Fig. 5. Questionnaire results of Statistics for Engineers and Principles of Technology Management

SE students use them for both preparation and review, and PTM students use them mainly for preparation as shown in Q2. That is because SE video contains the solution of exercises which can be used for both, whereas PTM requires preparation for the active learning in class.

The results of Q8 show more than half of SE students use both the textbook and the e-learning material whereas most of PTM students use mainly the textbook. As both courses have the good textbooks, students can learn from the textbooks. Even with e-learning materials, textbooks are effective to digital native students. They may not need to watch videos which explain the textbook contents. However SE students watch videos which the teacher explains how to solve exercises even if the exercise answers are shown on the textbook. Video contents are helpful to study how to solve exercises.

The results of Q9 show more than half of the replies support the flipped teaching and active learning rather than the class of a lecture entity. However 23% of SE students or 38% of PTM students do not prefer the flipped learning. In affirmative free descriptions, there are opinions that the understanding deepens and the motivation for learning increases by active learning as shown by many literatures. On the other hand, some students do not prefer the flipped learning because there are many assignments for other classes and it is hard to prepare for the active learning. Especially for PTM, as there are many technical terms, some students prefer the lecture of the teacher with rich experience to the group work of students.

~~5~~ SUMMARY AND CONCLUSIONS

The e-Syllabus is used as the integrated learning environments with the textbooks in "Statistics for Engineers" course and "Principles of Technology Management" course. These courses are carried out by flipped learning and active learning. The e-Syllabus is one of communication tools with students and is useful for students' active learning.

Questionnaire-based evaluation was carried out in order to measure the usage of video contents and the attitude on e-learning. More than half of the replies support the flipped teaching and active learning with e-Syllabus rather than the class of a lecture entity. It is verified that students' usage of e-Learning is different between the social sciences course and the mathematics course.

As the further research work, it is required to add INDEX FOR TECHNICAL TERMS to the e-Syllabus and to see an attendance student's response.

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Online Course for Mechanical CAD Education

K. Jaakma[1]
Aalto University, School of Engineering, Department of Mechanical Engineering
Espoo, Finland

P. Kiviluoma
Aalto University, School of Engineering, Department of Mechanical Engineering
Espoo, Finland

Conference Key Areas: Open and online teaching and learning, Integrated learning environments for the digital native learners

Keywords: automatic assessment, course design, mechanical engineering

ABSTRACT

Computer-aided design (CAD) is a known tool for all mechanical and civil engineers, and it has been utilized for decades to help carry out everyday engineering design tasks. The evolution of CAD software and various information technology tools, e.g. virtual/augmented reality or 3D printing, has broadened the amount of engineers utilizing CAD. While learning CAD is an essential part in the curriculum of mechanical or civil engineering, there is a growing interest for learning CAD in other engineering disciplines also. To extend our teaching to students from other disciplines, our teaching has to be freed from the scheduled classrooms. The development of learning management systems, with help of auto-assessment systems, allows creation of semi-autonomous courses. In traditional classroom teaching, the teacher can see the progress and the challenges in the learning during the contact sessions. In online teaching, more emphasis has to be put on the feedback and assessment methods.

This paper presents the findings from the development of a place and time independent CAD course. The course teaches the basic tools and methods in the mechanical CAD education, starting from the creation of simple parts and ending with parametric design automatons. During the course, various tools are used to evaluate the student's learning and to exchange feedback.

[1] Corresponding Author
K. Jaakma
kaur.jaakma@aalto.fi

1 INTRODUCTION

Teaching feature-based parametric modelling with Computer Aided Design (CAD) tools is a central part of mechanical engineering education [1]. 3D printing, virtual and augmented reality and digitalization have become a part of everyday life that has caused a growing interest to learn CAD in other disciplines as well. Typically, the CAD courses are heavily utilising computer classes and students' learning is assessed mostly with weekly practical exercises, small exam-kind-of-tasks or by broader final work (individually or in groups) [2]. The focus of CAD courses can vary from learning how to use the tools to how to choose the most suitable modelling technique [3]. The number of students participating in CAD courses can be quite high. For example, in our university the intermediate level CAD course has annually more than 300 students.

To better respond to the increased amount of students, more flexibility and online tools in the CAD course are preferred. The increasing capabilities of application virtualisation provide an interesting opportunity to run computationally heavy CAD software online [4]. This allows students with lower end computers or unsupported operation systems to access CAD programs. The Learning Management System (LMS) contains tools related to sharing (i.e. attachments) and to receiving information (i.e. returning box). Besides these tools, LMS allows automatic assessment in the form of quizzes as well as discussion boards for collaborative learning. [5] When LMS and automatic assessment tools are combined, an online CAD course can be created.

In this paper, an online CAD course is presented. The tools and methods utilized are tested in the traditional CAD course to collect students' feedback. The research questions are:

- What are students' perceptions for time and place independent mechanical CAD learning?
- How can time and place independent mechanical CAD course be implemented?

2 COURSE DESIGN

The online course is created on the basis of an existing CAD course (parent course). Elements of online course have been tested on this course in the previous year. The student feedback is collected with two online surveys during the course. In this chapter, the parent course, and the developed online course, are presented.

2.1 The Parent Course

Computer-aided Tools in Engineering is a 5 ECTS, 13 week long course aimed for the first year students in the fields of mechanical and civil engineering, energy and environmental engineering, and built environment. Annually, about 350 students take this course, including students from other disciplines. The intended learning outcomes of the course are:

- understanding the basics of computer aided tools
- ability to use computer aided tools.

Because the course teaches students from different disciplines, the course is divided into several modules with different aims (Fig. 1). All students learn 2D and 3D CAD during the first seven weeks of the course, and in the second part of the course, they select one of the tree offered modules based on their major or interest.

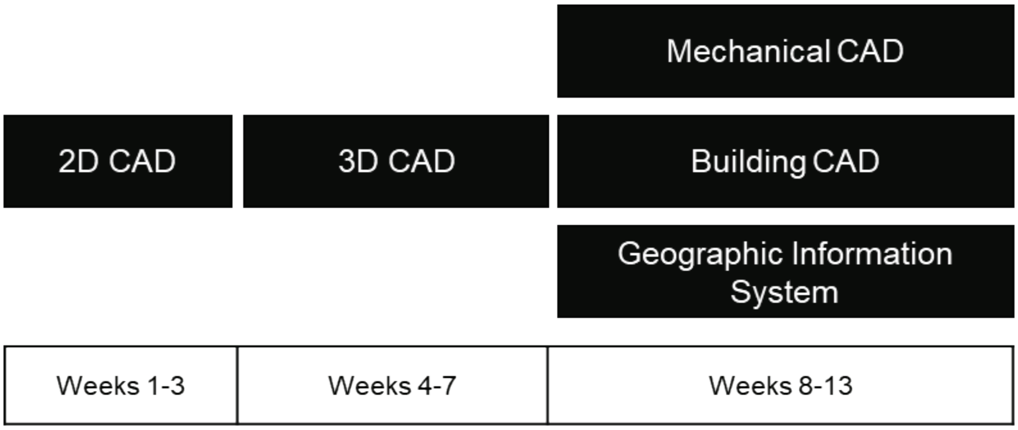

Fig. 1. The modules of the parent course.

The course contains weekly lectures and voluntary computer exercise sessions at the campus. The students are able to install various software utilised during the course on their own computers and thus complete exercises on their own. Most of the exercises are submitted thru Moodle-based LMS or auto-assessment systems, besides a couple of exercises that are demonstrated to the teaching staff. All of the course material is available at LMS. [6]

The course utilises two experimental auto-assessment systems. For the 3D CAD module, a geometry assessment tool is utilised to check that student's model's shape corresponded with targeted output geometry. In the Mechanical CAD module, an auto-assessment tool checks that the student's actual CAD model (not just geometry) behaves as designed when input parameters are changed.

2.2 The Online Course

To create an online course for mechanical engineering students, selected modules from the parent course are included. The CAD tools utilised in mechanical industry are mostly 3D, so "3D CAD" and "Mechanical CAD" modules are selected. To provide the same course length, the 3D CAD module is redefined and expanded to 7 weeks. The online course is divided into 14 weeks, each week having one main topic (Table 1).

Table 1. Weekly schedule and themes.

Week	Main topic	Week	Main topic
1	Turned parts	8	Family table
2	Milled parts	9	Sheet metal
3	Engineering drawings	10	Model Based Definition
4	Complex shapes	11	Parametrisation
5	Assemblies	12	Simulations
6-7	Project	13-14	Project

The online course is divided into two parts. The first part teaches the basics of feature-based CAD (how the tools work, how to create shapes, how to draft drawings, how to utilize assembly tools etc.) and ends with a project work, where all the previously learned tools are applied. The second part teaches efficient use of CAD (creating product families, parametrisation of models, basics of strength and mechanism simulations etc.) and ends with a project work where learned skills are utilized.

Siemens Solid Edge ST8 is software in the first part and PTC Creo 3.0 in the second part.

To trace the students learning and to receive feedback on how the exercises and tasks has been understood, is challenging. During a traditional course, the exercise sessions and lectures provide a good opportunity for this. To ensure that the student is well instructed during the weekly tasks, a weekly exercise structure is defined (Fig. 2).

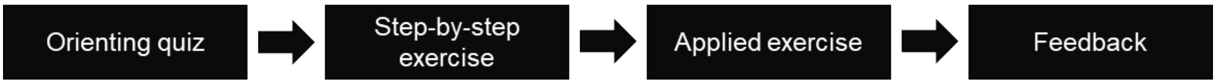

Fig. 2. Weekly exercise structure.

The week (topic) starts with an automatically assessed orienting quiz checking that the student has gone through the pre-assigned material. This can be for ex. a series of questions about engineering drawings projection rules (Fig. 3). When the student has passed the quiz, the CAD exercises are automatically opened. The exercises are submitted using automatic assessment tool or through LMS. When the exercises are done, a short feedback survey in the LMS opens. When this survey is completed, the next week is opened and the process repeated.

Fig. 3. An exercise about projection rules in the engineering drawings.

Assessing students' learning takes time and requires resources. The automatic assessment tools can check that the exercises with predefined outcomes are done correctly (i.e. the model has the right shape). Exercises with varying outcomes (i.e. engineering drawings can be modelled in different ways) and project works (i.e. the same devise can be modelled with many of ways) need still to be assessed manually. To help both the teaching staff to assess and the students to receive feedback, assessing rubrics are defined.

3 RESULTS

Students' attitude and capability towards online teaching was studied by two online Webropol surveys in 2018. The first (N=253), where student's possibilities to online teaching was surveyed, was carried out during the first weeks of the course. The second survey (N=236), where student's perceptions towards automatic assessment and working online was studied, was carried out in the middle of the course.

3.1 Starting survey

The students are well equipped for distance learning. 95.3% of students own a laptop computer and 96.4% a smart phone. Almost half of the students (43.1%) owned a desktop computer. Students are motivated to learn CAD and see the importance of CAD related skills (Fig. 4).

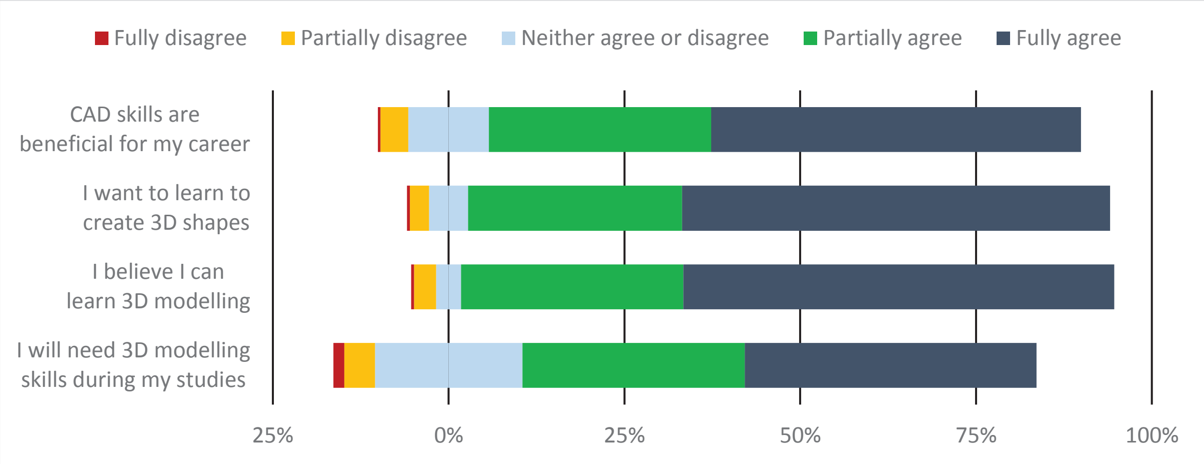

Fig. 4. Students' opinions related to 3D CAD.

3.2 Midterm survey

The majority of the students installed provided 3D CAD software on their own computers (Table 2). The major reasons not to install were related both attitude (wanted no extra software) and hardware (insufficient performance or incompatible operation system).

Table 2. Answers to survey questions related to software usage

Did you install 3D CAD software on your home computer?	%
Yes	61%
No	31%
If No, mention max three reasons	
Wanted no extra software	35.2%
Insufficient performance	33.0%
Incompatible operating software	28.6%
Did not want to use own computer	13.2%
Found hard to install	7.7%
Incompatible hardware	4.4%

When asked about submitting exercises time and place independent, two students out of total 236 didn't like this possibility. Students' preferred feedback types can be seen in Table 3. The automatic assessment system in the first half of the course gave both illustrated and verbal feedback. When asked about tolerable waiting time for the automatic assessments, students preferred a median of two minutes response time.

Table 3. Preferred automatic assessment feedback types. Scale from 1 (not preferred) to 10 (preferred)

Feedback type	Average	Standard deviation
Right/wrong	7.8	2.7
Verbal feedback	9.0	1.4
Illustrated feedback	9.3	1.1
Pointing to the wrong feature	8.9	1.6
Tells how the model can be fixed	8.0	2.2

4 DISCUSSION

Most of the students are prepared for an online course and they see the importance of learning CAD. The majority of students utilised the provided design software on their own devises. However, there are still some attitude, hardware, and software related challenges to fully get rid of computer physical classes (i.e. transfer all teaching to online environments). With the help of LMS and automatic assessment tools, an online course for mechanical CAD education can be implemented. Students value the time and place independent teaching that an online course can provide.

Future work will contain incremental improvement of an online CAD course based both on the experiences of the teaching staff as well as on the feedback of the students. It is planned to release the online course during the summer 2019. It will be beneficial to have some peer-assessed exercises to show students different ways to model the same geometry. To achieve this, a critical mass of students is required. This can be tested when the online course has been run for some time.

5 ACKNOWLEDGMENTS

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Combining Flipped Ideas and Online Learning

Hannu-Matti J¨arvinen
Tampere University
Tampere, Finland
ORCID 0000-0003-0047-2051
Pia Niemel¨a
Tampere University
Tampere, Finland
ORCID 0000-0002-8673-9089
Ulla-Talvikki Virta
Tampere University
Tampere, Finland
ORCID 0000-0001-5224-3504

ABSTRACT

Flipped classroom and flipped learning are quickly expanding in Finnish university pedagogy. In particular, videos and other distance learning options are preferred by such students who are already working while finalizing their studies.

This flipped learning experiment was executed in five implementations of two courses (2016– 2018). Flipped learning was carried out as a partial application: first, students read the topics in advance; second, they were supposed to make questions or otherwise affect on the contents of the lectures. Questions were implemented as weekly tasks to be completed in the learning management systems. The questions comprised both post- and pre-tasks. The post-task scanned the past lecture and pre-test one about the topics of the upcoming lecture. In addition, there was a comment section, where the students could leave questions about the topics they would like to be discussed in more detail in an upcoming lecture.

In results, we will discuss the correlation between the weekly activity, assignment and exam points and examine the functionality of the system.

Conference Key areas: Open and Online Teaching and Learning, Integrated learning environments for the digital native learners

Keywords: Flipped classroom, online course

1 INTRODUCTION

Digitalisation manifests itself in the realm of education, where the current era of the fourth industrial revolution (Industry 4.0) has lead to accelerated automation and digitalisation of services [1]. As a symptom of digitalisation, current university students in Finland implicitly assume downloadable learning materials; traditional printed matter starts to be scarcity. Learning management systems (LMSs) progress from simple pdf repositories and course point databases into ones promoting social interactions and collaborative problem solving among participants. In addition to formal learning resources, the students exploit extensively online materials such as videos, games, virtual worlds, and free online MOOCs, which further fosters informal learning practises and blending them with formal education [2].

MOOCs can be divided into extension MOOC (xMOOC) and connectivist MOOC (cMOOC) [3, 4]. In xMOOC, multiple functions, such as assessment, can be highly automated [5], so the contact with a teacher gets thinner, and contacts with peers cease to exist, whereas in the development of cMOOC, a trend of providing opportunities for more social interaction is emphasized, like the evolution of more socially geared LMSs. cMOOC facilitates fellowship activities such as group work and peer review. These social elements are found to be important in getting some students more committed, activating them and forming communities [6, 7].

Senior university students prefer distant and remote learning opportunities: MOOC-like courses are appreciated. At the same time in education, the ideas of the flipped classroom and flipped learning are trending with the promise of improved and intensified learning. However, combining the MOOC—or even parts of it—with flipped learning is not straightforward. This paper describes the steps towards flipped learning in selected courses, and examines the effect on learning outcomes. The main questions we address in this paper are:

1. What are the means to increase activity in the flipped learning when the interactive component of the lectures is missing?
2. Can this be implemented with a lower number of faculty hours?
3. Which are the first observations of the effects of the flipped learning practices on learning outcomes?

The paper is organised as follows: Section 2 contains a review of flipped learning, Section 3 describes the research context, Section 4 introduces the results, and the last section discusses the results and the future ideas to improve the approach.

2 ABOUT FLIPPED LEARNING

Some categorisation factors of MOOC, such as autonomy and social interaction, comply with the self-determination theory (SDT) of Deci and Ryan [8–10]. However, the third ingredient of SDT, the felt competence, is not that apparent. Supposedly, competence increases instinctively by deepening the substance knowledge. A good learning solution follows SDT principles and provides options for autonomy.

SDT theory is fulfilled in flipped learning that has attracted teachers seeking a more studentcentered way of learning after the hegemony of traditional learning culture. First, in the model of flipped teaching, students familiarise themselves with materials, such as text, videos and podcasts, and complete pre-tasks before arriving at a contact lesson or lecture. On the contrary to the past, lectures are not based on teachers' monologues, but instead on collaborative tasks such as group work targeting information retrieval and deepening skills [11].

Toivola and Silfverberg [12] unveil the difference between flipped learning and flipped classroom that can be considered conceptually inconsequential, but still separable in the continuum of teacher- to learner-centered didactic approaches, see Figure 1.

In the flipped classroom, a teacher still keeps the control to decide what will happen in the classroom and allocates the time for learning. In the flipped learning, in contrast, a teacher dares to give up direct control and trusts students' ability and desire to learn, thus transferring

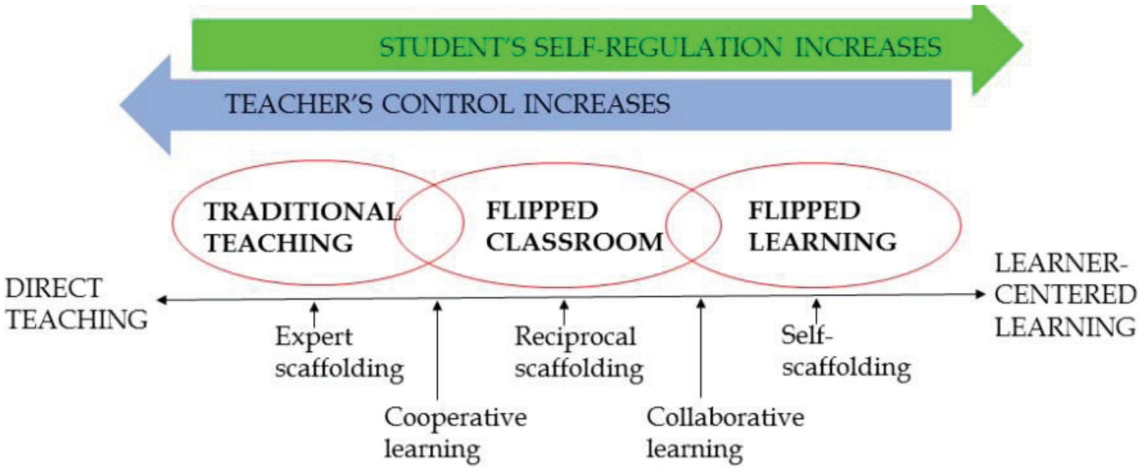

Figure 1: The dimensional view of the didactic approaches in the continuum from directed teaching towards learner-centred learning according to Toivola and Silfverberg [12].

the responsibility of the progress more to the student.

However, the strength of the flipped learning, i.e., the increased autonomy and responsibility of students may turn to be the biggest problem for adapting the flipped learning approach. Instead of the anticipated empowerment in regard to their own learning, some students may be left overwhelmed and clueless of how to proceed and study. Therefore, the amount of required autonomy should thus gradually increase and be at its largest at the end of the studies.

3 RESEARCH CONTEXT

The study is conducted in two courses, software testing and software architectures. Both courses belong to master level studies. Two consecutive implementations (years 2017 and 2018) of software testing are analysed, the first one without any online component and the second one with online exercises designed to support flipped ideas. For the software architecture course, three implementations (years 2016, 2017 and 2018) are studied. The first implementation was a traditional one with regular exercises, assignments and lectures. The second one had online exercises but the tasks were traditional post-lecture type only. On the third implementation, the weekly online exercises were altered to have one task post-lecture type and pre-lecture type.

3.1 Method

Design-based research (DBR) is a method of systematizing the practical process of developing an artifact which in the field of education can be, i.e., curriculum, or a new learning method, or as in this case, courses transferred to the direction of flipped learning [13–15]. A nominal feature of the design-based research is the development in cycles. Each design cycle comprises the phases of design, development, enactment, and analysis, which inserts new requirements into the redesign of the course [16, 17]. The cyclic development complies with subsequent course iterations; the courses are kept once a year. The lecturer remains the same, and the content alters only to a small extent between iterations, thus, the major alteration is due to the changes towards flipped ideas.

In the design phase, the learning targets of the courses are checked and harmonized with the content of other courses and the objectives of the curriculum. Development is mainly executed by the course personnel, but it includes dialogue with researchers in education. For example, the emphasis on flipped learning, and formative assessment with a peer-review rubrics may partly be backtracked to these discussions. Enactment inherently includes reflections on the functionality of new changes by the lecturer and teaching assistants. To complete the course, the students have to give feedback in the learning management system (LMS). In addition, the responsible teacher has to answer their feedback after the commenting period is out. The analysis of the course is based on the student feedback which is compared with the results of previous course iterations. The learning outcomes are compared against the course objectives.

3.2 Changes in the course environment

In the academic year 2016-2017, the university obtained the possibility to record lectures. The videos are available for the students after the lectures; however, live watching is not supported. In the software architecture course, Adobe Connect [18] had been used for some years, since the lectures were followed at another university. Adobe Connect provides a possibility also for individual students to follow the lectures live and make questions either orally or in writing. Hence, there were experiences of online lecturing with a possibility for the remote interaction, albeit they very rarely used the possibility; it was mostly used to notify problems in connection (‘*I can’t hear, please put the microphone on*’). After the university installed the automatic recording system, all courses were recorded by default. However, the lecturers have a possibility to cancel recording but they seldom do that, since students are keen to have the records. The records can be followed only afterwards and the system is not interactive. Consequently, this setup differs remarkably from the online lecturing conventions of standard MOOCs.

For both courses, there was a new responsible teacher since the earlier lecturers left the university. Unfortunately, new faculty members could not be hired to replace them. This meant that the courses had to be implemented with a smaller team than before.

3.3 Towards flipped ideas

The flipped classroom ideas had been used successfully in other courses of the university and when the lecturer of the courses changed, he wanted to move in that direction. Combining the flipped classroom with one-way recorded lectures is impossible as such. However, some ideas of the flipped classroom can be brought into this environment. These are

- reading the material in advance and

- making notes or questions that have an effect on the contents of the lectures.

These were implemented by introducing weekly exercises on an online environment (later referred to as flipped online exercises). Each week (except for those having a guest lecture) there were two or three tasks:

- one about the topics of the previous lecture (in the architecture course only)
- one about the topics of the upcoming lecture
- writing a comment where the student could ask something to be emphasised or explained better on the forthcoming lecture.

The first two tasks provided activity points for students, weight being on the upcoming topics.

3.4 Grading of the courses

The target was to reduce the role of the final examination as the major foundation for grading. Originally, the assignments had only a minor effect on the final grade rewarded by a few extra points in the examination. In the renewed system, the examination and the assignments were given the same relative weight: they affected the final grade equally (3/7 each). Thus, to complete the course, a student has to pass both the examination and the assignments.

Other smaller, online exercises were not compulsory but to encourage students to accomplish them, they were granted the weight of 1/7 in grading. In the testing course, the points of the online exercises and the fortnightly exercises (assignments) were combined.

3.5 Course evolution

The differences between the implementations of the testing course are collected into Table 1. Both implementations had lectures, guest lectures and fortnightly exercises targeted on practical skills like using the testing tools and environments. The assignment was two-phase teamwork done in pairs.

Table 1: Main changes between implementations of the testing course

	2017	**2018**
Lectures	trad., no recordings, 42h	recorded, 42h
Exercises	trad. fortnightly	fortnightly + weekly online post- and pre-tasks
Assignment	two-phase	two-phase
Examination	4 questions	3 questions

Three versions of the software architecture course were studied. All versions comprised an assignment, exercises, guest lectures and lectures. The assignments were made in groups of 4–5 students. Due to the transfer towards flipping, the implementations of all these parts have changes during the three-year research period. These changes are shown in Table 2.

Table 2: Main changes between implementations of the architecture course

	2016	2017	2018
Lectures	live, 42h	live and recorded, 28h	recorded, 28h
Exercises	trad. classroom	online, post-tasks	online, post- and pre-tasks
Assignment	several phases, peer	two-phase, peer	two-phase, peer
Examination	4 questions	4 questions	3 questions
Language	Finnish	English	English

Figure 2 illustrates how the implementations have evolved during 2016–2018. Notably, other aspects have influenced the placement in the timeline in addition to the transfer towards flipped learning.

4 RESULTS

Since the grading of courses included online exercises, assignment and examination, all the components of grading naturally have a positive correlation with the final grade. The most interesting correlations in this study are the correlations between exercises and the examination and assignment to see if the online exercises of new kind have an effect on learning. The

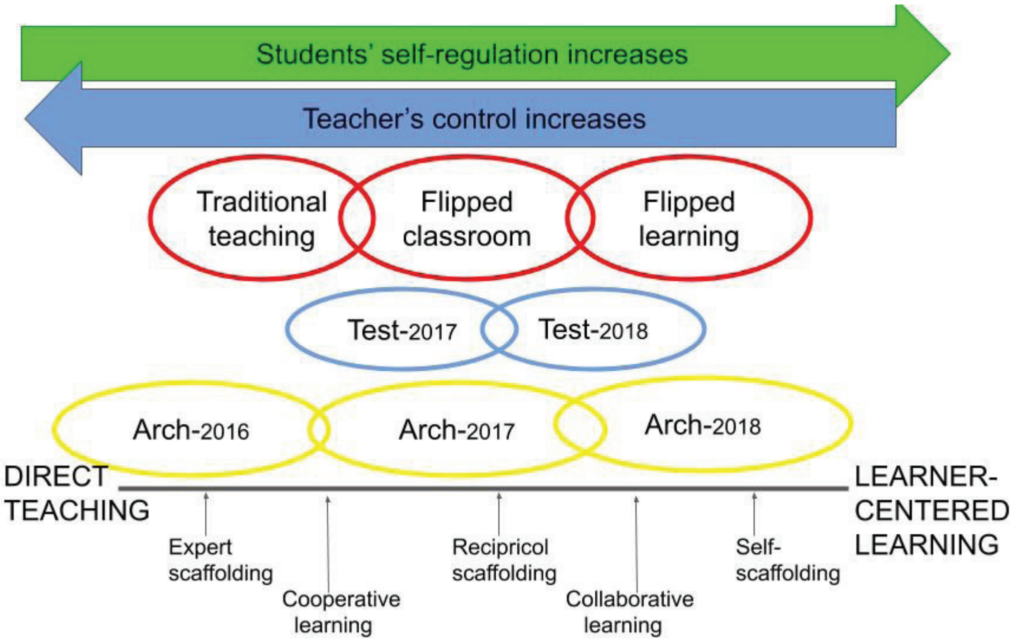

Figure 2: The testing and architecture courses situated in the continuum of flipped learning.

fortnightly exercises and attending the guest lectures were combined to "activity points" with the online exercises in the grading but as the effect of the online exercises was the main interest, their internal points are separated in the following.

Students not attending any of the three examinations available after the course were considered dropouts and left out of the statistics. Since most of them had not done anything else either, this actually decreased the correlations between other components of grading and the examination. If a student had attended several examinations, only the first one would be taken into account, since the student was likely to study much more in the later iterations either to pass the examination or to improve his or her grade.

For all the correlations, the two-tailed Student's test was used to compute their significance. On the tables below, values above the diagonal are correlations, and values below the diagonal are their p-values indicating significance. The p-value flagged with one asterisk implies a statistically significant correlation ($p \leq 0.05$); in case of two asterisks, the correlation is very significant ($p \leq 0.001$).

4.1 Software testing course

In 2017 and 2018, the software testing course had a two-part assignment, fortnightly exercises, guest lectures, a debate, and an examination. The students got some activity points from attending the debate; the function of the debate is to activate students and improve their oral skills, which, however, is not in the scope of this paper.

For the first implementation of the testing course in 2017, there are data on assignments and exercises only. The correlation between assignments and examination is 0.2634. With 105 students attending, this correlation is significant ($p = 0.0066$).

For the second implementation, all the correlations are very significant as shown in Table 3. Very significant correlations between the online exercises and the assignment and the examination support the hypothesis that the online questions will help to pass the course and get better grades.

The very significant correlation between fortnightly exercises and the assignment is mostly exTable 3: Correlations and their significance in the testing course, year 2018, n=81

	Flipped online exercises	Fortnightly exercises	Assignment	Examination
Flipped online exercises	1	$r = 0.78$	$r = 0.52$	$r = 0.42$
Fortnightly	$^{**}p < 0.0001$	1	$r = 0.45$	$r = 0.42$
Assignment	$^{**}p < 0.0001$	$^{**}p < 0.0001$	1	$r = 0.50$
Examination	$^{**}p < 0.0001$	$^{**}p = 0.0004$	$^{**}p < 0.0001$	1

plained by the fact that the fortnightly exercises were designed to support the assignment.

4.2 Software architecture course

Three versions of the software architecture course are studied as mentioned above, and their differences are collected into Table 2. Next, the correlations between different course components will be reviewed.

4.2.1 The first implementation in 2016

The first version was quite a traditional one. The weekly exercises were classroom exercises and the students could collect activity points by attendance.

Table 4: Correlations and their significance in the architecture course, 2016, n=71

	Classroom exercises	Assignment	Examination
Classroom exercises	1	*r* =0.43	*r* =0.39
Assignment	**p =0.0002	1	*r* =0.18
Examination	**p =0.0008	*p* =0.1244	1

As it can be seen from Table 4, classroom exercises correlate strongly with the other graded components of the course. The correlation between the assignment and the examination is not significant and actually quite low.

4.2.2 The second implementation in 2017

The architecture live lectures were streamed to another university and experiences gained on Adobe Connect were encouraging. However, adding automatic recording, and especially streaming and recording simultaneously proved to be tedious and error-prone. Furthermore, the new lecturer decreased the number of lectures by one third and changed the language of instruction into English. The debate that was used in the testing course was left out because students at the other university would not have the possibility to join the debate.

The classroom exercises were replaced with online exercises but the tasks followed the traditional style of post-lecture questions. There were two tasks each week. The assignment was replaced with a two-phase assignment where the first part was to design an architecture of the given system. On the second part, the students studied how the architectural design of other groups would stand a change in requirements and reported the results as a peer review.

In this version, the correlation between exercises and the assignment drops below the significance level. However, exercises still have a very significant correlation with the examination. It is noteworthy that the correlation between the assignment and the examination is not significant; actually, it is slightly negative.

Table 5: Correlations and their significance in the architecture course, 2017, n=105

	Online exercises	**Assignment**	**Examination**
Online exercises	1	*r* =0.22	*r* =0.41
Assignment	*p* =0.0549	1	*r* =−0.06
Examination	**p =0.0003	*p* =0.6304	1

4.2.3 The third implementation in 2018

The third implementation differed from the second one in one point only: the second task of online exercises was a pre-task concerning the forthcoming lecture. The students could also ask for some topics to be discussed in lectures.

Table 6: Correlations and their significance in the architecture course, 2018, n=90

	Flipped online exercises	**Assignment**	**Examination**
Flipped online exercises	1	*r* =0.26	*r* =0.31
Assignment	*p =0.0121	1	*r* =0.13
Examination	*p =0.0013	*p* =0.1884	1

The correlations between the online exercises and all the other aspects are significant (see Table 6). The assignment and examination do not have a significant correlation.

4.3 Summary of the cases

The grading components based on student's activity correlate strongly with each other in all courses with the necessary data available. This strengthens the hypothesis that some students have a completion strategy of being active which is consistently observable throughout the course. With the exception of the architecture course in 2017, exercises have a significant correlation with assignments.

In the testing course, the assignment has a significant correlation with the examination as well. Surprisingly, this correlation vanishes totally in the architecture course. The only one notable difference between the courses was the group size: in the testing course, the assignment was made in pairs, whereas in the architecture course, the group size was 4–5. The missing correlation might be an indicator of a free-wheeler behaviour in the bigger groups, where a few students received a good grade without their own effort. There may be several reasons behind the uneven distribution of the effort, e.g., student(s) having the highest target grade have actually made the whole assignment considering this to be the easiest way for them to accomplish the task. The problem has already been addressed in the ongoing implementation of the course.

4.3.1 Benefit of pre-tasks is more apparent

The type of pre- and post-exercises varied remarkably including short essays, the definitions of terms and concepts, the applications of introduced methods, drawing UML diagrams and arguing on the pros and cons on the given topic. Some questions were provided with external pre-lecture materials, or students could exploit their own sources. If the course had both preand post-exercises, the pre-exercises would be worth more activity points.

Answers were not limited with a minimum or maximum word count, although on the testing course short answers were warned to be of a partial value only. However, the expected answer length from course personnel side was around a couple of paragraphs to prove students' preparation for the upcoming topic.

While in the courses of this size it is to be anticipated that the quality of answers varies between students, most of the students had clearly put time and effort in their answers, writing often between 100 and 200 words, and even up to 400 words per question. The quality of the answers was mainly good, especially the longer answers discussing the topic comprehensively. Shorter answers were not necessarily low in quality, though more often so. While the answers were not graded as strictly as exam questions, the majority earned full points, some earned partial points and failed answers were rare. Based on the answers, it was evident that at least some of the students were using materials outside the provided lecture notes or linked external materials to familiarize themselves with the topic.

Based on the results between the software architecture course and the software testing course, the pre-questions seem to be more important for the students' learning or at least the lack of post-questions is not compromising the students' learning outcome. The software testing course did not include post-questions at all, yet the correlation between the online exercises and the examination was stronger.

4.3.2 Neglected comment field

As described above, the students had the possibility to ask for a more detailed discussion about topics they found interesting when they answered the question related to the forthcoming lecture. It was anticipated that students would not use this possibility extensively, however, they almost neglected it. There were very few suggestions, even if the rare ones were taken into account seriously and handled in the lectures with piety. This open comment was used more to make questions like ‘*when will the assignment open?*’, or, ‘*why the feedback of the weekly online exercise has been delayed?*’.

To increase the participation and help students to reflect on their blind spots or topics of interests, constructive alignment, active instruction, and granting activity points for making relevant suggestions on comments could be profitable in the next course iterations.

5 DISCUSSION

In spite of the reduced teachers’ work, the same level of the learning outcomes was achieved. In this respect, the flipped online exercises work fine. In addition, they seem to increase the connection between other graded components of the course. Although the results seem promising, the manifestation of the superiority of the flipped versions is too early. Definitely, they are not worse since the students obtained the same level with less teaching effort.

In the future, we are going to use and improve the idea of this study. Some evident things to improve the courses:

Practically a non-existent number of suggestions for lecture contents was a disappointment. However, this does not prove that the idea is not working. Instead, students should be encouraged to make suggestions. One way to do this is to offer activity points if the student proposes ideas in the comment field.

The weekly post-tasks have very small influence on learning and feedback of the students confirms this. We are likely to leave them out on both courses and concentrate on the weekly pre-tasks.

An additional discovery was that group assignments of more than two students do not work as intended. It has been known that in large groups some students are not active, but the correlations show that the phenomenon has a larger impact than expected. This can be addressed either by decreasing group sizes or by grading students individually. Enabling the individual grading is left for further study. The student feedback on this year’s (2019) architecture course supports the idea of small groups.

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Looking backwards to the evolution of the recommendations emitted by an accreditation agency

The case of French Engineering Education

A-M Jolly
Commission des Titres d'Ingénieur
Paris, France

C Freyermuth
Commission des Titres d'Ingénieur
Paris, France

Conference Key Areas: Quality assurance and accreditation

Keywords: accreditation, quality assurance, evolutions of engineering institutions

ABSTRACT

Since five years Commission des Titres d'Ingénieur computes, for each campaign of accreditation, the numbers and percentages of each kind of recommendations emitted towards the institutions that it has evaluated during the campaign.

After this time period it was possible to compare and analyze the evolutions of the different kinds of recommendations, in relation to the evolutions of CTI's criteria (launching of a new standard on criteria in 2016), and in relation to the evolution of ENQA's ESG, but also in link with the evolutions of society and companies.

It is interesting to see that Quality, that was not even considered five years ago, has become one of the major criteria, making CTI become as well an accreditation agency as a quality assurance agency. This can explain also the evolution of this agency to a lean accreditation experimentation using hypothesis that Global Quality could drive program quality.

Another recommendation which is now the more frequent one concerns internationalization of curricula, this recommendation has much to do with specific French recommendations on the necessary internationalization of engineering.

But criterion concerning recruitment of students always stay an important one because the quality of recruitment partly induces the success of the curricula.

The paper will analyze the main topics of recommendations and their evolution as well as the disappearance of some other ones, showing either that institutions have reached their aim or that experts are more concerned on other fields…

1 HOW CTI (COMMISSION DES TITRES D'INGENIEUR) WORKS

1.1 A campaign of accreditation

Each year, in France, a part of the Engineering education institutions is accredited according to a process which has a periodicity of 5 years. After this annual campaign an analysis is conducted to know on which fields most institutions have to improve.

With each accreditation decision, there is a series of recommendations emitted and the institution has to answer to these recommendations within the next 5 year's accreditation period. This is completely in accordance with ENQA principles that ask for more follow up of the institutions.

It is very interesting to observe the evolution of those recommendations because many processes intervene: the first one is the evolution of the criteria of the agency (our criteria evolved in February 2016) but also the evolutions of ENQA's ESG.

But there is also a global evolution of evaluation in all the countries, for example around us many countries (Belgium for instance) have replaced program accreditation by institutional accreditation, making Quality Assurance much more in the scope of their preoccupations.

Another factor is the evolution of society itself, for example student is now at the centre of the preoccupation of institutions according to ESG, so, taking into account their extracurricular involvement becomes something much more natural in institutions.

All these effects are also naturally filtered by the inertia of experts but, in France we have a double level of hierarchy of experts (some are members of CTI, others are external experts); for these "internal" experts, members of CTI, the inertia is smaller than in other agencies where all experts are recruited outside the agency. Furthermore, education of experts has progressed and we try to imply them at least twice in our accreditation processes each year.

1.2 How recommendations are elaborated

When the audit committee visits an institution it has to verify that all standards are fulfilled, some of them being more critical than others. But the committee as well as the institution knows the hierarchy of criteria for CTI.

This committee elaborates after the audit a report with a swot analysis, this swot analysis reflects only the opinion of the audit committee.

Recommendations are issued both from this swot analysis and by reflexions issued from members of the plenary assembly (32 people) who also know other schools of the same categories or who had audited this institution in the past.

The recommendations are formulated and improved by mail till the next meeting where they are voted so that they really reflect the debate that took place during the plenary meeting.

We tried some years ago to put in place a standard list of recommendations but this has not worked. So, very often each recommendation addresses 1, 2 or more fields.

To be able to evaluate CTI's activity and then to use this evaluation for improvement, it is necessary to analyse the whole set of recommendations for a campaign and then to present this analysis, firstly to the members, then to the institutions; each institution usually knows only its own recommendations, so this analysis is really very important so that the institution can benchmark itself against others.

This is not the only system, for example in French speaking Belgium there is a transversal analysis done after each evaluation campaign, this also gives a global idea of the state of institutions. But this ability to know where you are stays really important, this process (either computations of number of recommendations or transversal analysis) must be done to help institutions.

1.3 How institutions deal with their recommendations

According to the recommendation of ENQA, a follow up will now exist in CTI that is to say that institutions will have to give at the mid-term of accreditation duration a document indicating how they have tried to follow the previous recommendations emitted by CTI.

The following of recommendations will be studied more in details at next reaccreditation term.

The presentation of recommendations made at our February conference is also used by institutions that have not been accredited during the year but will be in another very close future, to know which tendencies are those of CTI.

2 GLOBAL EVOLUTION OF RECOMMENDATIONS

2.1 The global result

The first element to be mentioned is the increasing of the number of recommendations for each program:

in 2017-2018, 652 recommendations were emitted for 250 programs evaluated while in 2015-2016, we had only 504 recommendations for 349 programs. This is nearly twice!

Few deductions can be made on this point except the fact that, while the global quality of institutions is increasing, experts go much more in details during the audit.

The *table 1* below indicate the recommendations that were quoted at least 10 times in 2017-2018, there are also 32 recommendations that are less frequent and will not appear on the table, we will comment on some of them later on.

You can find the remaining of our recommendations on the website of CTI [1]

2.2 Considering the results of the top part of the array of recommendations

The 3 recommendations more quoted since the beginning of our studies on recommendations are:

-Internalization process

-Skills

-Recruitment of students

Internationalization processes: for some years (in 2012 this criterion already appeared), in France, the accreditation agency tries to strongly encourage international mobility in engineering studies, this was not evident at the beginning because, as everywhere in the world, students find that they are very well at home!

But both the fact that half members of CTI come from companies and are already convinced and the fact that the other half come from academy and has international relations for research purpose, makes members sure that, as for the minimum level B2 in English put as a condition 10 years earlier, the international mobility is necessary and has sense.

However, this recommendation stays at about 10% for the last years because in apprenticeship education, make this mobility mandatory is not so evident in some companies.

Skills: the description of programs in terms of learning outcomes is not new; the process in many institutions is still not completely achieved and particularly the learning outcomes evaluation.

14 years ago when this way of describing programs appeared, very few people in engineering education knew how to proceed and very often they only transformed syllabus without a real contribution of the professional world. That is why this recommendation still exist because in many cases links between modules of the program and skills does not really exist or when this matrix exists, in no matter evaluation of skill as required by ENAEE is realised.

Table 1. Table of more frequent recommendations

Thématiques des recommandations	2014-2015		2015-2016		2016-2017		2017-2018	
Internationalisation and multiculturality	27	22,50%	46	9,13%	41	8,32%	61	9,36%
Skills and learning outcomes	28	23,33%	51	10,12%	36	7,30%	56	8,59%
Recruitment of the students	24	20,00%	29	5,75%	34	6,90%	47	7,21%
Quality assurance					31	6,29%	40	6,13%
Communication			29	5,75%	24	4,87%	30	4,60%
Research			19	3,77%	23	4,67%	30	4,60%
Bologna process	22	18,33%	23	4,56%	10	2,03%	27	4,14%
Means			12	2,38%	9	1,83%	27	4,14%
Companies			24	4,76%	20	4,06%	18	2,76%
Employment			36	7,14%	29	5,88%	17	2,61%
Level B2 in English			12	2,38%	13	2,64%	16	2,45%
Student's failures			17	3,37%	7	1,42%	16	2,45%
Student and associative life	2	1,67%	12	2,38%	2	0,41%	15	2,30%
Sites			9	1,79%	16	3,25%	14	2,15%
Internships and projects	2	1,67%	13	2,58%	13	2,64%	14	2,15%
Fiche RNCP			9	1,79%	6	1,22%	14	2,15%
Human and Social Sciences			8	1,59%	7	1,42%	13	1,99%
Synergie			14	2,78%	3	0,61%	13	1,99%
Multisite					14	2,84%	12	1,84%
Hours/content			8	1,59%	15	3,04%	11	1,69%
Governance			14	2,78%	10	2,03%	11	1,69%
Councils			15	2,98%	15	3,04%	10	1,53%

Recruitment of students: in France, for engineering education institutions, recruitment is selective, that means that a specific competition exam is organized for recruitment, however these competition exams are very numerous and some institutions go very far in the lists so as to be able to recruit, or do not have any candidates to their competition exam, so CTI insists so that the size of programs are fitted with the potential recruitment of the institution either by increasing communication or by reducing the size of recruitment.

These 3 first recommendations are “classical” for engineering education, the 4th place of quality surprised all of us!

2.3 The case of Bologna Process (7th rank)

Since the LMD system exists, other basic rules such as transparency of programs but also ECTS rules [2] used for attribution of diploma exist too. In France there was another system existing before the ECTS system which was the use of pondered means as a condition to succeed for a diploma.

The following of the principles of Bologna process has improved but it stays hard to make institution consider capitalisation instead of compensation. So each year there are still about 4% of the recommendations that deal on this specific point.

3 NEW RECOMMENDATIONS THAT APPEARED IN 2016

3.1 Quality

Quality appears as the 4th recommendation since 2016-2017. It was new in 2016-2017 and it stayed at the same level next year.

This fact is very interesting for CTI. First it shows that quality culture is not completely integrated in our institutions, but it also shows also that experts are more sensitive to this point now.

The fact that this recommendation did not appear before is also very symptomatic of the importance that took ENQA in the elaboration of our processes. Before, some institutions were audited by ISO committees and CTI also put recommendations on the evaluation of curricula by students, but the most important part in the paragraph concerning Quality in the audit report concerned the following of recommendations.

Now this Quality process is considered in a much global way: is quality present from top to bottom? are there mechanisms allowing continuous improvement in the different services of the institution? how does the governance broadcast a quality culture? That are questions that we try to answer when we visit an institution.

The fact that in the report mission, the paragraph concerning quality is now situated just after the governance and no more at the end as previously is also something that helps members to take this part of the audit with more consideration.

In the process of lean accreditation that was put in place last year, only two information are asked to the institution: the evolutions that took place since the last audit and the quality process too; CTI suggests that if the quality system of the institution works, then it will be able to realise the evolution of programs with the opinions of all stakeholders, internal and external. This is a real subject of debate inside and outside CTI.

3.2 Multisite

The institutions are very encouraged to regroup themselves: Shanghai ranking, French Ordonnances….

In many circumstances the same diploma can be obtained in several places in France, in the same institution. This phenomenon was not very current before: before only 3 institutions in France had such configurations (ENSAM, CESI and CNAM).

When a diploma can be obtained at different locations CTI asks that the recruitment process be the same, the syllabus be the same, and the conditions of the final exam are the same. Very often we observe that these conditions are not respected that is why CTI has to give a recommendation on those points.

3.3 Working time of the student, feeling of belonging to the institution

In its last version of European Standard and Guidelines, ENQA asks that student be at the center of the education process. This was new for some institutions!

In 2016-2017, the percentage of these two recommendation was 2, 6% and in 2017-2018 it was only 1, 5 %; this show that institutions begin to take this point of view in consideration.

3.4 Multidisciplinary organization of courses

In most case, each engineering programs stay isolated inside the institution even if many other disciplines exist in the institution; CTI tries to make institutions reduce walls between programs, for example organizing projects, because innovation only occurs in multidisciplinary organizations.

This is a hard job because it obliges to change mentalities.

4 THE SPECIFIC CASE OF INNOVATION AND ENTREPRENEURSHIP AND OF SUSTAINABLE DEVELOPMENT

Recommendations concerning those two fields appeared very soon and before 2014, the strong advance on these subjects was made with creation of PEPITE which is a specific device for increasing student-entrepreneurs in France in 2012.

It is interesting to observe that the introduction of Sustainable Development in the programs was launched the same year but appeared in the recommendation only one year later, this show that the personal effect of minds of experts has its role in the recommendations given to institutions too: at this moment more people in CTI were convinced of the necessity to be preparing students to entrepreneurship and thought that initiation to Sustainable development could be done elsewhere!

The percentage of recommendations on those two fields slowly decreases: only 3 or 4 programs are considered as not having introduced for all the students an information on entrepreneurship and the same number of programs has not yet introduced Sustainable Development.

5 RECOMMENDATIONS THAT APPEARED IN 2017-2018:

ACADEMIC REGULATIONS, COACHING, DIVERSITY, RETURNS ON EXPERIENCE

These 5 considerations concern the engineering students themselves:

Academic regulations: The rules concerning scholarship of students have to be known by students, according to Bologna process, that means that academic regulations must include everything that concerns the students, particularly the conditions for graduation and recruitment, the number and organization of pedagogic modules, the conditions for payment of the fees, but also the way to issue an appeal. This last part is new for institution so the recommendation has been given to 8 institutions.

Coaching, bridges: With the increasing diversity of students, institutions have to put in place coaching and bridges so that all students recruited have the same opportunities to succeed. When CTI discovers that the rate of success in an institution is not as it should be, the institution is asked to put in place specific bridging or coaching devices.

Diversity: This is the main word of the past period concerning recruitment in engineering. In total 11 institutions have this kind of recommendation for either social diversity or gender diversity.

Returns on experience: In France students have to make 3 internships during their engineering studies. Very often when the student comes back to the institution, nothing is organized to share those experiences with other students, it is the same with apprenticeship education.

This recommendation aims that institution put in place specific hours of exchanges between students and teachers on what they did and lived in their companies.

6 CONCLUSION

We see in this study that many recommendations follow, sometimes with a little delay the new criteria of CTI or ENQA. This year we have launched a new R &O [3] that will be considered for the campaign from June 2019.

The role of accreditation agencies is to encourage initiatives and to share best practices, not to destroy institutions: recommendations must help institutions for their continuous improvement.

Many new fields could appear soon: digital evolution, a focus has been launched… Taking into account extracurricular involvement of students could also appear specifically: a new law was launched last year that made recognition and valorisation of involvement of student mandatory in all curricula.

Recommendations are a living object!

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Collaborative teaching as a tool in university development

E. Kähkönen
Aalto Design Factory
Espoo, Finland

K.Airo
Aalto Ventures Program
Espoo, Finlan

Conference Key Areas: New notions of interdisciplinarity in engineering education

Keywords: Interdisciplinary education, collaborative teaching, university teaching development

ABSTRACT

Goal of interdisciplinary education is to improve learning of students: to support deep learning and adaptation of working life skills. In this context, teachers are seen as resources at courses. However, interdisciplinary collaborative teaching can also be seen as a tool for teachers' continual learning, implementation of universities' education strategies, and seed when building cross-cutting communities in universities. All these perspectives have emerged in the interdisciplinary co-teaching context in Aalto University. Aalto was borne as a merger of three universities from areas of business, design and technology. Aalto aims at building competitive edge by combining knowledge from different disciplines. Consequently, interdisciplinarity in education must be central in Aalto. In this study, we focus on the course development process practices, which build have been used in development of interdisciplinary education in Aalto: i) pedagogical mentoring, ii) entrepreneurship integration, and iii) interdisciplinary minor program. The attempt of the present study on Aalto experiences is to bring visible the challenges and enablers as well as to make suggestions on best practices.

1 INTRODUCTION

1.1 Need for change in university education

University teaching development incentives stem both from inside universities and from the world outside. The pressure for changes from outside is the ever tighter competition in education field which has made good quality teaching a competitive edge. Universities themselves have own strategic targets for teaching development. For instance, integration of sustainability in teaching according to Sustainable Development Goals Accord is a goal which has been signed by dozens of universities globally (SDGA 2019). Other example is entrepreneurial mind-set, which has emerged as a central theme in university teaching during last decades and is in special focus area in Aalto Univeristy (Aarnio 2019). Furthermore, present study showcases a situation in which a merger of existing universities takes place, and in which the attempt is to enhance interaction between the different units. The combining factor in all three mentioned cases of strategic themes implementation in university education call for interdisciplinary education: Sustainable development deals with wicked problem which combine multiple disciplines, entrepreneurship education builds strongly on multidisciplinarity (Aarnio 2019), and finally: the merger of universities from different disciplines (Design, Business, Engineering) must have a goal in increased interdisciplinary collaboration. Notably, the collaboration includes research and education, but in this study we focus in education. Regardless of the source of the initiative to develop interdisciplinary teaching, the actual implementation will take place at courses. This, in turn, calls for teaching development done by teacher(s) at the courses.

1.2 Course development process

Course development can be seen as a continual process with four steps in it. 1) Goal setting stage defines the course goals regarding to students' learning, grades, course feedback and/or pass/fail-ratio. During 2) course planning stage, the resource requirements; spaces, teachers, assistants, prior learning requirement, schedule are defined. Here also the course activities: project work, syllabus, learning assessment tools are decided. 3) Actual course execution, which includes teaching sessions and their detail design, assessment, student information and communication. 4) Course evaluation covers learning assessment and course feedback. The evaluation outcomes feed the goal setting of the next round (Figure 1).

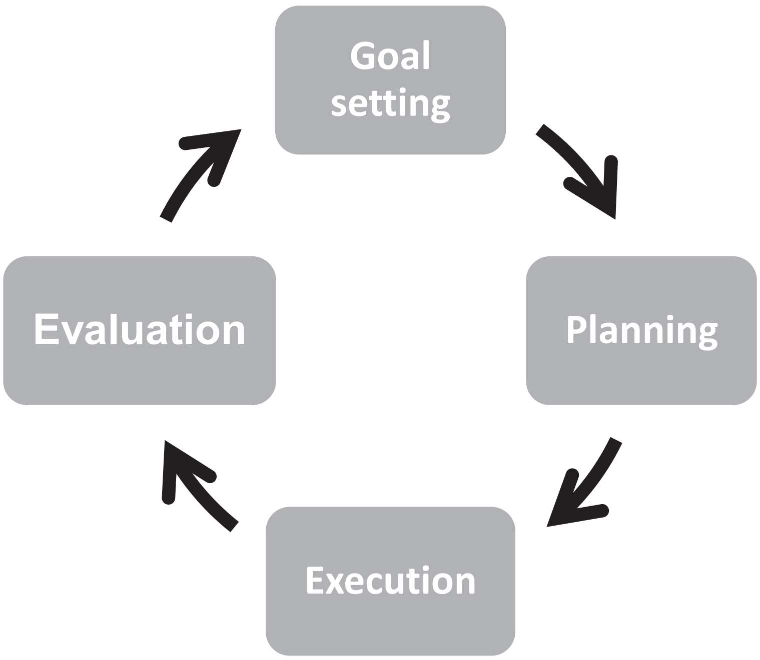

Fig.1 Continual course development process.

1.3 Co-teaching

Co-teaching may be defined as two or more teachers working together according to general definition of co-work. It is not studied in large in university context (Zhou et al. 2011). However, research in general indicates that co-teaching benefits for both teachers and students as summarised by Zhou et al. (2011). While students show for example more motivation, improved teamwork abilities and interdisciplinary learning, teachers will learn from each other's experiences and learning styles.

2 CASE STUDY APPROACH

2.1 Frame

We use the course development process as a framework to analyse the prospects and contradictions when teaching alone or with a multiple teachers (at least two).

2.2 Study material

The present preliminary analysis is based on experiences of teachers who have been involved in different types of teaching. The teachers come from Aaltonaut-program, Teaching partner-course (TP) and Aalto Ventures Program (AVP). They have experience on teaching alone, as teacher in charge at multi-teacher course, and a member of teaching team. The programs have been focusing on interdisciplinary teaching and collaborating with disciplinary courses in order to integrate transferrable competencies and new teaching practises. Teaching partner-course is a mentoring program to enhance development and experimentation in teaching.

2.3 Definitions in the study scope

The actors in the scope, Aaltonaut, AVP, and TP have strived to bring strategic themes in teaching: Aaltonaut interdisciplinarity and working life skills, AVP entrepreneurship and working life skills, and TP pioneering, student centred teaching.

Aaltonaut-program (est. 2013) has been forerunner for interdisciplinary teaching at Bachelor's degree studies in Aalto University. It has functioned as a teaching development platform and all the courses of the program (seven courses) are collaborative teaching courses. The teachers at the program come from different schools of Aalto University and represent different disciplines.

AVP is established (2013) to promote entrepreneurship ecosystem and entrepreneurial mind-set development. AVP has been activist in providing support for teachers in order to integrate entrepreneurial elements in their courses.

TP (est. 2014) is a pedagogical mentoring course which aims at supporting both individual teachers, teaching teams at courses and at study programs to develop teaching by practical experimentations. The program is largely based on research done by Clavert (2018).

All the named actors have perspectives in teaching as a solitary teacher and as a teaching team.

3 RESULTS

The results are presented here in chapters following the course development process stages and summarised in table 1.

3.1 Goals setting

Setting course goals as the only teacher at the course is straightforward as the results from previous round and the course basics are own knowledge. Evidently, there is no need to agree upon goals for the next round in terms of learning outcomes, course feedback, pass/fail ratio and/or other criteria.

When it comes to setting goals jointly, finding a consensus on the goals calls for discussion and agreeing. These goals may iterate and develop during the planning process. Furthermore, feedback from the previous round needs to be documented and accessible for the whole teaching team.

3.2 Planning

Course planning as a solitary teacher may be done according to own schedule with no separate time allocation. The whole picture of the course is in the head of the course teacher and there is no need to fix and agree on course concept, syllabus, emphasis on different areas, or any other topic. Fitting together the course components is straight forward. However, when planning alone, there is no direct need to adapt new approaches, new methods, or new course concepts. Accordingly, the only motivation for planning new teaching experimentations, comes from teacher her/himself. Furthermore, in the case of interdisciplinary course, lack of representative(s) from others discipline(s) reduces the balance between the disciplines. Similarly, when outsourcing e.g. the working life skill teaching to a visiting teacher (without joint planning), the theme may remain unconnected to the course. In both cases: interdisciplinary theme or working life skill integration may remain vague in case of joint planning is missing.

The planning stage becomes more and more laborious along with the increasing number of teachers involved in it. The scheduling of the planning meetings is a whole new activity compared to planning alone. The responsible teacher needs must be clearly named and he/she has to take the responsibility on inviting and planning of the meetings. She/he must balance between making solid plan and keeping the planning open for new approaches. It is very likely that one planning meeting is not enough and more are needed. The roles in planning must be clear concerning who takes care about practicalities such as space reservation, uploading and updating information in course pages, marketing, inviting guests, or organizing excursions. Once agreed course syllabus is more binding as the changes have impact on more than one teacher. The other side of the coin is, that during the planning meeting(s) the teachers learn from each other's experiences and disciplines. This realizes as transfer of course concepts, teaching methods, and best practises. As a consequence, new developments and plans for experimentations regarding to all these may take place. Furthermore, when teachers learn about each other's disciplines, the connection points between the disciplines become clear for all the parties in the process. Finally, when collaborating in professional context, teachers get to know each other, and in the case of interdisciplinary course, the community exceeds disciplinary and organizational boundaries.

3.3 Execution

When one teacher runs his/her own course there is flexibility in terms of changes during the course. There is no need to discuss or agree on these with others. However, in the case of unexpected changes, such as illness, there is no backup.

In the case of joint execution between two or more teachers, the changes call for communication and agreeing upon. On the other hand, there is possibility to agree and have backup when needed (for instance in case of illness). Furthermore, joint execution enables shared sessions during which students can learn multiple approaches and even debates. Moreover, joint teaching enables and/or facilitates applying various teaching methods: parallel streams of presentations, commenting on teams' work etc. Finally, when it comes to experimentation on a new method, sharing facilitates information gathering as there is possibility for making division into observation and practical execution roles.

3.4 Evaluation

Receiving course feedback and learning results alone is less significant in the case of positive feedback. When it comes to negative feedback, it may feel personal failure instead of potential for learning. Basically, dissemination of the course results is based on teacher's own decision.

When course evaluation is done jointly, the focus is in the course (not in teacher(s) as person(s)). This enables easier transfer of the negative feedback into corrective actions. Specifically, when it comes to new experimentations, the focus in new adaptations and learning instead of discouragement due the feeling of failure is crucial in order to keep on making experimentations.

Table 1. Prospects and contradictions comparison between one and many teachers.

	One teacher	**More than one teacher**
	Goal setting	
Pros	• *Easy to decide* • *Uniform view on goals*	• Multiple perspectives on course goals makes new goal setting more likely.
Cons	• *Hard to renew course goals.* • *Hard to recognize new approaches.* • *Limitations in own expertise area may restrict inclusion of transferrable skills in course*	• Agreeing on learning goals calls for consensus and discussion and is time consuming.
	Planning	
Pros	• *Easy to verify continuation between the sessions.* • *Easy make adjustments during the course.* • *Possibility to ask visiting teachers to fill in own gap areas and/or reduce workload.*	• Possibility for peer learning on teaching methods and course concepts. • Possible to learn connections between own and other disciplines. • Getting to know teaching personnel from other departments / schools. • Possibility for building teacher community. • Creating visibility for teaching development.
Cons	• Limits the course content near own expertise area. • Interdisciplinary course is challenging to plan from a single perspective	• Scheduling and planning calls for separate effort. • Agreeing on course concept calls for discussion. • Building a logical entity of the course calls for extra effort. Scattered course as a risk if no consensus is found.
	Execution	
Pros	• *No gaps in communication during the course.* • *No need to agree or reschedule adjustments in syllabus.*	• Possibility for backup (i.e. in case of illness) • Burden of experimentations is shared. • Co-existence at teaching sessions bring more dialogue and differing approaches in teaching.
Cons	• *No backup (in case of illness)* • *New experimentations is solely on own solders.* • *Visiting teachers sessions may remain super imprinted.*	• Changes in schedule must be commonly agreed.
	Evaluation	
Pros		• Shared feedback easier to focus on course and course development • Shared feedback easier to use in learning.
Cons	• *Feedback is more personal. No sharing of failures or victories.*	

4 SUMMARY

Co-teaching throughout the whole course development process: goal setting, planning, execution, and analysis, is an essential tool when developing interdisciplinary course. Without joint development process different disciplines do not fit together in a well-balanced way. During the development process the teachers get to know different disciplines and the connection points between these and own disciplines. Similarly, co-planning is tool for integration of a new theme in a course, such as entrepreneurship or sustainability. In general, co-teaching enables continual learning, supports teaching experimentations, brings visibility for teaching work, helps in transformation of course feedback into development activity, and build teaching community. In a nutshell, co-teaching is an intermediator for transformation of university teaching.

The other side of the coin is, that co-teaching requires more efforts from all who participate in the teaching, specifically when it comes to course planning and goal setting. Here, co-teaching calls for time allocation for scheduling meetings, planning for meetings, clarification of roles and responsibilities, and communication between the members of the teaching team. Notably, communication is an element, which is not needed in the case of solitary teacher while in the case of multiple teachers, it becomes a central part of the whole course development process. A whole new skill set is needed: On one hand, the teacher in charge of the course needs leadership and managerial skills. On the other hand, the teaching team needs teamwork skill. None of these are traditionally competences, which have been required from teachers.

From the university perspective, co-teaching as a tool for developing teaching to meet the strategic goals, such as integration of sustainability and/or entrepreneurship in education. Furthermore, multidisciplinary teacher community is base for building bridges between the schools and departments of different disciplines. However, in order to utilize the full potential of co-teaching, the challenges related to it must be understood and taken into account. Co-teaching requires support, especially in the beginning. The actual course development can be facilitated by pedagogical mentoring. In general, in order to encourage teachers to put effort in co-teaching, mechanisms to reward the efforts are needed. Rewarding can take place as pedagogical credits or as tenure track proceeding criteria. From organization perspective, incentives are needed for departments and schools which allocate resources for co-teaching. As a conclusion, co-teaching requires resources to produce the sought change in university teaching. Regarding the resource requirement, co-teaching doesn’t differ from other teaching development activities, such as pedagogical courses, seminars and workshops on different topics. The difference between co-teaching and the before mentioned activities is that co-teaching impact directly in teaching simultaneously with peer learning and teaching community development.

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Smart collaboration for skills and competitiveness in Engineering Education

A Kakko[1]
JAMK University of Applied Sciences
Jyväskylä, Finland

Conference Key Areas: New notions of interdisciplinarity in engineering education, Diversity in Engineering Education

Keywords: Internationality, innovation, multidisciplinary, flexible mentoring

ABSTRACT

Smart HEI-Business collaboration for skills and competitiveness (HEIBus) is Erasmus + Knowledge Alliances 2 project. Its duration is 36 months (January 2017 – December 2019) and it aims to develop and test smart and innovative new methods including virtual implementations for High Education Institution (HEI)-company cooperation for mutual benefit. With a budget of about one million euros, the project brings together HEIs and companies from five European countries with strong expertise and experience in different engineering fields.

HEIs have many challenges to meet future needs and to develop teaching methods in constantly changing world. Focus must be in matching the needs of working life with the provided education which can only be reached with good and efficient HEI-company cooperation.

Competent and motivated personnel is one key factor for the success of the companies. One way to achieve this is deeper cooperation between companies and HEIs offering companies a good recruiting tool.

The project focuses on strengthening the collaboration between HEIs and companies by creating new innovative cooperation models and teaching methods. These models and methods facilitate the involvement of HEI students and teachers and company experts in international and multidisciplinary R&D&I projects proposed by companies.

1 BACKGROUND AND BASIC INFORMATION OF THE HEIBUS PROJECT

1.1 Background of the HEIBus project

Europe is trailing behind the USA, Japan and Canada with regard to building a smarter economy. Competitiveness and rising levels of productivity are a crucial force behind sustained levels of economic progress and the wellbeing of citizens. In short, Europe needs improvements. To tackle the problems, Europe has launched

A Kakko
anneli.kakko@jamk.fi

the Europe 2020 strategy with objectives on employment, innovation, education, social inclusion and climate/energy. The Europe 2020 strategy identifies actions to boost growth and jobs.

The schooling system in Europe is on a very good level, but we still need to improve the velocity of innovation, productisation and commercialisation. At Higher Education Institutions (HEIs), both students and personnel are frequently handling innovations that could be the basis of improved business in small- and medium-sized companies (SMEs) or create new business possibilities for larger enterprises.

Economic success demands that the company is innovative, which in turn requires different kinds of multidisciplinary know-how. The purpose of the Smart HEI-Business collaboration for skills and competitiveness (HEIBus, www.heibus.eu) project is to increase, improve, widen and deepen HEI-company cooperation at the student and expert levels, promoting entrepreneurial thinking and innovations. The feedback of earlier research projects, such as RePCI (www.repci.eu), showed a clear need for deeper and wider HEI-company cooperation, such as multidisciplinary study area and HEI-company expert level cooperation.

HEIs have many challenges, such as meeting future needs set by working life and developing teaching methods, which motivate students to learn and carry out their studies successfully in time. The labour market is constantly evolving, with the necessary skills, competences and qualifications changing over time. Traditional education does not always answer the needs of the field, and new teaching and learning methods for new skills are needed. It is important that the needs of working life is matched with the education provided. This is an ongoing process and can only be reached with HEI-company cooperation.

One key factor for the success of the companies is competent and motivated personnel. One way to achieve this is through deeper integration of the company with the student groups throughout the studies, which provides companies a good recruiting tool.

1.2 Research of HEI-company cooperation models

Currently, HEIs and companies around the world are experiencing a renewed interest in strengthening their forms of cooperation. It has been proved that bridging the gap between HEIs and companies benefits both parties. Cooperation between HEIs and companies is not a new concept. There are cooperation programmes, which date back to the first decade of the 20th century [1] or are well-known internationally that have served as a reference model [2]. However, the idea of integrating working life with the learning process has its detractors. They place strong emphasis on exploitative internships and non-enriching jobs in which students are just observing instead of being engaged in productive work. To tackle this problem, there are associations such as the Canadian Association for Co-operative Education (CAFCE) [3], the Cooperative Education & Internship Association (CEIA) [4] and the German Central Evaluation and Accreditation Agency (ZEvA) [5] that guarantee the quality of cooperation agreements.

The mechanisms offered by HEIs to provide students with the opportunity to gain work experience in their career fields are included in the generic concept of Work-Integrated Learning (WIL) [6]. According to the definition adopted by the Higher Education Quality Council of Ontario [7], work-integrated learning is the process through which students come to learn from experiences in educational and practice settings. It includes the kinds of curriculum and pedagogic practices that can assist, provide and effectively integrate learning experiences in both settings. Depending on the context, the term WIL is often used interchangeably with other similar terms such as “work-based learning,” “practice-based learning,” “work-related learning,” “vocational learning,” “experiential learning,” “co-operative education,” “clinical education,” “internship,” “practicum” and “field education” [8]. However, many of these terms are also used to describe specific types of work-integrated learning. The most widespread types of WIL are cooperative education, internship, apprenticeship, field experience, mandatory professional practice, applied research learning and service learning.

1.3 Partners

The HEIBus project consists of five university partners and seven company partners from five different European countries (Finland, Germany, Hungary, Romania and Spain) taking part in the project as full partners:

- JAMK University of Applied Sciences (JAMK, main partner, www.jamk.fi/en/) and ITAB Finland Oy (www.itab.fi/en/) from Finland
- Technical University of Cluj-Napoca (TUCLUJ, www.utcluj.ro/en/), SC PRO Tehnic (www.pro-tehnic.ro) and Automates ACM SRL (www.automatesacm.ro) from Romania
- University of Miskolc (ME, www.uni-miskolc.hu/en/), Electrolux (www.electrolux.com) and Robert Bosch Power Tool (www.bosch-garden.com/gb/en) from Hungary
- University of Applied Sciences Esslingen (HE, www.hs-esslingen.de/en/) and Stoebich (www.stoebich.com) from Germany
- University of Jaen (UJA, www.ujaen.es/serv/vicint/home/index) and Valeo Lighting Systems (www.valeo.com/en) from Spain.

The group of company partners consists of SMEs as well as some large companies. Three HEI partners are academic universities while two are universities of applied sciences. The partnership comprises a perfect variety of different types of organisations and professionals. This provides very interesting and fruitful cooperation with different perspectives on each aspect of the project. There are also 17 associated partner companies and institutions and several external partners around Europe who have followed the progress, utilised the results or taken part in some of the project activities.

The project focuses on strengthening the collaboration between HEIs and companies by creating new innovative cooperation models. These models facilitate the involvement of students and staff from HEIs in international Research & Development & Innovation (R&D&I) projects proposed by companies.

1.4 Work packages

The HEIBus project consists of eight work packages, which are shown in Fig. 1 and include Management (WP1), Best practices of HEI-company cooperation (WP2), Multidisciplinary student level real life problem solving (WP3), Expert level real life problem solving (WP4), Flexible student mentoring by companies (WP5), Quality assurance (WP6), Evaluation (WP7) and Dissemination & exploitation (WP8). Four of them (WP2, WP3, WP4 and WP5) are implementation work packages which will be explained deeper in the following chapters.

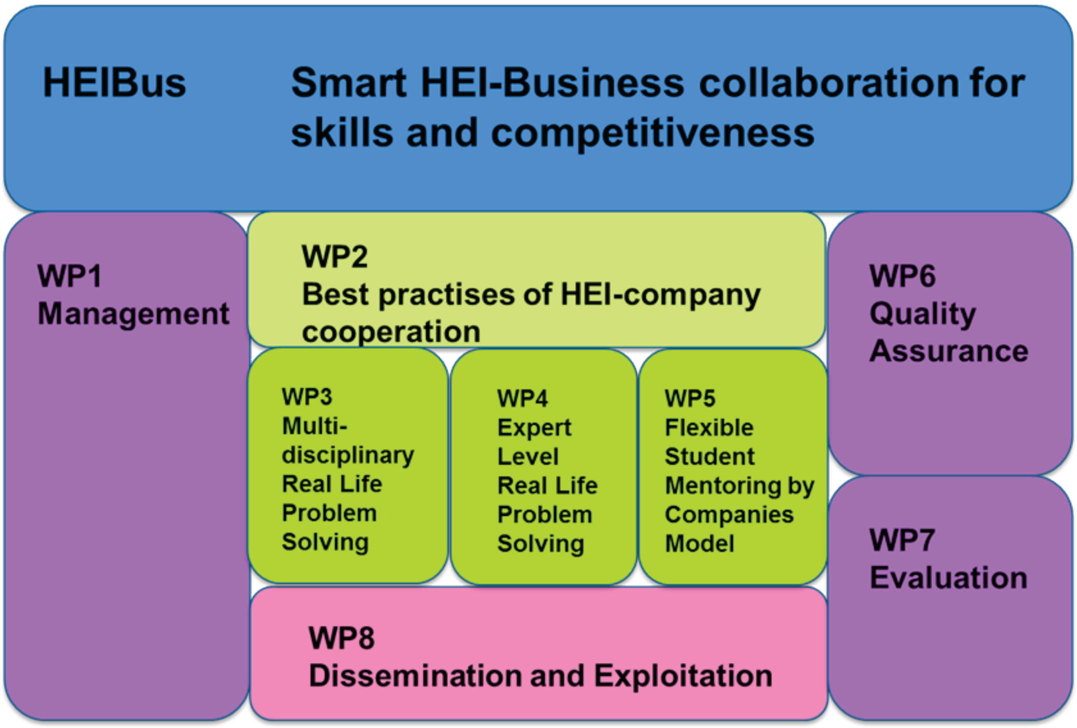

Fig. 1. Work packages of HEIBus project.

The project addresses the flagship initiatives of innovation union, youth on the move and an agenda for new skills and jobs. The HEIBus project carries out several tasks where students, HEI experts and company experts are involved in solving real-life problems of companies. This boosts the new innovative ideas that can be quickly taken into use in companies.

2 BEST PRACTICES OF HEI-COMPANY COOPERATION

The aim of the Best practices of HEI-company cooperation work package (WP2) was to analyse the existing cooperation models providing real-life experiences between HEIs and companies in the following issues:

- the state-of-the-art HEI student-company cooperation models
- the state-of-the-art HEI expert-company cooperation models
- different platforms and forums used in HEI-company communication
- the best practices on company involvement in HEI education.

In the beginning of the HEIBus project, all work package leaders searched existing methods and models for HEI-company cooperation, which the leader of WP2 then collected. During April - May 2017 the best models for deeper analysis were selected. Regarding the outcomes of this work package, the best and most comprehensive ideas and models for HEI-company cooperation were expected to be found. These models have formed a good background for the other implementation work packages, WP3-WP5.

3 MULTIDISCIPLINARY STUDENT LEVEL REAL LIFE PROBLEM SOLVING

The Multidisciplinary student level real life problem solving (RLPS, WP3) work package focused on bringing students, HEI staff and companies together. The idea was that students from different study programmes and nationalities form mixed groups in order to solve a real life problem that has been given to them by a company, as shown in *Fig. 2.* The aim of the RLPS was to create a new model on how to spread the real life problem solving method to a new multidisciplinary cooperation level and to build a virtual implementation of the RLPS method. Virtual implementation frees the RLPS method from the confines of space and makes it more accessible to students unable to travel. It also makes the method easy to use anywhere in Europe.

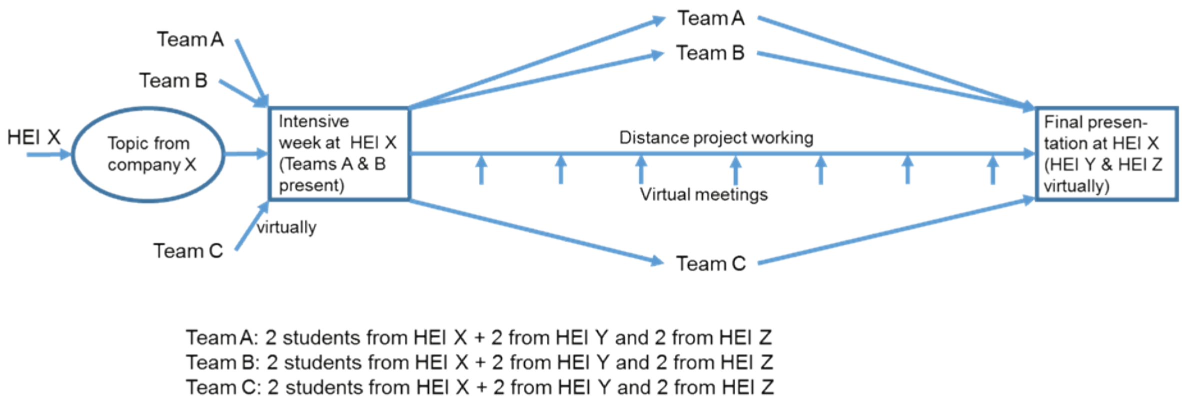

Fig. 2. Pilot Projects of WP3.

In every pilot project, three multidisciplinary and international student groups solved the proposed topic during one academic semester and competed with each other. At the end of the semester, the company tutors selected a winning solution and HEI supervisors gave grades. This work package was expected to produce motivated students with good teamwork, project management, cultural and language skills.

Pilot projects were carried out in two rounds, first three in autumn 2017 and the second three in autumn 2018. Preparations of these pilot projects started in previous spring including meetings with partner companies, finding topics, planning of tailored lectures, creating information material and having information sessions for suitable student groups. The list of chosen companies for the first round pilot projects, real life problems and HEI partners can be seen in *Table 1* and the second round pilot projects in *Table 2.*

Table 1. List of chosen companies, real life problems and HEI partners for the first round multidisciplinary student level pilot projects

Chosen company	Country	Real life problem	Host HEI	Other HEI partners
ITAB Finland	Finland	New concept for self service station in order to enhance customer experience	JAMK	HE and UJA

SC AutoMates ACM SRL	Romania	Design a fully pneumatic slicing machine for use in food industry to portion hard and semi-hard cheese	TUCLUJ	ME and HE
Centro Tecnologico del Plastico, Andaltec	Spain	Reducing the environmental footprint through the development of new and biodegradable plastic products	UJA	JAMK and ME

Table 2. List of chosen companies, real life problems and HEI partners for the second round multidisciplinary student level pilot projects

Chosen company	**Country**	**Real life problem**	**Host HEI**	**Other HEI partners**
FESTOOL GmbH	Germany	Create New Product Ideas for the FESTOOL Product Range by using a very agile Innovation Process	HE	ME and UJA
Robert Bosch Power Tool	Hungary	Connected power tool development for hobby and home decoration	ME	JAMK and TUCLUJ
Sensor Integration & Robotics (ISR)	Spain	Construction of a Prototype for the automatic control of a horizontal centrifuge machine	TUCLUJ	JAMK and TUCLUJ

In every student group there were two students from every three HEIs, so together six students. In the beginning of the implementations, two student groups had an intensive week in the home country of the company giving the topic and the third student group took part virtually in this intensive week. After the intensive week, all students worked at their own HEIs and student groups cooperated virtually until the end of the implementation. After the pilot projects, feedback from students, HEI supervisors and company tutors was collected and generally, it was quite positive. Here under some important observations for projects:

- Enough time for group work is needed during the intensive week.
- Well tested communication tools are necessary and important for the virtual meetings.
- Working with people from different countries and different study programs is very fruitful and important also for the future.

The HEI supervisors wrote an evaluation report of the results of the implementation for each team. This evaluation report was based on an evaluation criteria table created by HEI supervisors. The evaluation criteria table contained the project management
(planning, implementation and schedule), the results compared with the objectives, social skills (team work, communication), reports and presentations. The importance of different parts of the criteria might vary in different projects. The grade for individual student was the same as the team grade. However, if a student performed clearly better or worse than the rest of the team, the grade of that student could be higher or lower than the grades of the rest of the team.

As interesting summary of the RLPS projects it was found out that:

- In all implementations of the first round, the winner group was the group, which took part in face-to-face intensive week, but all implementations of the second round the winner group was the virtual group. Based on this we could say that there is no difference if the implementation is partly or totally virtual.
- All student groups worked hard and tried their best.
- Motivation of students was mainly high during the whole project.
- Not only professional, but also international and language skills of every student improved.

In autumn 2019 the partner HEIs will write a step-by-step guide of the RLPS model. The model will consist of three different levels of RLPS: original implementation, partly virtual implementation and totally virtual implementation.

4 EXPERT LEVEL REAL LIFE PROBLEM SOLVING

The Expert level real life problem solving (EXPERT, WP4) work package aims to develop and pilot a new cooperation model between HEIs and companies. This enables companies to bring more complex problems to be solved by international and multidisciplinary experts. This promotes innovation and knowledge transfer between HEIs and companies as well as increases the skills of HEI experts and the working life relevance of education.

In the beginning, a step-by-step process model was built and pilot projects for testing the model was planned, as shown in *Fig. 3.* The EXPERT pilot projects in two rounds were implemented in Finland, Hungary and Romania in spring 2018 and 2019. In order to search for companies and their topics for the first and the second round pilot projects, an information sheet about expert level real life problem solving was created. Each HEI involved (JAMK, ME and TUCLUJ) contacted companies and asked potential project topics. The topics of the first round pilot projects are described in *Table 3* and of the second round pilot projects in *Table 4*.

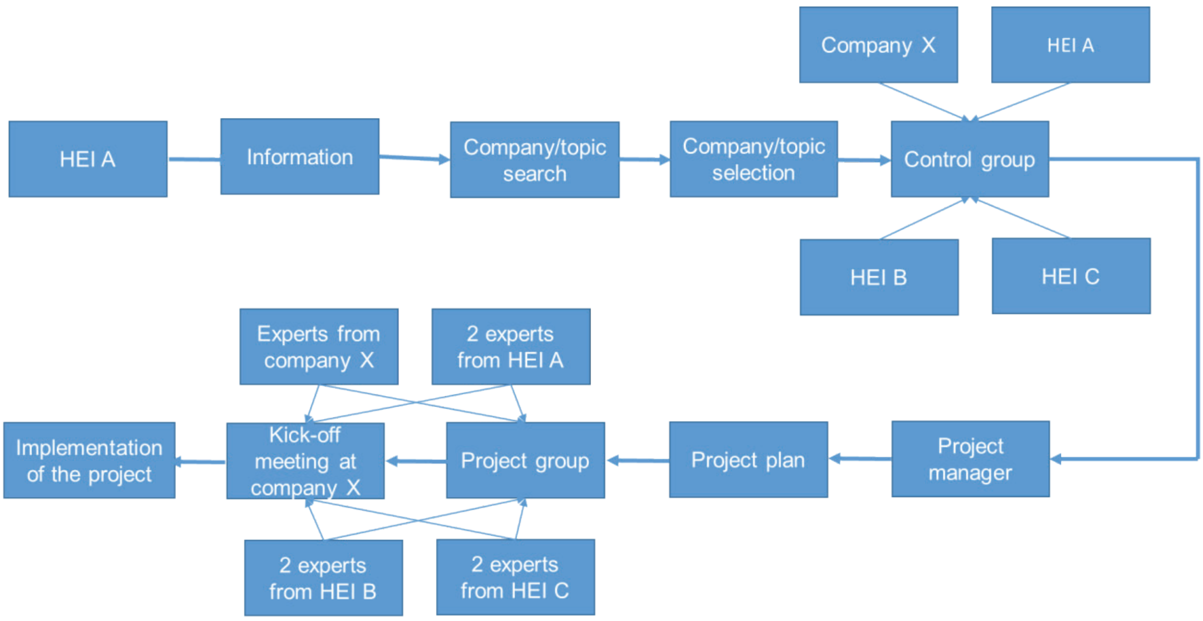

Fig. 3. Pilot Projects of WP4.

Table 3. List of chosen companies, real life problems, HEI partners and needed expert areas for the first round expert level pilot projects.

Host HEI	Company	Topic	HEI experts	Expertise areas
JAMK, Finland	ITAB Finland	Inventory management by smart fittings	2 from JAMK 2 from ME 2 from UJA	Machine vision, Mechanical engineering, Electronics, Data collection
ME, Hungary	Electrolux Lehel	Developing a pipe air flow resistance measuring device for vacuum cleaner pipes	2 from JAMK 2 from ME 2 from TUCLUJ	Mechanical engineering, Electronics, Aerodynamics (fluid dynamics), Data collection
TUCLUJ, Romania	SC ProTehnic	Implementing IoT and lifecycle management in photovoltaic area	2 from JAMK 2 from ME 2 from TUCLUJ	Electronics, Sensors, Data acquisition/ Measurement systems, Microcontrollers, Actuators/control systems, Programming for embedded systems

Table 4. List of chosen companies, real life problems, HEI partners and needed expert areas for the second round expert level pilot projects.

Host HEI	Company	Topic	HEI experts	Expertise areas
JAMK, Finland	Valtra	Benefits of audio feedback enhancing user experience in an agricultural tractor	2 from JAMK 2 from TUCLUJ 2 from UJA	Usability and ergonomics, Product development, Automation, Electronics
ME, Hungary	Bosch Power Tool	Perceivable noise reduction of power tools	2 from ME 2 from TUCLUJ 2 from UJA	Mechanical engineering, Vibration technology, Ergonomics
TUCLUJ, Romania	Bosch Jucu plant	Elimination of the air bubbles during the conformal coating process of PCB’s	2 from JAMK 2 from TUCLUJ 2 from UJA	Conformal coating of PCBs, Fluid mechanics, Material science (fluid coating materials), Mechatronics (automated machines/robots)

In every pilot project a project plan was made by the project manager who was a representative of the company. The schedule of each pilot project depended on the needs of the company and the problem to be solved. The HEI partners found and selected the best experts for the problem to be solved, and these experts formed the project team. One team included six experts from three different HEIs (three different countries) and experts from the company whose problem the team was solving.

In the beginning of each project, a kick-off meeting in the company was arranged where the whole project team was present. Other project meetings and the final meeting at the end of the project were arranged by video conferences (virtually). The project team agreed on the best ways of working together, including virtual meetings, individual work, forming smaller teams inside the project team, etc. The project team worked on solving the real life problem of the company and proposed a solution. With the help of the project team, the project manager reported the results of the project to the company.

After the pilot projects, a feedback was collected. The feedback was very positive and it seemed that there were not many issues which need to be changed for the next similar projects. The biggest challenge was to find suitable experts and to have an equal workload for the experts. In addition, it is important to pay attention for planning of the project meetings from the kick-off meeting until the final meeting as well as to select the proper communication ways for those meetings. It seemed that it is important that the kick-off meeting is a face-to-face meeting but for the other meetings virtual methods can be used.

Based on the process model and experiences of the pilot projects an action plan to widen the international expert cooperation model outside the HEIBus-project will be created.

In addition, the Expert level real life problem solving work package included the building of a virtual Expert Support Service (ESS) with easy and quick access for all companies looking for expert services by HEIs. The ESS offers direct expert contacts for starting an expert level RLPS, and a possibility to ask quick support for smaller problems.

The developing work of ESS started with finding out and analyzing the existing models. The website was developed using WordPress software and the ESS database platform is available at www.heibus.eu/experts. The platform was designed to be fully responsive, being able to work also on mobile devices. The main functionality of the website is to return a result from an expert database after a “Search” operation. The search results may consist of the personal and professional data of an expert, or a list of experts meeting the search criteria.

5 FLEXIBLE STUDENT MENTORING BY COMPANIES

The Flexible student mentoring by companies (Flex Mentoring, WP5) cooperation model aims to find and test flexible ways to involve companies in the education process of students. Flexibility comes from different levels of involvement. Virtual reality, which is not dependent on time or place, is present in many activities, such as expert lectures and info sessions for a wider audience that makes it possible for students from international HEI partners, among others, to join by video conference, etc. The cooperation model also seeks to find out if Flex Mentoring could be a feasible solution for improving students’ post-graduation employment and helping students lagging behind in their studies or at risk of dropping out completely.

The Flex Mentoring implementations started in autumn 2017 and they will continue until the end of the HEIBus project or longer in every partner HEI. In every HEI one or more companies walk hand-in-hand with one study group from the beginning until the end of the studies. Each HEI partner has selected two suitable student groups: one group consisting of students at the beginning of their studies and another group in which the students are at a more advanced level.

Flex Mentoring work package contains the following tasks:

- making plans on how the Flex Mentoring programme is implemented
- selecting the most suitable involvement methods and making detailed plans for the execution for each study year
- reviewing the plans after every study year and modifying if needed
- creating info materials of Flex Mentoring
- introducing the materials to selected companies and student groups.

Each HEI and company have chosen the involvement level and methods best suited to them, in a flexible way. Used methods have been for example workshops with company representatives, tailored lectures and project supervision by company representatives and job fairs.

The main outcomes of this work package will be increased motivation and study success for students, easy recruitment and a good labour force for companies and good knowledge transfer between HEIs and companies.

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Towards Mechanical Engineers' Expertise with Problem Based Learning

M-S., Kantanen
Senior Lecturer
Department of Mechanical Engineering, Lapland University of Applied Sciences
Kemi
mari-selina.kantanen@lapinamk.fi

M., Ruottu
Senior Lecturer
Department of Mechanical Engineering, Lapland University of Applied Sciences
Kemi
martta.ruottu@lapinamk.fi

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ABSTRACT

Working in the Lapland area, the Mechanical Engineers need diversified knowledge. In the area, there exists steel, paper and mining industry and maintenance and design enterprises supporting these industry operations. The demands of the engineer knowledge are not only restricted to mechanical engineering but the engineers also need e.g. social, analytical thinking, problem solving and language skills, and especially how to combine their own knowledge with other specialists.

The curriculum of Mechanical Engineering Education is based on competence and problem-based learning and it was introduced in the autumn 2017. The curriculum consists of the academic year and semester themes and every semester has a CDIO-type semester project course. This article describes the experiences of the curriculum so far and how new teaching contents are integrated in the education. The curriculum permits flexibility to the contents and it can be updated if there are new subjects to be taught e.g. Circular Economy. The curriculum requires collaborative teaching and development of the learning methods and environments. It can be seen that the motivation of the students has increased and the dropouts decreased with this curriculum.

[1] Corresponding Author
M-S. Kantanen
mari-selina.kantanen@lapinamk.fi

INTRODUCTION

Lapland University of Applied Sciences has developed the curriculum of education and the competence and problem-based learning curriculum started in the autumn 2017. The curriculum of Mechanical Engineering consists of semester projects and various study modules reflecting the competences. The names of these projects and study modules are inspiring and modern and try to illustrate better the theme of the academic year to the students. In this curriculum the teachers plan, check, guide and assess the courses together and are more like counsellors in the students' learning processes. Competency-based curriculum considers the students more as individuals than as groups and this requires the students to be more active in their learning process.

The professional growth of the mechanical engineers proceeds gradually from the first academic year to the last year in every academic year and semester themes. The problem-based learning project is in the centre of every semester theme and the contents of the different study modules are integrated into the content of the semester project. The curriculum permits flexibility to the contents and it can be updated if there are new subjects from the engineering field to be taught for the students. Especially for young students the professional field of the studies may not be so well known so it is important to familiarize them with the Mechanical Engineering field. It is also very important to support the students to learn to know each other well so they can work in groups and smaller teams. With these actions, the students' motivation to study can increase and they complete their studies as planned.

1 DEVELOPING THE CURRICULUM

The curricula of Lapland University of Applied Sciences (later LUAS) are based on competence and problem-based learning (later PBL). The aim of the problem-based learning is to increase creativity and communality in the students' learning processes. The individual students study as active team members resolving learning problems where the alternative proposition of the solutions expand the students' individual knowledge. In that way, the learning is work-oriented learning. The essential themes are interaction and co-operation between the students, communal learning, the guidance of learning, invocation of the group dynamics in the learning process and developing evaluation. Learning by the PBL method is widely used in Engineering Education. The target of the LUAS curriculum is to confirm a creative and learner-centred culture of learning. Fragmentary courses are integrated into larger modules and the students together process the phenomena and problems of the working life. (Kangastie, Mastosaari, 2016)

The teaching with these competence and problem-based curricula started in the autumn 2017. The development process of the curriculum was presented at SEFI Conference Autumn 2017. Most of the courses are taught by "teacher teams" that mainly consist of two to four teachers. Every teacher teaches different subjects so the team teachers plan, teach and assess the pedagogic learning process together. The individual teachers gain better overview of the education and have an insight into different subjects. Therefore, the integration between different subjects deepens. The role of the teacher is changed when the curricula is competence and problem-based.

The teacher is more like a counsellor, and instead of giving a lecture, the teacher introduces a problem and the students search for information and try to solve the problem. Therefore, information retrieval is essential in the learning process. The competence-based curriculum considers the students more as individuals than as groups and it also requires the students to be more active in their learning processes. (Kantanen, Ruottu, 2017)

Bachelor of Engineering studies take four years to complete containing 240 ECTS credits. The structure of the Mechanical Engineering curriculum consists of Basic and Professional studies 180 ECTS (Basic Studies (50 ECTS) and Professional Studies (130 ECTS)), Elective Studies 15 ECTS, Practical Training 30 ECTS and Thesis 15 ECTS. The professional growth of the Mechanical Engineer proceeds gradually from the first academic year to the last academic year with different semester themes. The same curriculum is applied both in full time and part time education, only some of the vocational subject studies are compensated with practical training e.g. the part time students do not have the first-year semester projects in their curriculum. The students in part-time education study in the evenings and on Saturdays, and so the number of contact lessons is smaller. The teaching methods can consist e.g. of flipped classroom, simulation, online teaching and independent studies.

In the department of Mechanical Engineering, the new curriculum consists of the academic year and semester themes. The academic year themes are *Learning about Work of Mechanical Engineers*, *Engineer's Toolbox*, *Creative Engineers* and *Pre-Engineers*. The learning and/or problem-based CDIO-type semester project is in the centre of every semester theme and all the other courses support this project course. CDIO organization is a worldwide network to develop and reform the Engineering Education (http://cdio.org/about). The letters CDIO stand for Conceiving - Designing – Implementing – Operating and so is the framework of the curricula planning and outcome-bases assessment. The CDIO Initiative developed 12 standards that describe the programs giving educational program reform and assessment; and this framework can be used for continuous development and improvement in educational institutions. Each institution can apply the CDIO standards, because there is no formal certification as a CDIO program. The standards include program philosophy, curriculum development, design-build experiences and workspaces, new methods of teaching and learning, faculty development and assessment and evaluation. Thus, these all serve as good guidelines for educational development and improvement. The names of the academic years, semester projects and study modules in the curriculum of the Mechanical Engineering illustrate better the theme of the academic year to the students. The professional growth of the mechanical engineers proceeds gradually from the first academic year to the last year of their education having different semester themes every academic year supporting the student's professional growth.

2 SEMESTER THEME PROJECTS IN MECHANICAL ENGINEERING EDUCATION

The learning and problem-based project is in the center of every semester theme. The contents of the different study modules are integrated into the content of the semester project. The competence of the student is based on these semester themes. (Kantanen, Ruottu, 2017)

In the first academic year, the field of Mechanical Engineering becomes familiar to the students and they practice basic subjects of Mechanical Engineering combined with natural science, language and social skill studies. The content of the first Academic Semester is illustrated in table 1.

Table 1. The content of the first Academic Year.

1. Academic Year					
Academic Year Theme	Semester Theme	Study Module	Extent	ResponsibleTeacher	Other Teachers
Learning about Work of Mechanical Engineers	On the Way to Becoming an Engineer	**Project**: Familiarization with Arctic Working Environment	5	N.N.	A.A., B.B., C.C.
		Perspective on Work of Engineers	5	N.N.	A.A., B.B., C.C.
		Natural Sciences of Engineers	5	N.N.	D.D.
		Tools and Software of Learning	5	N.N.	E.E.
		The basic of Technical Design	5	N.N.	
		Basics of Industrial Engineering	5	N.N.	F.F.
	Language of Engineers	**Project:** How to Use the Tools of Engineers	5	N.N.	A.A., B.B., C.C.
		Tools of Mathematics and Physics	5	N.N.	G.G.
		Basic of Mechanical Engineering	5	N.N.	A.A., B.B., C.C.
		Manufacturing Processes and Material Science	5	N.N.	
		Basics of Technical Mechanics	5	N.N.	
		Projects and Workshops	5	N.N.	A.A., B.B.

First year's semester projects are in the autumn "On the way to Becoming an Engineer" and in the spring "Language of the Engineers". In the autumn projects, the students are familiarized with different kinds of industries of the Lapland region. The semester project is culminated with a fair where the students introduce their semester project results, and the companies introduce activities and practical training possibilities for the students. At the fair the student teams also compete, the participants of the fair can vote which group has the best poster and the performance. In the spring project the students build spaghetti bridges in smaller teams and for that the students need competence e.g. in design and technical mechanics. The results are presented in the topical themed seminar (project day) which is arranged for the co-operative companies and other important partners of the LUAS. In this seminar, the student teams also compete which team has the greatest bridge. The participants of the fair vote for the greatest bridge.

In the second academic year, the basic tools of the Mechanical Engineering become more familiar and the students learn how to apply all the knowledge they have achieved. The students can also work on the projects and they can apply different kinds of problem-based methods. The content of the second Academic Semester is illustrated in table 2.

*Table 2.*The content of the second Academic Year.

2. Academic Year					
Academic Year Theme	Semester Theme	Study Module	Extent	ResponsibleTeacher	Other Teachers
Engineers toolbox	Pouch the toolbox	**Project**: Product development	5	N.N.	A.A., B.B., C.C.
		Mathematics of the Engineers	5	N.N.	A.A., B.B., C.C.
		CAD as a tool	5	N.N.	D.D.
		Technical mechanics	5	N.N.	E.E.
		Automation solutions	5	N.N.	F.F.
		Practical training 1	5	N.N.	F.F.
	Solving practical problems	**Project:** Prototype	5	N.N.	A.A., B.B., C.C.
		3D design of the product	5	N.N.	G.G.
		Energy and environment	5	N.N.	A.A., B.B., C.C.
		Material properties	5	N.N.	C.C.
		Effective production environment	5	N.N.	A.A. B.B.
		Application of the physics	5	N.N.	A.A.

The second year's autumn project is a product development and the theme of the project is to design a table fan in a smaller group. In the spring project, these student groups manufacture prototypes of these table fans. The second year's projects follow CDIO project steps and the students need competence in material science, manufacturing processes, CAD design, energy technologies. The students can manufacture the parts of the table fans with 3D printing or machining steel. The table fans are presented in the semester project day together with the first-year students' spaghetti bridges.

The third year's semester projects are company-based and real working life problems and the first projects with this curriculum will be started in the autumn 2019. There are three different kinds of alternative professional study options in the Mechanical Engineering education curriculum and the students choose one of them in the third academic year. These alternative professional studies are: Industrial Professional, Product Development Professional and Mining Professional. All these alternative professional studies contain semester projects, mandatory courses and optional courses. In the region of Lapland, there are steel, paper, energy, mining, design and engineering workshop companies so the subjects of the projects can vary a lot and the student can participate in a project which best suits for his/her career plans. The students can choose some of the semesters study modules, which are integrated into the content of the semester project and best support the competence of the students. The curriculum is flexible and the content of the semester study modules can be modified if there are some special competence needs from the industry. For example, the theme Circular Economy was very important in the industry and thus current in the engineering education. Therefore, in the Mechanical Engineering education, these themes were included in the different professional subjects, as a cross section theme and it did not demand any changes in the curriculum and all the students gain sufficient knowledge about the current themes. In the last academic year, the students deepen the Mechanical Engineering competence and at the end of the year they will graduate.

2.1 Learning about Work of Mechanical Engineers: the first year semester projects

Especially for the young students the professional field of the studies may not be so familiar and if the students they do not recognize and understand that, the motivation for the studies may not be high and they can possible drop out their studies. It is also very important to support that the students get to know each other well so they can work as group and smaller teams. It is well known that grouping of the students increases the commitment to the studies which also increases the motivation to the studies. To reinforce grouping, both the young and the adult students make together first excursion at the beginning of the studies to the old mill and sawmill museum Kukkolaforsen which is located quite near to our school, at the shore of the Tornio River in Sweden, figure 1.

Fig. 1. The young and adult students familiarize themselves with the old sawmill.

In the curriculum of Mechanical Engineering, there are many studies were the engineering work and working environments are demonstrated in the basic and professional studies. In the autumn semester projects, the students are familiarized with different kinds of industries of the Lapland region and they also visit different companies. The semester project is culminated in the fair where the students introduce their semester projects results. One of the main goals of the semester projects is to arrange the fair where different companies of the Lapland region can introduce their activities and practical training possibilities for the students. The students make posters on a selected industry for the fair and present them at the fair. The students must also prepare an elevator pitch of their subject. It is a very important competence for the future engineers to sell his/her own competence and with these different training the students can learn and reinforce these skills. At the fair, the student teams also compete which group has the best poster and the performance and the participants of the fair can vote their own favorite group, figure 2.

Fig. 2. The company desks at the fair (left) and the winner of the student projects (right).

In the spring project, the students build spaghetti bridges in smaller teams and the results are presented in the project day, which is also, a topical themed seminar arranged for the co-operative companies and other important partners of the LUAS. In this seminar, the student teams also compete, and the participants of the fair can vote which group has the greatest bridge, figure 3.

Fig. 3. Learning basics of teamwork on the lessons and semester day.

2.2 Engineer's Toolbox: second year project

The autumn semester theme of the second year is Engineer's Toolbox containing the following supporting courses Engineer's Mathematics, CAD as a Tool, Technical/Engineering Mechanics, Automation Solutions. These courses give the students tools for the semester project Production Development. The subject of the project is given by the teachers and in the academic year 2018-2019 it was a table fan. In this project, the students learn about product development process and its different sections by teamwork. In addition, the students strengthen their team working and documentation skills. Based on the teachers' evaluation of the students' participation in and contribution to working in teams the previous year. Additionally, the skills of the students were taken into account to balance the team's skills as much as possible. In this academic year, the exchange students participated in the semester and due to this teaching on the courses was in English and the students got a lot internationalization at home. This course is strongly linked to the C (Conceive) and D (Design) phases of the CDIO model that is widely used in technology. The students participate in the design process, CAD labs, material selection and planning the design and functions of the product. They also draw up technical drawings and charts and evaluate the expenses and cost-effectiveness of the product.

The spring semester project continues the semester project of the autumn term and focuses on the final I (Implementation) and O (Operate) phases of the CDIO model. During the spring semester, the students complete the design and prepare a prototype of the product and the students need competence e.g. in material science, 3D design, effective production methods (Lean, 5S), energy technologies. The students can manufacture the parts of the table fans with 3D printing or machining steel and they can manufacture the parts of the fans at school or at home or at work. They also pay attention to the life cycle of the product and make improvements in the design. Additionally, they also consider operation and maintenance. Furthermore, they learn how to productize products and services. The solutions of the table fans by the different student teams were very different, and they presented the project progress with slide shows and the fans were on display in the semester project day together with the first-year student's spaghetti bridges, figure 4.

Fig. 4. The winning table ventilator solution by the adult student team (left) and the solutions of the different ventilators by the young students (right).

The third year's academic year theme is *Creative Engineers*. The third year's semester projects continue through the whole academic year and they are company-based real working life problems. The students have practised teamwork in the first and second academic years and they have different kind of professional competence. These skills are needed when solving the problems together. Solving real working life problems together helps the students to solve problems later at work. The last, fourth year's academic theme is *Pre-Engineers*. In that academic year, the students start their theses which are company-based subjects in Mechanical Engineering. In the thesis, the student solves real working life problems alone with guidance by the counsellors, but it is important that they have practised problem solving in the earlier studies.

3 THE DEVELPOMENT OF THE CURRICULUM, DOES IT HAVE AN INFLUENCE ON THE MOTIVATION OF THE STUDENTS?

One of the goals for the curriculum development is to influence the student's motivation to study and reduce possible dropouts. In addition, working life and job descriptions are changing quite rapidly, the educators need to consider what kind of competence is needed in working life in the future. In engineering education, it is necessary to teach natural sciences and selected subjects of the technical field but also social skills, analytical thinking skills, problem solving skills, language skills are considered important in working life. The students must know how they learn and adopt new and how they can combine their own knowledge with other students.

The Mechanical Engineering department is quite a small unit in the LUAS, other engineering departments are Electrical and Automation Engineering, Civil Engineering, Information Technology, Land Survey Engineering and Forestry Engineering. The applicants can apply for fulltime or part-time education and there are about 50 starting places in Mechanical Engineering education. The first year of the studies is very critical and usually if the student is going to break the studies, it usually is going to happen after the first year.

It is evident that the dropouts of the studies has reduced some with new curriculum. Generally, the students drop out their studies after the first or second year of the studies. Earlier with old curriculum about 10-20 % of the young students (full time students) dropped out the studies. The percent of the dropouts of the part time students (adult students) was even higher but usually there are more elements which affect the motivation of the studies (lack of time, family, job and other competing elements). It has been seen that these dropouts have decreased but there is only two-year experience and evidence of this curriculum. It is also important that the studies proceed as planned in the curriculum and it has proven that this factor has improved with this competence and problem-based curriculum. The semester themed projects and study modules may reinforce the interest of the students in the Mechanical Engineering field and they find diverse job opportunities in the field. There has been many other development actions in the education with development of the curriculum e.g. development of the learning environments. This contains development of the virtual learning environment and the laboratory environment. In virtual learning environment, the clarity of the layouts and the evaluation tools of the students' learning process have improved and develped. In Mechanical Engineering Education there is an investment project going on where brand new laboratory facilities are being built for the educational purposes. The new laboratory is called “Intelligence workshop” that will be modern with diverse equipment for laboratory work (industry 4.0). Student counselling is being developed, and with this new curriculum the teachers are more like counsellors in the students’ learning processes. Further reviews should be made to find out what the main reasons are that influence the motivation of the students and reduce dropouts.

4 SUMMARY

The new problem-based curriculum has changed the roles of the teachers as well the students. It has deepened the teachers’ cooperation and the students have learned working life skills along with their engineering studies and taken more responsibility of their studies. The different courses are integrated into the projects to give an overall insight into the contents of the semester theme. This is also seen in the virtual Moodle environment where all the semester courses are presented in the same course environment as interleaves.

In the future, the challenge is to make Mechanical Engineering more popular for the candidates. The population of the Lapland is decreasing and still there are quite a lot job opportunities for engineers in the area. Furthermore, when the students start the education it is important that their interest in the studies is high and they perform their studies as planned. The content of the education must be attractive, diverse and ahead of time. The challenges in lifelong learning and development of the competences challenge the educators to develop the contents of the degree programs. In the future, more short time updating training courses are needed and diverse implementation of the education. This challenges the educators to acknowledge and recognize the former competence of the students even better.

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Teaching Innovation To Engineer Students:

A Proposal For An Operational Process Model

Villads Keiding
Tecnical University of Denmark, vkei@dtu.dk
Copenhagen, Denmark

Conference Key Areas: New Complexity Quest in Engineering Sciences

Keywords: Innovation processes, managing complexity, process models, teaching innovation, boundary objects.

1 ABSTRACT

This paper addresses the future reality of engineer students, facing an accelerating uncertainty, ambiguity and interconnectedness. The dominant models for innovation process lectured at universities, e.g. CDIO (link 1), the Double Diamond (Council 2007), Design Thinking (Brown 2009) implicate a process with defined phases. Experience from practice indicates that the models do not prepare the students for the actual uncertainty and ambiguity. Moreover, the students confuse the concepts of *Project* and *Process*. The paper outlines a theoretical basis for an operational model resting on design theory (Jancke 2013, Lawson 2005, Schön 1983/2008), innovation theory (Darsø 2001), process theory (Hernes 2007), and project literature (Larson, Clifford 2014). A distinction between *Process* and *Project* is established, and the paper discusses a prominent understanding of the innovation process as divided in divergent and convergent phases, here named *The DC Diamond Model.* The concept of *emergence*, that is the becoming of something new, is identified as constituting for the Concept of Process. The paper proposes the *Extended Diamond,* integrating emergence, as the basis for an operational model for situated process analysis, design, and management of innovation processes. The proposal is the outcome of a participatory innovation process resting on 4 years teaching practice at bachelor level at the Technical University of Denmark (link 2). The framework VINCA is a presented as a manifestation of the proposed model. Finally the paper draws perspectives to actual experiences from engineer education and proposes further development of the framework to reflect an Actor Network perspective (Latour 2005/2007)

2 INTRODUCTION

2.1 Context, background and rationale

In autumn 2013, while teaching innovation to engineers in the bachelor program "Process and Innovation" at the Technical University of Denmark, my fellow teachers and I realized that it can be difficult to communicate the difference between the concepts of Process and Project. The students find the Concept of Process problematic and intangible. Both processes and projects aim to carry out activities to make a change. The Concept of Project offers the idea that a defined objective can be achieved through planning and control. Contrary to this, in literature about innovation (Darsø 2001, Lawson 2005) it is claimed that in a process neither problem nor outcome is known in advance. Furthermore, the quality of the outcome depends on the participant's ability to avoid *premature closure,* that is, when participants decide on a problem definition early in a process (Keiding, Gish, 2018). This is not easy; students must endure uncertainty and ambiguity, which can cause frustrations. Students need methods which support a process-oriented practice. Scholars need means to communicate the Concept of Process to students. This made us ask *how an operational framework should be, which helps the student and the practitioner to orientate themselves in a complex reality?* (Keiding, Ulrich 2014, authors translation)

The question initiated an ongoing process. One outcome is the VINCA framework, *a visual alphabet for innovation and learning processes*, utilized in 2014 as learning material (figure 1). VINCA is explained later in this paper.

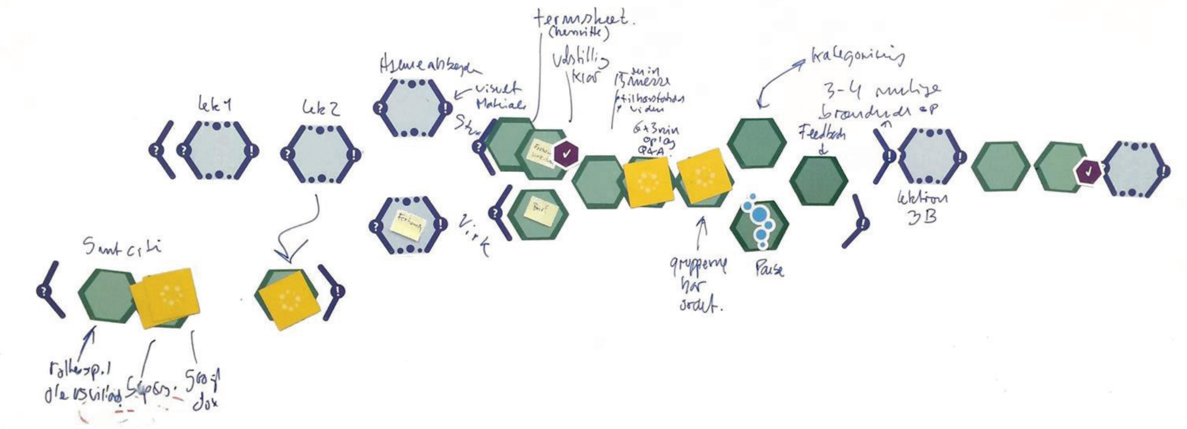


Figure 1: An example of a learning design modelled with VINCA. The example shows an internal process outcome intended to be further processed in order to be communicated to third parties.

VINCA has emerged in a practice oriented participatory design process (Simonsen, Robertsen 2012) Students, scholars, and external partners have participated. Innovation and process theory have informed the development as well as the author's reflections on the experiments.

Students have used the VINCA concept on several courses in the period from 2014 to 2019 as a means for reflection on their own learning process and for their design of innovation processes.

3 THEORETICAL OUTLINE

3.1 Scope of the work

The aim of this paper is to outline a distinction between Process and Project, to present a theoretical basis for the innovation process, and on this basis propose VINCA as an operational model for innovation processes.

3.2 The concepts of Project and Process

In this paragraph the concepts of Project and Process and the relatedness between the two will be outlined.

3.2.1 Project

According to The Project Management Institute (PMI), a project is *a temporary endeavor undertaken to create a unique product, service or result* (link 3).

Larson and Grey (2014) point out five characteristics for projects:

1. *An established objective*
2. *A defined life span with a beginning and an end*
3. *Usually, the involvement of several departments and professionals*
4. *Typically, doing something that has never been done before*
5. *Specific time, cost, and performance requirements (Larson, Grey, 2014)*

3.2.2 Process

The Process perspective is widely accepted in innovation. Ikujiro Nonaka, influential Japanese organization theorist, constitutes innovation as "*a process in which the organization creates and defines problems and then actively develops new knowledge to solve them"* (Nonaka 1994).

The Concept of Process refers to the basic idea of philosophy that the world is moving and constantly changing. It relates closely to the concept of *emergence* that describes the becoming of something new. In a process, something is *"constant in the making [and] the future is to be considered an open field"* (Hernes, 2007). In a process perspective it requires an effort to stabilize and maintain an order, for example as *a thing* understood as a social construct (Storni 2012), a structure, a routine, or a narrative. Even when a result has materialized it will only be temporarily stable. This uncertainty is often referred to as "fuzziness" (Brown 2009, Sanders 2001), illustrated by Daimen Newmann with the 'Squiggle Model' (figure 2 (left), link 4).

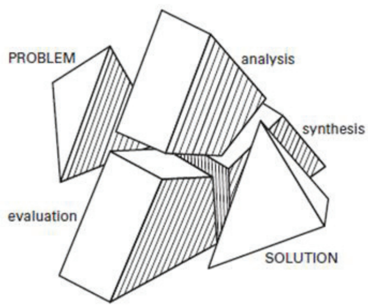


Figure 2: (left) "The Squiggle" (link 4). (Right) The Brick Model (Lawson 2005)

3.2.3 Emergence

Design theory (Shöen, Jancke, Lawson and others) discusses the emergent nature of the Design Process.

Bryan Lawson, architect and psychologist, criticizes a linear perception of the design process and identifies three distinct kinds of activities: Analysis, synthesis, and evaluation. Lawson argues that you should neither expect the activities to take place in a given order, nor to be able to distinguish between them. The process as such is a web of the tree kind of activities as illustrated with the Brick-model, (figure 2 (right)) and consistent with the “Squiggle Model” (figure 2 (left)).

According to Lawson the activities are wobbling around an axis with the problem and the solution as pivots. Over time, the understanding of the problem as well as the solution is refined and the pivotal points stabilizes. The Brick model illustrates a reflective practice (Schön 1983/2007) and Lawson refers directly to Schön who argues that the design process is not about problem solving. Rather the designer *enters problematic situations associated with uncertainty, disorder and indeterminacy* (Schön 1983/2007). According to Lawson, *it’s more likely that problem and solution emerge together* (Lawson, 2005).

3.3 A Matter of Concern

To initiate a process *something problematic* must be present (Schön 1983/2007, Lawson, 2005) and *an intention* must exist. According to Bruno Latour, co-originator of Actor Network Theory (ANT), processes of knowledge creation take place in chains of *translations* performed by actors. A *matter of concern* (Latour 2005/2007) is present in the origin. The *outcome* of a process emerges through numerous translations where *the matter* is temporarily articulated and stabilized as *proposals* and then re-translated. Figure 4 illustrates this in a two-dimensional model for hermeneutic innovation (Keiding, Lauritsen 2011). In the VDI model the matter of concern is represented as a unity of a question mark (?) and an exclamation mark (!).This is compliant with the Brick Model (figure 2 (right)) where the matter emerges as a unity of *problem* and *solution*. The stepwise emerging articulations of *the matter* (“?!”), numbered 1, 2, 3, 4, are shown at the lower part of the vertical axis.

Figure 3: The VDI model (Vision Driven Innovation) (Keiding & Lauritzen 2011)

In the VDI model the question mark represents the presence of *something problematic* and the exclamation mark represents *the intended outcome.* Since the outcome not is known in advance (Lawson) the intention should not be confused with an objective. Rather it has the character of *a vision* (Lerdahl 2004); an indented future state.

3.4 Projects and Processes are interrelated

One outset for this paper is that engineer students confuse projects and processes. Future engineers will work in organizational contexts where they will experience both. A modern organization is a project based environment where resources are allocated and managed to meet objectives. A lot of work is organized and named as projects. At the other hand, ambiguity and uncertainty are inherent parts of modern work life, not least because innovation and creativity are imperative. Many activities, like workshops, brief meetings, ongoing dialogue about matters, interaction with costumers and activities related to management, have the characteristics of processes. Processes, whether they are short and simple or complex and ongoing, are embedded in projects and also often founded by projects. To deliver newness, projects depend on the emergence of the process.

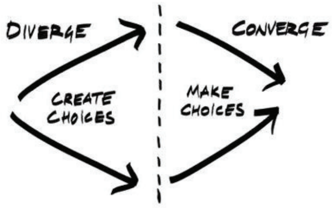
3.5 Prominent models

Innovation processes are closely associated with design processes. Design Thinking (Brown 2009) is a widely spread example, and also The Double Diamond (Council 2007, figure 3 right) is rooted in design. In CDIO (link 1), a framework for engineer education applied at DTU and many other universities, the D stands for ‘Design’.

3.5.1 The Diverge - Converge Diamond

Authors to the innovation models Design Thinking and The Double Diamond describe creative practice and innovation processes as organized in divergent and convergent phases (Brown 2009, Council, 2007), illustrated as diamonds, hence the name *Diverge – Converge Diamonds* or in short *DC Diamonds* (figure 3 (left)).

Divergence is about unfolding, expanding a space, creating choices, producing and explicating *more* of something, typically information, material or *ideas.* This refers to the *analytic activities* in Lawson's brick model (figure 2 right). Convergence is reduction and decision-making and can be associated with the *evaluation* of a materialized outcome in the brick model (Lawson). The Double Diamond, mapped out by Design Council (Council 2007) is a four-phase innovations model where the innovation process is represented by two DC Diamonds, one following the other. See figure 3 (right).



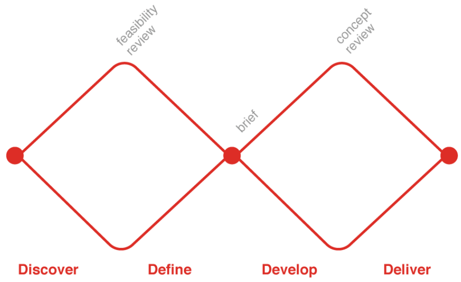


Figure 4 (Left): "Diverge – Converge in Design Thinking" (Brown 2009). (Right): "Double Diamond" (Council 2007)

Yet simple, both models are also abstract and generalized. The DC Diamond model serves mostly as a metaphor for the innovative mindset (Brown 2009). Double Diamond is based on empirical studies and introduces the idea that more diamonds (and hereby sub-processes) can be combined and nested into more complex process visualizations.

3.5.2 The Extended Diamond

As mentioned above, the concept of emergence is a constituting factor for a process, but emergence is not explicitly included in the DC diamond models. With the words of design theorist Marcus Jancke, the aim of a divergent Process phase is not to create *options* but rather to create *a mess* of material *or nodes,* (Grey et.al. 2010) representing the actual matter of concern. Jancke uses the term *the necessary messiness (Jancke 2013)*. *The newness* is a translation of the matter, and emerges as a new order and a new meaning recognized as a pattern in the mess. This refers to *synthesis* in the hermeneutic Brick Model (Lawson 2005, figure 2 (right))

There is compliance between hermeneutic innovation processes explicated for instance with the VDI or the Brick Model, and the diamond extended to a 3-phase model, where the phases are

- the divergent phase - compliant with *analysis*
- the emergent phase - compliant with *synthesis*
- the convergent phase - compliant with *evaluation.*

The idea that simple elements, like activities, can be combined or nested into more complex systems is supported by the Double Diamond but also well known from

Gantt diagrams in project management. When visualized as combined and nested sub-processes, a high level of details and complexity can be represented.

3.6 Shared terms but different meanings

The Concepts of Project and Process share some terms and attributes, but their meaning are different. Some of the differences are summarized in table 1:

	Process	**Project**
Intention	Someone wants something to change, wants to crack a wicked problem or to see a vision come true.	An objective is established
Initiation	A question is raised or a matter of concern is articulated	A management decision is made and time, cost and performance requirements are specified, and resources are allocated
Objective	Not known in advance but an intention (above) with the character of a question and/ or a vision is articulated	Benchmarks and deliveries has been decided
Ambiguity and uncertainty	Fundamental conditions for emergence, creativity and the becoming of newness	Risks that must be tamed and reduced
Outcome	The most actual articulation of a matter of concern, only temporarily stable	A solution, a delivery

Table 1: Terms and attributes and their meanings ind the context of Process and Project

4 THE VINCA FRAMEWORK– A PROPOSAL FOR AN OPERATIONAL MODEL

The following is a description of the VINCA framework: VINCA has the form of an alphabet built from 8 symbols, organized by a syntax. The concept is available for students as image-files and symbols printed at carton and magnetic foil.

VINCA is a model that encapsulates the constituting elements of the Concept of Process described above: The VINCA process icon (figure 5 (left)) shows the three phases of the extended diamond. The matter of concern is represented by the question mark on the left side of the icon and the exclamation mark on the right side. The 8 symbols can be nested and combined to build detailed representations of complex processes.

Figure 5: Left: The VINCA Process icon. Right: A process in the context of a project.

In the teaching material a process is explained as *a web of interacting activities that lead to emergence: Something new is coming into being. A Process starts with a question or a problem. It is explorative, guided by a vision and controlled by feedback. Processes have 'fuzzy' goals. You do not know the outcome in advance, but you can specify which form it should have.*

Processes have 3 phases:

- ***The divergent phase** where the process opens and the participants gain a deeper understanding of the problem*
- ***The emergent phase** where the participants explore and do experiments*
- ***The convergent phase** where the process is closed and the results take a form that makes sense to others"* (Keiding & Ulrich 2014, author's translation).

The black brackets (figure 5, right) represent *the project* and indicates that *a process will always take place in the context of a project* (Keiding & Ulrich 2014, author's translation).

The process icon is a container: Sub-processes and activities can be nested hierarchically inside. A process can be expanded and nested activities and other processes inside can be described and arranged. See figure 7. An activity (the green icon) is the lowest level hierarchically and cannot be further expanded. An activity has most of the attributes of a process, for instance is it constituted by a question and an expected outcome. An activity will sometimes be guided by a method (the yellow icon) (figure 7, 8, 10).

Figure 7: Left: A process containing 3 activities. Right: A process is built from one activity guided by a method (the yellow square) and one not-expanded sub-process.

The sole elements can be arranged and the attributes can be described in a Power Point slide or similar document formats. The physical instances of the elements can also be used in a more casual manner as design material in a creative dialogue on a whiteboard (figure 1). In 2016, a group of IT-engineer students conceptualized a VINCA app. They treated VINCA as a programming language, analyzed the use of it and formulated the syntax shown in figure 8.

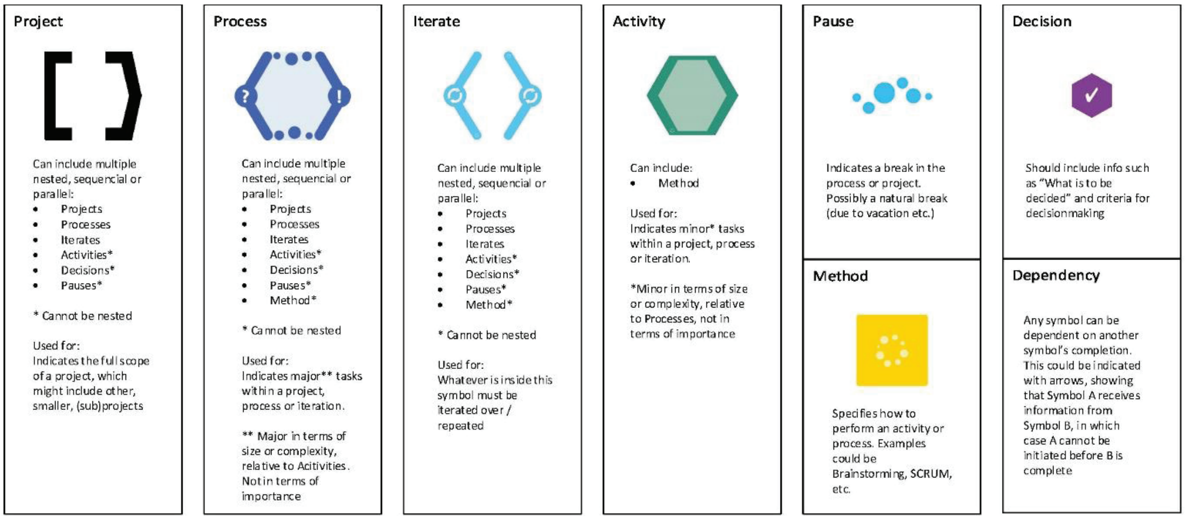


Figure 8: The VINCA syntax

Emergence is a primary distinction between the concepts of Process and Project. In VINCA the bubbles in the process icon represent emergence, but the phenomenon also has its own independent icon called *reflection* or *pause* (figure 9 (left)). In the teaching material is it described as *an unscheduled activity that connects activities and processes and allows reflection. The Pause is a special activity whose explicit purpose is reflection, incubation or emergence in pure form"* (Keiding & Ulrich 2014, author's translation)

4.1 A generic model

VINCA claim to be a generic model for innovation processes in the sense that it can model other known models. Students can add details reflecting their actual process, and redesign known models or process designs to adapt to the actual context. Figure 9 (right) shows a visualization of The Double Diamond. Each of the four phases in the model is shown as independent processes. Consequently, each process can be expanded and students can decide and organize appropriate activities and methods to be nested inside.

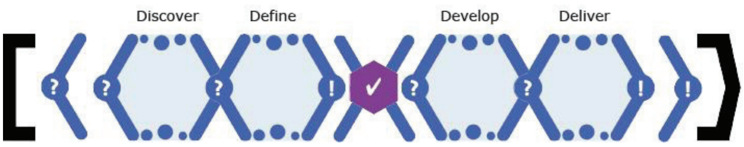


Figure 9 (Left): The Pause. (Right): The Double Diamond visualized with VINCA

5 APPLICATIONS

Since first introduced 2014, VINCA has been a mandatory element at the courses Innovation and Creativity (link 5) and Innovation and Knowledge Management (link 6). Students primarily use VINCA for process reflection (link 7, p66) and process-design.

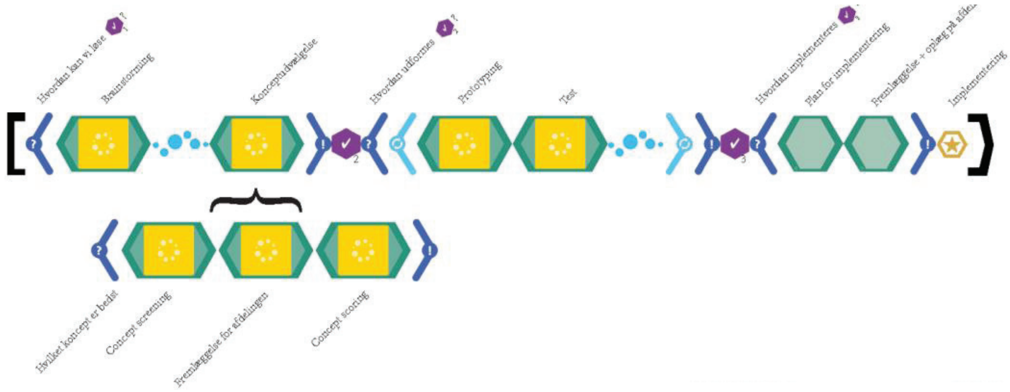


Figure 10: Process design performed by a student group (link 6). The example shows an internal process outcome intended to be further processed in order to be communicated to third parties.

5.1 Other Applications

VINCA has been applied for various purposes:

- For course planning in a learning context at DTU and other Danish universities
- In several Danish municipalities as a management tool for process analysis and as a collaborative planning tool
- To facilitate the initiation of several DTU innovation projects with external partners and to maintain the projects.

6 FINDINGS AND PERSPECTIVES

The aim of this paper is to propose an operational framework for an innovation process, not to conduct an in-depth analysis of the use of VINCA.

The effect on the innovation outcome and students' learning are subjects of further research, which, initially, can make use of 4 years of documented processes and material submitted by students.

6.1 Feedback

The general feedback from students and fellow teachers indicates that VINCA makes the Concept of Process more tangible, offers a common frame of reference, and operationalizes the work with innovation processes. VINCA serves as a boundary object (Star, Griesemer 1989) in the dialogue between actors at an innovation arena.

6.2 Future research

Feedback also indicates that some factors and some levels of complexity are not represented in VINCA in its actual form.

Most recently VINCA has been applied on the courses Innovation and Knowledge Management (link 6) and Innovation in an Organization Context in the 4th semester at the bachelor program Process and Innovation at DTU. The teaching is case-based, the learning philosophy is design-based and the courses share the same cases (Keiding, Gish 2017). Teams of students' use hospital departments as cases and co-work with the management and the practitioners to analyze the context, identify a problem, and conduct innovation processes to solve it. Cases are acquired through the project CHI, Copenhagen Healthcare Innovation, a project that aims to create collaboration between the healthcare sector and universities (link 8).

A hospital is a highly complex arena and the innovations processes taking place in the arena are likewise complex. In the spring 2018 Actor Network Theory (ANT) was added to the curriculum to empower the students to capture the complex dynamic of a hospital department. This affected the student's perception of the innovation process and added new layers to the needed process representation, namely the actors and the network. It made me ask *how a process framework (like VINCA) can be further developed to empower the students and the practitioner to facilitate innovation in a complex and interconnected arena with many actors with opposing interests?*

Another question to be taken in consideration origin from the interrelatedness between the concepts for Project and Process: How does VINCA differentiate form available flowchart tools? And further: *How could the fuzziness and the ambiguity of the process be further operationalized to benefit the value creation of the innovation process?*

6.3 Perspectives for the field of Engineering Education

A sense of emergency has been driving the development of the present work. A paradigm shift is taking place in engineering education. Future engineers face a reality of accelerating volatility, uncertainty, complexity, ambiguity and interconnectedness. Problems are no longer given and you cannot rely on a well-defined objective and a good plan. Engineers must be empowered to *enter problematic situations* (Schön 1983/2007) and to master the emergent process in arenas characterized by high complexity and many opposing interests. It is my hope that this work will support future engineers in this process.

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8 LINKS

Link 1: http://www.cdio.org/. Accessed 01052019

Link 2:https://www.dtu.dk/uddannelse/diplomingenior/proces-og-innovation/. Accessed 01052019

Link 3: https://www.pmi.org/. Accessed 01052019

Link 4: https://thedesignsquiggle.com/ Accessed 01052019

Link 5: Creativity and Innovation https://kurser.dtu.dk/course/6200/. Accessed 01052019

Link 6: Knowledge and Innovation Management: https://kurser.dtu.dk/course/62043/. Accessed 01052019

Link 7: http://www.ffe-ye.dk/media/784193/bedoemmelse-afentreprenoerskabs-undervisning.pdf/. Accessed 01052019

Link 8: Copenhagen Health Innovation: http://copenhagenhealthinnovation.dk/. Accessed 01052019

Innovating exams design in lifelong learning
New Exam Design - Another Way of Learning

Isa Keller-Andreasen MSc (Econ SOL) (ID1302)
Head of Study, Ass. Professor
DTU Diploma
Copenhagen, Denmark

Poula Helth Ph.D. MSc. (Pub adm)
External Lecturer, Researcher in Management
DTU Diploma
Copenhagen, Denmark

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Keywords: Transfer; Exam and assessment design; Occupational context; Learning in practice, Transformational learning; Digital media.

1 ABSTRACT

The aim of creating new exam designs is to increase the impact of learning in diploma programmes in continuing and further education[1]. By developing new designs we create situations where the student can demonstrate the integration of theoretical knowledge in their practical experience, as well as their inter- and transdisciplinary capabilities[2]. The ruling hypothesis is *that an in-depth involvement of the student's occupational context supports and develops active transfer and lasting learning*[3]*.* Six prototypes have developed mixing exam design i.e. individual oral exams with audio or video clip or pitches, group exams, and experiments/interventions in the occupational context. Subsequently, we have been evaluating the prototypes in relation to the impact of the learning process compared to new competences and abilities relevant for the students' practice. The results show that by bringing the occupational context of the students practice into the "room of exam", support the transformational learning, providing the external examiner and the examiner a better basis of assessment regarding the students' practice based competences and abilities. The didactic used has enabled the students to practice and experiment, during classroom teaching and between the classroom setting in the students' own practice, together with peers or co-students. Moreover, learning

[1] *Continuing education is characterised by students having a full-time occupation outside the university, and the educations in focus in this project are Diploma-programmes. The programmes are related to level six of the Danish Qualifications Framework of lifelong learning which is based upon the Bologna framework (Ministry of Higher Education and Science, 2018)*

2 Nygaard, Courtney & Frick 2011; Ledelseskommissionen, 2017

3 Walgreen, 2009; Andersen & Tofteskov, 2016; Laursen & Stegeager, 2017, Helth 2018 experiences using digital media in exams have proven to be relevant for exams within further education.

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2 INTRODUCTION

The innovation of new designs of exams has taken place in continuing and further education programs at DTU the Technical University of Denmark; programs where the students work full time in private and public enterprises. In this context, exam is regarded as an integrated part of the learning process in the programs, focusing competencies at level six of the Bologna framework, which includes the capability to handle complex and development-oriented situations in work contexts.

The aim of the presented project is *to increase the impact from educational contexts to practical contexts through transfer and transformative learning* when the design of the exams facilitate exam situations where the student can demonstrate the integration of theoretical and methodological knowledge in their practical experiences. Thus, bringing more value for the student and the labour market. The aim is then to explore how innovation of exam designs can improve the students' opportunities to use what they have learned in the education, contrary to many educational programs, where the focus is primarily on the student's exam grades (Vince 2002, Gray 2007, Zundel 2013)

The consequence is that learning in continuing education are mostly based on the literature relevant for the learning subjects, combined with teaching theoretical and methodological skills in the classroom, and the cases the students bring into the classroom. This combination of teaching, learning and facilitating seems to be working well in the classroom due to the high scores; however, the current exam form is not incorporating the occupational context of the students (Schön 1983). To focus on the abilities to use new competences in practice, students need to work differently with their learning than they often do in further educations.

The project unfolded in this article has explored new ways for assessment to address the needs for exams as an integrated part of learning processes in future programs in continuing and further education at DTU. Shortly, the impact of exploring the new design of exam seems to underline that the teacher's support of learning by training methods is relevant for a professional and organisational practice. This means a learning process that reinforces transformative learning rather than transfer. A transformation of practice does not happen through theoretical knowledge. The student has to train and rehearse new competences in practice, if practice has to be changed.

2.1 APPROPRIATE CONTEXT AT THE UNIVERSITY AND IN STUDENTS' PRACTICE

The project's experiments have taken place within six different Diploma programmes for continuing education at DTU.

Continuing education in Denmark is characterised by students having a full-time occupation outside the university. The programmes at this level are related to level six of the Danish Qualifications Framework of lifelong learning which is based upon the Bologna framework (Ministry of Higher Education and Science, 2018).

This means that the students work in private and public enterprises and need to develop new competencies in order to handle more and more demanding job situations. Thus, the exams are not a pure assessment of explicit knowledge but seen as part of the learning process as the final learning outcome includes the capability to handle complex and development oriented situations in work contexts in a reflective manner.

The reasons to innovate the design of the exams are multiple. The trends in postgraduate education in Europe are that the labour market is more complex, and demands more advanced training and ongoing development, including technology and technological applications, more integration of theoretical knowledge with the practice experiences, inter- and transdisciplinary capabilities, to mention some (Nygaard, Courtney & Frick 2011; Ledelseskommissionen, 2017). In addition to these trends, the implementation of constructive alignment at DTU Diploma as a concept and the sheer increasing number of students calls for development of new forms of examinations and assessment.

2.2 CONCEPTUAL FRAMEWORK FOR THE NEW DESIGN OF EXAMS

The courses included in the project are part of the Diploma in Leadership which is a national education offered to professionals and postgraduates as part of the Danish Continuing Vocational Education programmes. The focus is on personal leadership and management within a complex organizational context. Common for the Diploma-programmes is the structure with 30 ECTS compulsory courses, 15 ECTS elective courses, and a final 15 ECTS thesis.

The students following these programmes are typically leaders to be or leaders of teams, departments, organisations, projects or processes in public, private and NGO organisations. The learning outcomes are as mentioned above formulated according to the Bologna framework. A typical exam design for a course (compulsory as well as elective) is individual and a combination of a written synopsis/assignment and an oral presentation followed by reflection and discussion to put the analysis, conclusions and actions into perspective.

Among others, the following aspects are important for transfer, learning and use of new competencies in the daily work life (Walgreen, 2009; Andersen & Tofteskov, 2016; Laursen & Stegeager, 2017, Helth 2018):

1. The students are brought into situations that create a field of learning in their daily job context
2. The job context gives the necessary potential and resources to practice the learning
3. The job context has a culture of change that inspires and supports innovative approaches, i.e. an acceptance of making errors and openness towards difficulties, challenges and dilemmas
4. There are communities of practice and social groups with an educational framework, where reflections and knowledge sharing are an important part of the interactions in the daily life in the organisation
5. There is a possibility to make systematic reflections upon the application of, for example, written reports

These factors encourage a closer connection between students at the university and their practice in the companies. Thus, teachers have to establish better circumstances for the learning context throughout the programmes and the final exam. In the project, the context creation took place through the teacher's organising of study groups, room for experiments, facilitating role-plays, sometimes combined with written reflections in blogs or logs. Bringing the occupational context into the "room of exam" could be done in several ways for example through group exams or exams taken place in the students' workplaces, recording the students written and/or oral presentation in relation to the employees, colleagues, managers etc. Below we unfold the six prototypes used in different types of exams.

2.3 SCIENTIFIC LITERATURE IN THE FIELD

As we have observed in the project, transformative learning can change students' social practice and sometimes their identities (Lave and Wenger 1991, Wenger 1998 Mezirow 1992, 2009, E. Taylor 2007, 2009). The background for using transformative learning is a study unfolded in leaders' practice in 10 companies in Denmark, where the empirical study was based on action research (Helth 2018, McNiff and Whitehead 2011). The purpose was to create a learning environment that promoted leaders' potential to obtain the transformation they wanted and needed.

As mentioned above, transformative learning can change students' practice and enable a more direct training and experimenting with practice. A student does not learn his or her profession reading books alone, but also has to practice. Students who participates in continuing education often focus on how the knowledge as a 'product' can be transferred from the education system unto the working practice. However, this does not give the student sufficient competences. Transfer is based on a non-personal kind of learning, which consists of learning far away from the organisational practice (Helth 2011).

More attention has to be on transformative learning (Mezirow 2000), which includes a creative learning process where knowledge emerges in new forms, depending on different events and leadership interventions. Researchers have argued that transformative learning focuses more specifically on connecting theory to practice (Harris et al 2008). Hence, transformative learning may be more relevant in accordance to an organisational practice than learning as transfer that focuses on the individual learners' ability to bring knowledge from one context to another.

However, there are barriers to enable learning in an organisational practice, if learning theories are dominated by the notion of transfer. In contrast to transfer, transformative learning seems to have different advantages over learning in practice. To fulfil this target, we have used three didactic "rooms of learning", see figure 1. The figure shows the combination of teaching in the classroom, exercises in the classroom (laboratorium) and experiments in practice (practicum).

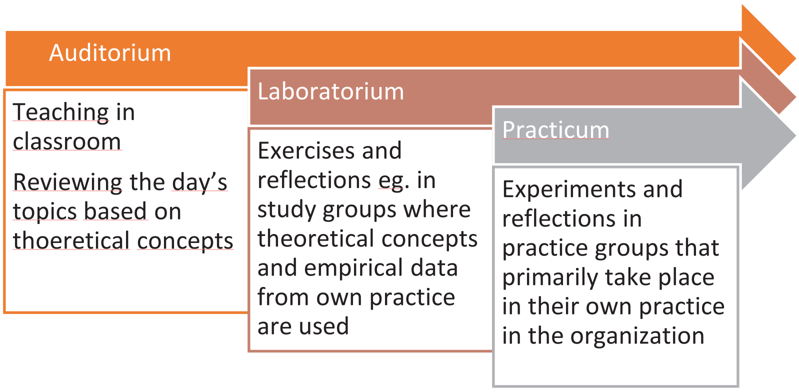


Figure 1 Three didactical "rooms of learning" (Dauer, Stegeager, Willert 2011, 2019)

3 HYPOTHESIS AND METHODOLOGICAL DESIGN OF EXAMS

The goal of the project is to develop analogue and digital prototypes and combinations of the two, with a primary focus on inviting the practice of the students into the exam situation. Additionally we want to contribute to a higher level of professionalism for the students and educators in an increasingly digital world.

The hypothesis for the innovative work *is that an in-depth involvement of the student's occupational context supports and develops active impact and lasting learning through transformative learning and learning environments in the classroom and in the organisational practice* (Walgreen, 2009; Helth, 2018).

As the students are working in different contexts and the different programmes have different learning objectives, we cannot generalise results. Actions that work well in a course in "Economic Leadership" based upon accounting principles and economic theory in a leadership perspective, will not automatically work as well in a course in "Management and globalization". Similarly, we cannot copy the best practices from our project into other countries and apply the experiences directly from the Danish programmes. This is due to differences in culture and tradition, legislation and systems.

The purpose is to explore the knowledge of how individuals and groups are making sense of the different theories applied to the challenges in the occupational context, and how we as educators can support transformative learning in further educations.

As the exam is an integrated part of the learning process, and is the formal framework for assessing the knowledge gained, the acquired skills and the acquired competencies, we must focus on assessment of the competencies that includes the capability to handle complex and development oriented situations in work contexts in an increasingly digital world. Thus, we must establish a "room of exam" where the students must demonstrate their competencies of acting in complex work contexts in a reflective way.

Due to the Bologna framework in Denmark, we always use learning objectives in relation to knowledge, skills (abilities) and competencies. Below we will unfold the six prototypes in our project in relation to the learning objectives.

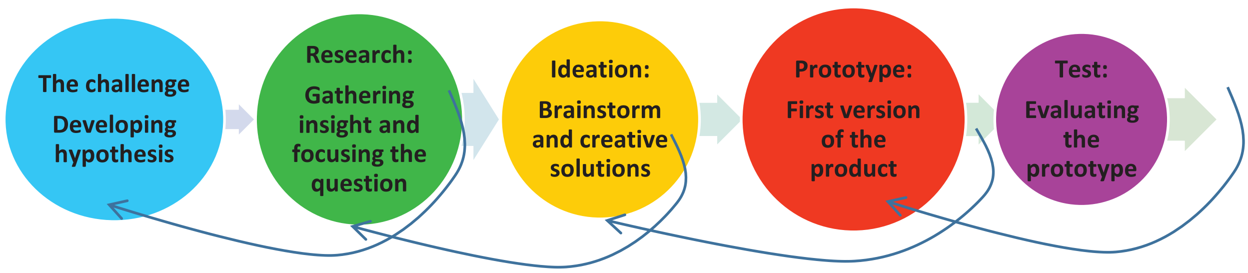
3.1 DESIGN OF EXAM

The project consists of three stages:

- Exploring the possibilities for new exam designs and designing prototypes that comply with current academic regulations for the diploma programme
- Completing a number of exams based on the new prototypes
- Evaluating the new designs with students, teachers, heads of studies and – if possible – with the employers of the students

In the work with innovating exam design, we are inspired by the ideas of the Design Thinking Process (IDEO[4]) as depicted in figure 1 and start by forming a hypothesis, “the **challenge**”. Next, we focused on the question and **researched** the audience we designed for, i.e. the students, and began the **ideation** process coming up with creative solutions. Building a representation of one or more of the ideas, we created several **prototypes**, which we subsequently tested and evaluated. The results help revise the research questions, fuel the creativity for new solutions, and refine the prototypes.

Figure 2 The five stages of the design thinking process. Ref: IDEO https://designthinkingforeducators.com/



In the first part of the project, the teaching staffs of the diploma programmes have participated in a workshop with the purpose of designing new prototypes. They have subsequently been encouraged to volunteer and test the new exam forms in either the semester fall 2018 or spring 2019. Evaluation and revising of the new exam forms was carried out during summer and fall 2018, winter and spring 2019 in a continuous loop process, following the ideas of the Design Thinking method.

Thus, the project developed as we experimented with different types of alternatives to the most used combination exam, where the student has an oral exam based on a written synopsis, concerning a problem relevant for the specific subject.

3.2 EMPIRICAL DATA FROM PROTOTYPES OF DESIGN OF EXAMS

Data for the project consist interviews with students, teachers, and employers and observations from courses, exam situations and teaching staff meetings and workshops. A number of compulsory and elective courses are part of the project (table 1).

[4] https://www.ideo.com/post/design-thinking-for-educators

*Table 1Overview of courses in the project in 2018-19, * not included in this report, but are test of prototype*

Focal point Subject in the Diploma programme	**Compulsory/ Elective**	**ECTS**	**Exam**	**#students**	**Status summer 19**
Research the field Technical experiment Management and Globalization	Elective	5	Individual Oral with audio clip + written assignment	6	Prototype Testning
Technical experiment bigger scale Organizational and management communication*	Elective	5	Individual Oral with audio clip + written assignment	20	New Prototype
Pitch exam Strategic management	Elective	5	Individual Oral with synopsis and video clip	24	Permanent
Practice training Leadership and coaching*	Elective	5	Group exam Oral with video with essay and team reflections	10	Permanent
Training of collaboration Organisation and Processes – Management and Organisation 1	Compulsory	5	Written group exam	14	New prototype
Learning through practice Personal Leadership 1+2 Leadership Communication Professional leadership	Compulsory	2*5	Written group exam + Oral with synopsis based on experiments performed	20	Permanent

3.3 METHODS INVESTIGATING IMPACT OF THE PROJECT

The primary methods for data collection are questionnaires with the aim of uncovering trends, and focus group interviews, as well as individual qualitative interviews, with the aim of uncovering in-depth qualitative data. These methods are combined with observations performed during actual exams. The project participants carry out all project investigations, evaluations and reflections.

The focus of the questionnaires is to explore how the new format of exams works. It consists of a number of questions with special focus on three factors that can explain a substantial part of the transfer taken place, namely **job benefit, transfer climate, and rewards** (Walgreen, 2009). Furthermore, the focus is also on the possibility of the student for integrating theory and practice. Qualitative interviews were carried out with groups of participants guided by semi-structured and open questions to obtain their reflections upon the method, the learning process, and the transfer of theory in to practice.

On the topic of transfer climate, the questions address time available for studying, workload, and possibilities for experimenting with the new skills, which Walgreen points out as the three most important barriers for transfer. E.g. "*How did you find the possibility to work with the video clip/assignment/the intervention*?"

The rewards achieved after completing a course or a whole programme could be financial or personal e.g. fringe benefits, promotion, more responsibility, etc. Researching for the job benefit we asked: "*Did you get any benefits after completing the course? Which? How?".* The students are often not aware of their new competencies. The questionnaire made them reflect when we asked about their experience with integrating theory into their practice. One question was: "*Where did* *you have bigger learning in relation to the examination*?" followed by optional. The questions posed were focusing on factors that facilitate the transfer mentioned above.

After group exams we conducted an individual interview to explore the individual transfer climate and job benefits as well as learnings. In the last prototype in the project we observed interactions and responses to various exercises as well listen to the dialogues though classes as well as examination. A focus group interview is set up with all teachers together with the Head of studies to collect and share all learnings.

4 FINDINGS IN THE PROTOTYPES

The challenges was to develop analogue and digital prototypes and combinations of the two, with a primary focus on inviting the practice of the students into the exam situation, grounded in the hypothesis: *that an in-depth involvement of the student's occupational context supports and develops active impact and lasting learning through transformative learning and learning environments in the classroom and in the organisational practice.*

The process unfolds in the following descriptions of the prototypes starting with a co-creation with students and explore the technical abilities and challenges of the students and teachers finding the technical and didactical potentials to train practice and collaboration ending up learning through practice. Three of the prototypes are now permanent forms of examination and assessment at the programme. This means that 6 prototypes have been developed into 4 new designs of exam.

4.1 AUDIO/VIDEO PITCH, SHORT WRITTEN ASSIGNMENT AND ORAL EXAM

This development took place preliminary in a course with 6 participants to test the didactical and technical potentials and challenges to put to bigger scale in course with 20 participants. The teacher and the students co-created the prototype to capture the occupational context best and accelerate their learning. It became a combination of an individual oral exam and a video/audio clip accompanied by a short written assignment. This assignment addresses management issues and challenges within the global professional context, and includes a theoretical as well as a practical perspective. The learning objectives set requirements to the case. The oral exam consists of the examination, evaluation and feedback. The form is dialog-based and can have the following content:

- Students oral presentation agenda based on the video/audio clip
- The video/audio clip based on the case will be the starting point. The student will elaborate questions, analyses, reflections, conclusions and perspectives
- Discussions about methodology, applied theory and possibly alternative theory as well as the management-based context.

The co-creation process created a direct connection from translating learning objectives into the occupational context of the students. The teacher was excited as the assessment of the learning objectives, especially concerning the skills and the competencies were built upon a more solid basis. The students could demonstrate their level of knowledge and capabilities and could put conclusions into perspective in their own occupational context based on different scientific paradigms as the required[5] In making the audio clip they had to find a case that demonstrated a cross-cultural issue in their working environment. As they used both the social constructivist paradigm as well as the realistic paradigm, they gave themselves an opportunity to learn even more as the exam unfolded as a dialogue.

The later research showed due to transfer climate that 33% used external networks of interest, had no co-workers as co-students and 100% used their leisure time for the study. The bigger part found the highest level of learning in preparing the exam by themselves, in the group preparation with the teacher as well as in the dialogue at the table. An interpretation of the results is that the learning has increased while at the same time the teacher and external examiner found the format giving a better foundation for the assessment. The average of marks for the exams were “A-“.

Key points and learnings:

- The training in doing interviews and research have changed in the way the students act in a more reflective manner
- The exam form created a stronger commitment from the students
- The technical support of the exam, i.e. the learning management system, must have the necessary functionality and sufficient power to handle the uploading of videos and audio clips
- The teachers must make time for training pitching and scoping as well.
- Didactically, the teacher takes a more facilitating position and put the responsibility to learn the technical capabilities of the student to create the videos and audios.
- Created bigger awareness of management communication and the potential of digital forms of communications channel
- Students developed their communications skills and competences in the occupational context afterwards.

Taken the learnings into account the prototype was modified and developed to an individual oral “pitch” exam combined with a written synopsis.

4.2 VIDEO PITCH, NO WRITTEN ASSIGNMENT AND ORAL EXAM

Taken the learnings from the former development of semi digital prototype, the practice training was introduced and developed at another elective subject within the same programme. Thus, most of the students had experienced recording and performing a video pitch. The prototype of the exam is a combination of an individual oral exam and a 3-5 minutes video pitch that addresses how the student understands strategy and strategic leadership and gives a short analysis of a specific strategic challenge of the student. The oral exam consists of the examination, evaluation and feedback. The form is dialog-based and can have the following content:

- Students oral presentation agenda; the video pitch in a broader perspective
- Critical evaluation of theories and methods supporting the strategic leadership
- Most important learning from the course and how the student share the learnings with other members of the organization.

[5] Level six requires a reflection of fourth order due to Bologna framework

After experimenting and keeping the rules concerning examination, this prototype is now the concept as the student experienced a transformative learning process and a higher capability afterwards. The planning of the course has been changed thus, the students bring the scope of the strategic challenge they want to work with during the course before the course starts to support the transformational learning.

4.3 WRITTEN GROUP EXAM

Parallel to the former process we conduct the development of this prototype in an exclusive course for a management group of 24 persons at a public organisation with about 250 employees. This mandatory course is part of a continued programme to strengthen the professionalism in management and leadership as well as the cross-organizational collaboration. The additional purpose challenges the format of exam that should create a solid ground for evaluation and transformational learning. The new format is a written group exam starting from three defined strategic goals given by the top management.

The groups were formed across the sectors and departments at the beginning of the course, thus they got used to working together, carrying out analyses, reflections and other activities during the classes. Every group defined their own working problem statement and each member analysed the issue from their own perspective using the theoretical frameworks and models of the subject. The group then wrote a joint discussion, conclusion and perspectives based upon the findings. After the exam, they received oral feedback from the teacher. This meeting also served as a room for reflections upon their lessons learned and learning.

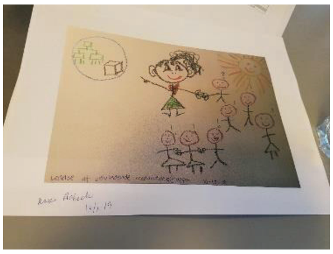
The results concerning the transfer climate and learning were that the participants found a high level of learning in the writing process as their reflections emerged in the process, even though they had a big challenge to find time to coordinate. The development of a more professional behaviour as well an increased awareness of sensemaking and the interdisciplinary leadership have emerges at the organizational level, which show a transformational learning more than transfer.

4.4 ORAL EXAM AND WRITTEN ASSIGNMENT.

The following course for the before mentioned management group explored the learning through practice with focus on professional and personal leadership. The prototype was an individual oral exam and written assignment bounded in experiment in practice performed before the exam.

To get an in-depth involvement of the students occupational context the instructor attempt to create a connection between learning objectives during the classes by setting some requirements for the didactics to create a correlation between the student's own practice, the classroom teaching and the examination assignment that completes the module. A storyboard was design for each class. The three didactical “rooms of learnings”; Auditorium, laboratorium, and practicum (Dauer, Stegeager og Willert 2011 and 2019, Figure 1), were visited, and created a movement through aesthetic performance, that help the leaders to express new thoughts and integrate their experiences in neural networks (Peterson, DeCato og Kolb, 2015). The following research found that leaders learned reflect on the influence of aesthetic performance to reach the recognition of the transformation they achieved. Moreover, they developed new practical based leadership competences with success for themselves and the organisation.

Figur 1 Training methods and communication skills



Figur 2 Illustration during examination

5 PERSPECTIVES

The hypothesis for the work *is that an in-depth involvement of the student's occupational context supports and develops active impact and lasting learning through transformative learning and learning environments in the classroom and in the organisational practice.* New forms of exams have strengthen the capabilities of the students in their practice. All activities and intentions of the project have been very well received among teachers, students, and organisations. Three prototypes are now permanent practice in the curriculum and has been adopted into catalogue of assessment and exams for the national study programme of Diploma of Leadership.

Concerning the benefits of the new forms of exam being part of the learning, the teaching and learning must be based on action learning and must be well structured by creating storyboards and include time for training of relevant methodologies.

In addition, the organisation has to take responsibility for more emphasis on students' learning in practice. As the effect of this project documents not only the instructor, but also top managers from the students' working context, have to be involved and encourage learning at the workplace. The perspective of learning could be a new co-creation of transformative learning between education systems and human resource departments in organisations, thriving for new forms and technologies of transformative learning in organisational contexts *and* in leadership learning programs.

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Herding Cats? Reflections on Colleagues' Perceptions of Learning & Teaching in Engineering Education

G. Knowles
WMG, University of Warwick
Coventry. UK

R. Clark
WMG, University of Warwick
Coventry. UK

J Andrews
WMG, University of Warwick
Coventry, UK

Conference Key Areas: Managing Change in Engineering Education, Talent Management

Keywords: Change Management, Phenomenology, Staff Perceptions.

ABSTRACT

Set at a time of unprecedented uncertainty, this paper presents a critical analysis of one of the themes to emerge out of a phenomenological study in which 48 colleagues from across one of the UK's largest Engineering Education Departments were interviewed about their perceptions of the Department's strategic direction, strengths, challenges and weaknesses. Undertaken with the specific intention of providing a solid basis for the development and launching of an Strategic Organisational Change Strategy, the colloquially termed *Herding Cats Project* follows an Action Research philosophy embedded within 'Positive Organisational Scholarship'.

In critically reflecting upon the early stages of the first part of the Organisational Change Strategy the paper provides an interpretive analysis of one of six themes to emerge out of 48 qualitative, semi-structured interviews conducted with learning and teaching colleagues from a range of engineering programmes and courses. In doing so it deliberately adopts a positive stance, contributing to current debates about managing change in organisations through allowing Engineering Educators individual voices to be heard and reflected on.

The paper concludes by acknowledging that whilst on the whole the idea of "managing change in academia" is often viewed as an oxymoron with analogies such as 'herding cats' used to describe the nature of the challenge, the formation and

launch of a multi-disciplinary Education Innovation Group (EIG), which has a focus on collegial support, scholarship through empirical investigation and implementation of evidence-based practice, innovation and leadership in learning and teaching, means the time is right to begin to effect organisational change. It is an exciting time to be working with WMG. This paper represents the first of what will be a detailed and empirically grounded account of the issues around effecting change within the UK Engineering Education Sector. Without a doubt, such a debate is both timely and much needed!

1. INTRODUCTION

This paper draws upon the emergent findings of one thematic classification resulting from a phenomenological analysis of 48 interviews conducted within one of the UK's largest Engineering & Applied Science Educational Departments. Commencing by providing a short introduction to the organisational context in which the paper is set, the need for Strategic Organisational Change to be implemented is explained. Following this, the methodological approach adopted with this stage of the Harding Cats Project is explained with particular attention paid to the manner in which the data was collected, coded and analysed.

Whilst six distinctive themes have been identified in the first iteration of the analysis, it should be noted that this paper represents a small part of the initial steps taken under the Change Management Strategy. Very much a work in progress, the findings section concentrates on one single theme, that of colleagues perceptions of the positive aspects of learning and teaching within WMG. Whilst the decision to focus on one theme only was deliberate, the fact that the challenges and problems discussed by colleagues are not discussed here is not only reflective of the fact that the work is in its very early stages but also represents a managerial decision to begin the work by concentrating on the 'positives'. This decision was taken in an purposeful attempt to countermand some of the negativity abound in UK Higher Education & Industry at the moment, primarily as a result of Brexit we find ourselves unwittingly drawn into.

2. BACKGROUND

An academic department of the University of Warwick, WMG is located in the heart of the Industrial Midlands in the UK. Founded in the 1980s, up until recently the Department's main focus was cutting edge Engineering & Technical Research conducted in collaboration with numerous industrial and public sector partnerships. Although research was prioritised, shortly after its inception, WMG began educating future Engineering Managers, offering modular part-time Degrees to UK students from the end of the 1980s. This provision expanded in the 1990s to include overseas MSc Programmes although numbers remained relatively low until a few years ago when changes in the way in which Higher Education is funded over the past two decades[2] have resulted in a rapid growth in student enrolments and an unprecedented expansion in the variety of programmes offered.

Now employing over 600 staff, WMG comprises seven research and education centres located on the Warwick Campus in the UK. It also delivers education programmes in seven countries outside of Europe. With a global vision, the Department now has around 1,500 students with 1,200 studying for a full-time MSc on one of 14 different MSc Programmes in Engineering, Applied Science (including ICT focused programmes) Logistics and Innovation Management. In addition to this, WMG also delivers a number of Full and Part Time Undergraduate Engineering Programmes in cooperation with the University's Engineering Department. It also works in partnership with industry to provide a range of Higher Apprenticeships in Engineering, Manufacturing & Health Technology[1].

Whilst indicative of a successful approach to, and excellent reputation in, learning and teaching, the rapid rise in full time student numbers, from around 400 studying a handful of programmes around five years ago to one-thousand two-hundred and forty students studying full-time on the campus has not been without issue. Unprecedented growth has been accompanied by numerous managerial, practical, technical and educational challenges, the full implications of some are only now coming to the fore as the difficulties of balancing quality and quantity are beginning to hit home. Determined not to allow standards to slip and with the intention of redeveloping the Department's pedagogic practices and provision, an empirical approach to Change Management is in its early stages with an Organisational Change Strategy currently in the early stages of implementation.

In an attempt to assure collegiality and staff engagement, the first part of the strategy has been to undertake a cross-Department analysis of colleagues' perceptions of the challenges and strengths of the organisation. Somewhat ironically labelled the 'Herding Cats Study', it is part of the results of this study that form the basis of the paper. Based upon a phenomenological interpretive analysis of 48 interviews conducted over a 10 week period, this paper provides a distinctive critique of colleagues' perceptions of the positive aspects of learning and teaching within the Department.

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2.1 The Role of Pedagogic Research & Organisational Change

The overall strategic aim of the Organisational Change Strategy is to affect a paradigm shift within the Department so that those responsible for delivering learning and teaching are viewed **by themselves and their colleagues**, managers and students as equal in status to those whose focus is research. Whilst notions of the traditional 'Engineering Academic' as being a white, middle-aged, male professor from a privileged middle or upper class background[3] with little or no 'real-life' work or life-experience represents an inaccurate stereotype that does not apply to WMG,

the majority of those who teach within the Department hail from an industrial background. Indeed, WMG is unique in that it's highly qualified and experienced staff bring with them a depth and breadth of real-life, hard-gained work experience. Yet with pay levels in academia being below that of industry and staff-student ratios soaring exponentially over the past few years, morale has dropped and, like much of the UK H.E. Sector, many Engineering Educators in the Department perceive themselves to be under unprecedented stress with rising student demands matched by increased departmental expectations in terms of increased bureaucracy and accountability.
It is within this contested space that this Project is set.

In setting out to tackle head-on cultural changes and unrest linked with rapid growth, the need for strategically planned and delivered organisational change within the Department has come to the fore[4,5,6]. Commencing the process of organisational change, an innovative methodological approach to capturing teachers' perspectives has been developed. Representing the first of the 10 key steps to Successful Organisational Change described by Jick (1993) (to '*Analyse the organisation and its need for change'*[7]) the success of the Herding Cats Project will be dependent on continual, authentic and honest communication between colleagues and management working together to create a shared vision of a better future.

3. METHODOLOGY

With the intention of building a solid foundation for Organisational Change, the paper authors and other colleagues from the Education Innovation Group are working across the Department to put place a number of evidence-based learning and teaching innovations and practices. To gauge the level of need through gaining a first-hand insight into staff perspectives and experiences, 48 semi-structured interviews have been conducted with teaching focused staff. Aimed at capturing colleagues' views of a number of different issues associated with all aspects of learning and teaching, student support, staff training, and organisational management an Action Research 'problem / change' based philosophy[8] has been adopted utilising semi-structured interviews which followed a phenomenological approach.
Rooted in early 20th-century European philosophy a phenomenological approach encourages participants to express themselves through the use of 'thick' description. It involves a detailed analysisof lived experiences, purposefully seeking out individual perceptual embodiment to gain a depth of understanding of a given setting or situation[9,10]. In terms of WMG the approach proved to be ideal as it allows for demographic variables to be set aside to guarantee anonymity of the participants whilst allowing the researcher to gain a deep understanding of the shared lived experiences of colleagues. Exposing embedded assumptions, traditions and practices, the interviews were structured so as to encourage colleagues to open up and speak freely about all aspects of their daily life as a teacher within WMG.

3.1 The Fieldwork

Adopting a purposive sampling approach[11] eighteen senior colleagues were initially interviewed using traditional semi-structured interviews which were recorded contemporaneously before being transcribed and analysed. Based upon three core questions the interviewer encouraged colleagues to explore all aspects of their lived experiences of working within the Department. The three core questions core questions, each of which was supported by a series of prompts and sub-questions, were:

1. **What** part of your own and others' teaching practice do you feel to be of high quality?
2. **Which** aspects of teaching and learning could be improved?
3. **What** practical and pedagogical innovations could be put into place to help you improve your own teaching?

Following the initial interviews, a further thirty colleagues representing, amongst others, junior and senior lecturers, student support officers, project and personal tutors, module and course leaders were interviewed using a purposefully developed approach which, whilst being grounded in phenomenology incorporated phenomenographic visualisation[12,13]. Each colleague was asked to draw a SWOT analysis visualising the Stengths, Weaknesses, Opportunities and Threats they perceived to be relevant to WMG at this time. Drawing upon an approach developed by two of the three researchers[14] in a previous study, the value of asking colleagues to draw visual images was that it immediately placed people at ease. The opportunity to discuss why they had depicted certain images and words within each of the four 'SWOT' allowed the above the three questions to be explored in considerable depth.
The value of using visualised diagrammatic imaging as a methodological tool is that it allows researchers to explore in some depth the main concepts, whilst allowing the participants to express themselves in a creative and imaginative manner. Each diagram was accompanied by a key descriptive words which were then explored using the three interview questions as a framework. As before each interview was recorded contemporaneously and along with the visual images analysed utilising phenomenological techniques.

3.2 Analysis Techniques

Like all interpretive techniques, phenomenological analysis requires an iterative, inductive process whereby the data is decontextualized and re-contextualised[15]. The first stage of the analysis involves 'decontextualization' whereby individual data was separated from its original context and coded into units of meaning. Following this, the recontextualisation of the data involved identifying codes and patterns within the units before reintegrating and organising the findings into thematic classifications. Distilling the data into a set of classifications involved building on the process of systematic coding to allow the important elements of each participants lived experiences of the various day-to-day lived phenomena to be captured and critiqued. Methodically classifying and re-classifying the data into units addressed issues of internal and external validity with, for the third iteration, the three researchers working together to finally agree upon the main emergent themes and meanings[16]

4. EMERGENT FINDINGS

This paper is written at a time when the analysis of data is about a third of the way through. Using the iterative and reiterative processes described above, the second iteration of the data has resulted in six distinctive classifications: Assessment & Feedback: Challenges & Weaknesses: Learning & Teaching Support Needs: Positive Practice: Student Matters: Technology Enhanced Learning.

Thus far one of these themes have been subject to third and fourth iterations allowing for the emergence of distinctive classifications and sub-topics: Positive Practice in Learning & Teaching. This paper focuses on this theme, interpreting and critiquing each theme, classifying the data into groupings which reflect colleagues' lived experiences.

4.1 Colleagues' Perceptions on Positive Practice in Learning & Teaching

4.1.1. Staff skills and experience

Undoubtedly key to the organisation's success, the skills, talents and experiences of teaching colleagues was widely discussed in the interviews with several colleagues pointing to the teaching talents of others:

> *Some of the teaching is brilliant. [ ] Some inspirational teaching where they do simulations. The Management of Change is very good. What she delivers sticks in students' minds. If we could get others to at least be as enthusiastic in their teaching, they don't have to use simulations just find their own way of engaging students.*

> *The depth of experience in the teaching staff is remarkable, nearly all on a second career, few are on a third career. We have some really knowledgeable staff who bring a good deal of industrial experience into what they teach. This gives WMG kudos.*

Many of those interviewed were confident teachers, each expressing high levels of self-awareness regarding what skills, competencies and experiences they themselves brought to the classroom:

> *The one thing I'm good at resource investigation. I have a workload. I like to network. I communicate well with industry and end up with a more experiential set of modules and programmes.*
>
> *My strengths are coming from industry – automotive industry. I'm credible in front of an audience. I teach JLR students and am running a short course at Crewe. My colleagues are stronger in their research and academic literature. I have colleagues who are up to date on the research.*
>
> *People who work in organisations and bring with them real-life experience. I bring in my own experiences and case-study learning and we try to constantly work on the blend between theory and application.*

4.1.2 Pedagogic Practice

As the basis of the primary interview questions, learning and teaching practice was widely discussed throughout the interviews. For some colleagues, certain areas of the Department stood out as being examples of good practice:

> *Some modules are interactive; students need to be encouraged to move and change…. …People learn by doing not listening. The way that e-business is set up – they are a perfect team. They all teach together. They have team teaching and it works really well. Each teacher has different areas of responsibility. Sometimes the modules run simultaneously, but academics don't cause any problems because they control their elective choice.*
>
> *On the teaching side we have several USPs, we do stuff in small classes, which allows good team working and syndicates. The students don't like teaching in big classes*

Whilst 'small group' teaching was almost universally recognised as being one of the positive practices within the Department for some colleagues the positive side of this was that it enable lecturers to build good learning relationships with students:

> *It's pedagogically better to teach in small groups. The fact*

that we rarely have more than 30 students to teach is great for building learning relationships and engaging the students.

The relationship between supervisor and student is a strength
We use people who know what they're talking about

4.1.3. Evidence-Based Learning & Teaching

Across the department the concept of 'evidence-based learning and teaching' was divided into two distinctive and very different groupings; the first of which related to pedagogic research and the use of reflection and reflexivity:

I have done pedagogic research in the past but I don't think I'll have much time to develop this any further.
But a lot of my teaching reflects on my previous pedagogical research

My area of teaching is evidence driven. I look at two bodies of evidence. Student feedback and module reviews, chucking into Nvivo – the other is looking at journeys through the use of Moodle – trying to understand where students go, their journey

The use of such pedagogically driven evidence-based practice was very much a minority pursuit, conversely industrially experienced evidence-based practice proved to be the opposite of this, with the majority of colleagues citing the use of experience and evidence gained in industry as being central to good teaching practice:

WMG needs to use externals, experienced people from industry. To develop materials and deliver lectures

Most of what I do is for part time programmes. The externals bring a lot of experience. My modules have a lot of more external people than others. I get positive feedback from the students about this.

For some colleagues, the notion of involving industrial stakeholders was at the heart of their teaching:

I'm involved in apprenticeships. I'm managing the design… …. A workshop at the beginning, a small set of industrial and academic stakeholders, meant we could deliver

Such stakeholder involvement, with industry at the centre of teaching practice and content was highly regarded amongst all of the interviewees. So much so that 'links and collaborations' with industry represented a distinctive classification of data in itself.

4.2 Links & Collaborations with Industry

From a learning and teaching perspective, the opportunity afforded by close relations with industry meant that lectures were both credible in nature and set against a 'real-life' context making teaching meaningful:

> *On the whole we're quite traditional. We're very reliable. We have credible links into industry which enable us to contextualise what we do very well. We use people from industry a lot to make our teaching meaningful*
>
> *Contacts in industry our one of our greatest strengths. We invite senior guest speakers from industry. All out tutors have a hybrid of academia and industry – this gives them credibility with the students*
>
> *I'm involved heavily with [ ] in the new course development. The way we interact with business and allow business to drive content is positive.*

One of the most striking features of colleagues' reflections on working with industry was the strength of the academic-industrial relationships:

> *It's a true collaboration. Completely embedded. Both [companies]. We meet senior management every two weeks.*
>
> *The course Development is ongoing. They get involved with every module, we look at the business need, and this is shaken down to course level, then expertise, and then to how we deliver.*

For one colleague, the need to maximise the links with industry built within the Department's research centres represented a source of untapped potential which could be used to enhance teaching to a far greater extent:

> *I'm not convinced we're fully optimising value from industry. Whether the relationship between us and WMG in research go beyond the lab and into teaching is something that we*

could build on

This final idea sums up the uniqueness of WMG and in many respects reflects one of the key opportunities expressed across all of the themes, the need to make Scholarship in the Department much more than linking research and teaching through evidence-based teaching practice, but through the development of a new approach to teaching in which industry and academia work as equal partners to educate the engineering talent of the future.

5. SUMMARY DISCUSSION: IMPLICATIONS FOR PRACTICE

Encouraging colleagues to engage in discussion about their teaching is notoriously difficult[17]. Such difficulties are augmented by the fact that in WMG, the majority of teaching staff are engineering and management professionals; mostly from industrial backgrounds where they more used to expressing themselves creatively or practically than in prose or in long reflective conversations. This unique methodological approach has been purposefully constructed so as to encourage colleagues to freely express their successes, triumphs, concerns and challenges in a non-threatening environment. By focusing on the three key interview questions and by encouraging the non-senior staff to express themselves visually before the interview began the interviews have proffered a depth of data.

As previously stated it is important to note that this paper and indeed this work represents a small part of a much larger project which is aimed at promoting and supporting a paradigm shift across all teaching in WMG; a challenge which, at this stage feels analogous to 'Herding Cats!' (Brown & Wareing, 2016). The driving force behind the work is a top level desire to promote high quality evidenced-based teaching whereupon individual teachers will become empowered to be reflective and reflexive practitioners, conducting their own educational research and constantly developing and evolving their own teaching practice.

The focus on the single theme *colleagues' reflections on the positive areas of learning and teaching* provides a distinctive insight into the breadth and depth of the uniqueness of WMG itself. Whilst weaknesses and challenges will be discussed elsewhere, the decision to focus this first academic paper on the positive aspects of working in Engineering Education is not accidental. At a time when the idiosyncrasies and opaqueness of Brexit is causing uncertainty within the UK, impacting business and education alike, it is important to identify, reflect and build upon our strengths. Furthermore, whilst the whole the idea of "managing change in academia" is often viewed as an oxymoron with analogies such as 'herding cats' used to describe the nature of the challenge WMG has taken the bull by the horns by launching a brand new, multi-disciplinary Education Innovation Group (EIG). With a focus placed firmly on collegial support through scholarship, empirical investigation and implementation of evidence-based practice together with an ethos of leading change through innovation in learning and teaching not only means that the time is right to begin to effect such organisational change but that people are in place to support and bolster such change as it occurs.

In conclusion, this is an exciting time to work at WMG, a unique academic-industrial department at the cutting edge of innovation, where teachers bring industrial experience and a genuine enthusiasm for applied learning. By purposefully approaching teaching in a scholarly and critical manner, innovative pedagogies will be developed, tested and disseminated. This paper is the first of many!! Watch this space as the future unfolds…

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Peer learning and concept tests in physics

G. S. Korpås[1]
Department of Physics, Norwegian University of Science and Technology
Trondheim, Norway

M. S. Kahrs
Department of Physics, Norwegian University of Science and Technology
Trondheim, Norway

T. H. Andersen
Department of Physics, Norwegian University of Science and Technology
Trondheim, Norway

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ABSTRACT

The experiences and conceptions about the physical world that students bring into the classroom may support or inhibit them in gaining an understanding congruent with the physical theories. This is relevant for classical mechanics generally, and Newton's laws specifically. Students' preconceptions can therefore represent a threshold for learning.

To address this and get a picture of the students' understanding, they are individually asked to make a drawing of the forces acting on a moving object, provided some initial information. Then, they are given multiple-choice answers based on typical misconceptions. The students choose one of these alternatives by voting with a student-response-system. They also indicate whether they have doubts regarding their answer. After voting, the teacher provides a few comments and gives hints if necessary. The students subsequently discuss the problem in groups, and thereby learn from their peers.

Our results show that even though students indicate few or no doubts regarding their answers to force concept questions, they show signs to hold misconceptions about Newton's laws. Following a group discussion, a second voting in most cases indicates that misinterpretations have been addressed and resolved. In addition to the exercises and the discussion with peers, the students write a short reflection on how the discussion went and how it affected their understanding, in order to utilise the potential of formative assessment.

[1] Corresponding Author
G. S. Korpås
guri.s.korpas@ntnu.no

1 INTRODUCTION

In physics, conceptions from everyday life play a critical role for students' understanding [1]. The experiences and conceptions about the physical world that students bring into the classroom may support or inhibit them in gaining an understanding congruent with the physical theories. This is relevant for classical mechanics generally, and Newton's laws specifically, as Newton's laws are typically applied to situations with which students have extensive experience from everyday life.

In this paper, we present a learning and assessment procedure, in which concept tests are used for identifying and addressing typical misconceptions regarding Newton's laws. Through the students' written reflections, there are indications that this assessment procedure helps to address and resolve their misconceptions.

2 BACKGROUND

Some preconceptions concerning Newton's laws appear to be common among students. One of the most well-known preconceptions implies that in order for an object to maintain a state of motion, there needs to be a force acting on the object in the direction of movement [2]. In an everyday context, this conception makes perfect sense, as friction is ever present. Needless to say, this conception is not congruent with Newton's laws of motion.

In this project, we identified this preconception through a problem (*Fig. 1*) which the students had to solve as part of an in-class mandatory exercise. The problem involved an ice hockey puck which is slid across the ice. The students' task was to identify the forces that were acting on the puck as it slides across the ice, both frictionless and with friction present.

The specific intention with the mandatory exercises is that they should be an incentive towards the students to work evenly on a regular basis. More importantly, the idea is that the students should be able to learn from these exercises, which implies providing the students with information that could further guide them in their learning, i.e., the intention is that these exercises function as formative assessment. Formative assessment, although loosely defined, is an activity characterised by feedback which aims to modify or accelerate learning [3]. Formative assessment can thus be an appropriate way to address students' preconceptions.

A key aspect associated with formative assessment is that the learning activity, and the feedback students receive and provide, should support a mastery goal orientation, which is characterised by students aiming towards learning goals for the sake of learning [4]. In this project, the formative aspect of the mandatory exercises, as well as the feedback that is provided by the teacher, follow the seven principles for good feedback practice developed by Nicol and Macfarlane-Dick [5] (p. 203). Good feedback practice should:

1. Help clarify what good performance is (goals, criteria, expected standards).
2. Facilitate the development of self-assessment (reflection) in learning.

3. Deliver high quality information to students about their learning.
4. Encourage teacher and peer dialogue around learning.
5. Encourage positive motivational beliefs and self-esteem.
6. Provide opportunities to close the gap between current and desired performance.
7. Provide information to teachers that can be used to help shape the teaching.

In order for the teacher to provide accurate and immediate feedback to the students, the students' solutions are gathered by using a student-response-system (SRS). Through the use of SRS, students can also signal whether they have doubts about their solution. Based on the results from the SRS, the teacher decides which problems that need to be addressed, provides the students with some guiding tips, and then instructs them to discuss the problem and possible solutions in small groups. At the end of this discussion, the students are given the chance to give a second response to the problem being discussed. Finally, the teacher makes a summary, providing arguments for both valid and invalid answers. This latter scheme follows the peer instruction method, described by Crouch and Mazur [6].

3 LEARNING ACTIVITIES

To develop the students' understanding of Newtonian mechanics and especially the force concept, lectures and other learning activities address the topic. The learning activities consist of different elements, such as textbook exercises with or without calculations, and practical exercises with a discovery approach.

Once the topic has been thoroughly covered through the structured learning activities, their understanding is addressed through formative assessment. Both discussion and reflection are used as tools, as feedback is a vital part of formative assessment [5]. The aim is that the assessment makes out a learning opportunity, where misconceptions can be addressed and resolved.

3.1 Force concept questions

To address the students' understanding of Newtonian mechanics, they are asked individually to answer the two concept questions shown in *Fig. 1,* where an ice hockey player sends a puck to the right across the ice. The only difference between the two questions is that there is no friction in a), while there is friction in b).

a) An ice hockey player sends a puck to the right across the ice (which has a horizontal surface). First, we assume that there it is no friction between the ice and the puck. Draw a figure, of the puck and all forces acting upon it, after it has been hit.

b) Now assume there are some friction between the puck and the ice. Create a new figure that shows all the forces acting on the puck after the ice hockey player has hit it.

Fig. 1. The two concept questions.

After the students have solved these two concept questions and in addition three calculus-based questions individually, multiple-choice answers are handed out, and the students compare their own answers to the multiple-choice alternatives. The layout of the six alternatives for the two concept questions in focus here, are shown in *Fig. 2*. The alternatives include a various combination of up to four forces acting on the puck, these are the weight (G), the normal force (N), the friction force (R), and a force acting in the direction of movement (F). It is important to include alternative F "None of the previous alternatives are correct" to accommodate other, less known misconceptions among the students.

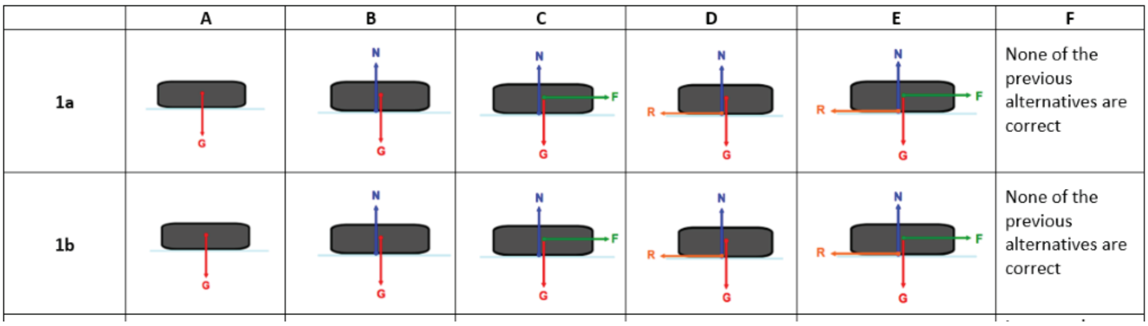

Fig. 2. Multiple-choice answers.

The students answer by using a student-response-system and at the same time signal whether they have doubts regarding their answer. The results of the voting are not revealed to the students at this point. Instead the teacher, based on the results, gives a few comments or even hints if necessary, before the students discuss their solutions in groups. After the discussion, the students are given a second chance to vote. At this point results from both the first and the second round of voting are shown, and it is possible to see how the peer discussion has affected the results.

3.2 Individually written reflection

At the end of the assessment, the students are asked to write an individual reflection. These reflections are handed in as a part of the assignment. According to the seven principles [5] this can help develop self-assessment for the students and it also provides the teacher with information that can be useful shaping further teaching. In the reflection the students comment on how the discussion went and their understanding of the Newtonian mechanics.

4 RESULTS

4.1 Peer discussion increases the number of correct answers

Data is based on assignments from in total 178 students collected from three student groups. The results from the first voting before the discussion and the second voting that is done after the discussion, is compared in *Fig. 3* for both questions.

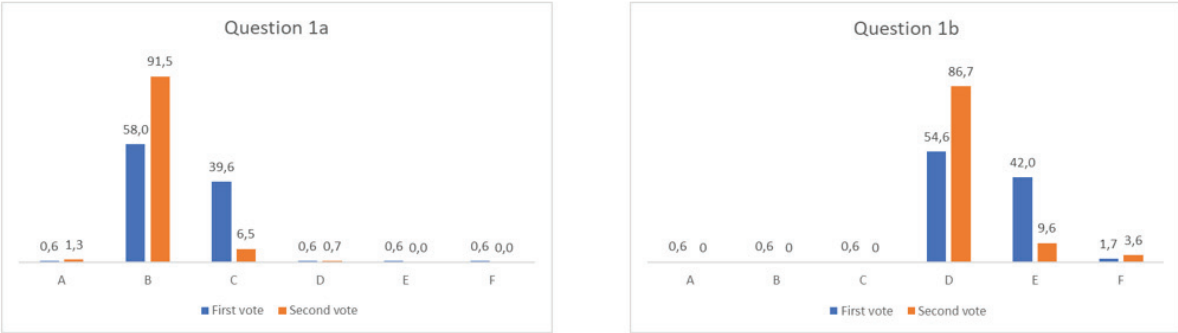

Fig. 3. Percentage distribution from the first and second voting.

The blue columns to the left present the distribution from the first voting, and the orange columns to the right present the distribution after the discussion and the second voting.

The correct answer to question 1a is alternative B. In *Fig. 3* it is seen that more than 40% of the students vote for another alternative. After peer discussion of the problem the second round of voting clearly shows that for most student (91,5%) misinterpretations have been detected and the students choose the correct answer. A similar trend is observed for question 1b, where the obvious answer is D, however alternative F in this case is also considered correct as one may argue that the friction force (R) a should be of a smaller value than the normal force (N) and therefore should be drawn with a significantly shorter length as is the case in alternative D.

For both these concept questions the greatest number of misconceptions deals with the preconception of a force acting on the object in the directions of movement, as described by Gilbert and Watts [2]. As the students vote in the first round only 12% and 13% flag to have doubts regarding their answer to questions 1a and 1b, respectively.

For a comparison, up to 60% have doubts about some of the calculus-based questions also included in the test. This is an interesting result, as most of the students who have misinterpreted the Newtonian mechanics are not aware of it.

4.2 Students' written reflections

The written reflections presented here are written by students which have accepted to share them. The focus is on comments that reveal what happens when students learn. When the students are asked to reflect upon potential misconceptions or misunderstandings, this is what they say:

"But after the discussion in the group I realized I was wrong because this was after the puck had been pushed."

"First, I thought that the questions seemed easy to solve, so when we discussed them in the group and I got several views, I noticed that it is easy to misunderstand the questions. I've learned that I must read the texts more carefully next time, before I start doing the calculations. I also noticed that I misunderstand the use of Newton's laws, today especially Newton's 2nd law."

This indicates that the questions have worked as intended. Another student emphasises the time to make up one's own mind before engaging in a group discussion:

"I think this was very good! The group discussed, and I think I learned even more because I was able to think and calculate by myself first."

Before the students start discussing they are instructed to let everyone in the group explain their way of thinking. Every student has a contribution to the discussion since everyone has spent time trying to solve the questions by themselves:

"I think the group discussions work very well, everyone in the group contributed and we discussed the procedure, which I find very useful."

"Physics is logical, but sometimes it is difficult to understand "all the logic", but it becomes easier when we work in a group. […] Furthermore, I want to improve my critical thinking and to trust myself and the answer I think is correct. There were several times I thought correctly, but because I was uncertain, I answered something else."

This last reflection shows when using multiple-choice answers in a formative assessment practice, the possibility of signalling doubt regarding the answer provides important information to the teacher, which should be taken into consideration before the discussion. Several of the students point out that a vital part of the feedback is to see the overall voting result for all the students, which they thereby can relate to their own performance:

"It is also okay to answer using the student-response-system, since you can see that you are not the only one with the wrong answer, as well as seeing the improvement that has occurred from the first to the second voting."

The multiple-choice feature makes it possible for students who does not have a complete understanding of the solution, to contribute to the group discussion. Some students value being able to discuss both valid and invalid solutions:

"Multiple-choice is very nice since you can come up with an answer without understanding all the parts of the task. And it is very easy to discuss afterwards since we can then discuss not only why something is right, but also why something is <u>not</u> right."

"By discussing with the group, one must argue for one's own way of thinking, which means that one reflects more on what one can / cannot do."

Through the reflections from these two students it is obvious that not only the correct alternative has value but also the incorrect ones. By discussing the alternatives, the students learn from their misunderstandings.

5 DISCUSSION AND SUMMARY

Force concept tests in the form of multiple-choice questions are well known in physics education. When looking at the answers alone, one does not see the whole picture. By adding the information about the students having doubts or not, it is possible for the teacher to get a deeper understanding of the students' misconceptions and

immediately give appropriate feedback. Our results show that even though the students indicate few or no doubts regarding their answers, as much as one third to half of the students have serious misinterpretations in the first round. This shows that the students are not aware of their own misconceptions regarding Newtonian mechanics. The discussion and the second voting are therefore important part of the immediate feedback and helps to address the challenges and help them in their learning process.
Using this method, the students receive feedback in several ways; the results of the voting, the explanation given by peers during the discussion and the summary given by the teacher at the end. In addition, the students write a short reflection on how the discussion went and how it affected their understanding. This gives them insight into their own learning experience and promotes learning.

6 ACKNOWLEDGMENTS

We are thankful to all the students that accepted to let us share their reflections.

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The future of universities in a digitalized world from a STEM students' perspective

T. Kovaleva[1]
Saint Petersburg, Russia
E-mail: tatiana.kovaleva@BEST.eu.org

A. Bosten[1]
Liege, Belgium
E-mail: armin.bosten@ BEST.eu.org

M. Brandão[1]
Aveiro, Portugal
E-mail: maria.brandao@ BEST.eu.org

B.T. Forgacs[1]
Budapest, Hungary
E-mail: boglarka.timea.forgacs@ BEST.eu.org

[1]BEST-Board of European Students of Technology

Conference Key Areas: 4th Industrial Revolution, Integrated learning environments for the digital native learners

Keywords: STEM education, Engineering education, University digitalization, Students' opinion

ABSTRACT

The fast emergence of digital developments during the 4th industrial revolution is accompanied by a strong demand for institutions of higher education to adapt the methods of teaching to the digital world. The purpose of this paper is to investigate the possibilities offered to universities by digitalization, whilst also discussing the potential problems digitalization creates, from the perspective of STEM students. This paper reflects how European STEM students see the future of universities in terms of teaching methods, the use of online content and professors' competencies.

This research is based on the outcomes gathered from European STEM students with different fields and levels of study. The students' opinion was collected through several sessions, with diverse facilitation formats, at BEST Symposia on Education (BSE), organised by the Board of European Students of Technology (BEST).

The analysis demonstrates that digitalization is not only considered an efficient way for diffusing information, but also renders the work of the student more flexible and increases collaboration possibilities among students. A lack of social interaction that could hold back the development of essential social skills has been identified as the principal potential drawback. This paper contributes to the existing knowledge by drawing conclusions based on the opinions of STEM students. Along with complementary work, it could lead the way towards defining practices that maximize the beneficial effects of digitalization on higher engineering education and minimize its downsides.

1 INTRODUCTION

The 4th industrial revolution is introducing overwhelming developments at a fast pace. Artificial Intelligence, Data Analytics, Internet of Things and Robotics are some of the key players in what is described to be one of the biggest revolutions humankind has ever experienced. The implications of such technological developments across several fields, merging barriers between the digital, physical and biological dimensions, influencing society, politics, economy and education [1].

In the process of adapting and preparing current and future generations to this rapidly changing world, education has to be used as a central tool [2]. Science, technology, engineering and mathematics education, frequently referred to as STEM education, is a particularly important area to take into consideration for that regard. It is fundamental to understand what is the crucial set of skills students of these particular fields need to develop in order to successfully face the future challenges. How can universities provide preparation for the emerging revolution, where a few years of technological breakthroughs can represent a complete alteration on the world we face today [3][4]?

In order to understand how to engage with the emerging challenges and needs, it is also important to understand what new opportunities are now available and how to take the most out of them. Digitalization has fundamentally altered information dynamics, as accessing and sharing information has never been so easy. With the increasingly larger number of accessible mobile devices, processing and data storage, distance no longer represents a barrier to knowledge. Universities need to take this into consideration, understanding how to effectively guide students into the changing scenario, while also understanding how they can adapt themselves and harness digitalization in a successful way [5][6][7].

This paper explores the visions of STEM students regarding this matter, through the analysis of reports produced by the Board of European Students of Technology (BEST). BEST is a non-political, non-governmental and non-profit voluntary student association, present in 97 universities, across 34 different countries. Striving to create opportunities for students to develop themselves and grow internationally minded, BEST offers a set of different events that are intended to bring universities, companies and students closer. One of these events is the BEST Symposium on Education (BSE) [8].

2 METHODOLOGY AND MATERIALS

The Educational Involvement Department of BEST aims to gather students' opinions regarding their experience with higher education in order to improve STEM education. With this in mind, BEST organizes BEST Symposia on Education – BSEs (formerly known as Events on Education – EoEs) where students have the opportunity to express their concerns and suggestions on several education-related topics. Each of these events welcomes more than 20 European STEM students from different universities, fields of studies and cultural backgrounds. This diversity ensures a more comprehensive picture of the current situation of engineering education in Europe according to students.

During the week-long events, professors and facilitators from BEST deliver sessions and workshops about different problems based on the theme of the given BSE. Several facilitation formats are used, such as brainstorming, world café, SWOT analysis or group discussion, in order to achieve the desired outcomes of the sessions and engage students to actively participate. Professors, education experts and industry representatives are also invited to deliver sessions or give an introductory presentation on the given topic in order to increase the quality of the content and to bring diverse perspectives to the participants. The outcomes of these events are collected and presented in reports, which are later used for further research and disseminated toward higher education stakeholders.

This paper is based on three BSEs held in Lisbon, Krakow and Aalborg in 2018, which sessions tackled either directly or indirectly the matters of digitalization and online learning, hence providing valuable resources for the analysis of students' perspectives on the paper topic. At BSE Lisbon, 21 students from 17 universities discussed the skills needed in Industry 4.0 as one of the focus points of the six working days [9]. During BSE Krakow, 21 engineering students from 18 universities gathered for 7 working days to provide input on the topics "Internationalization of Education in Europe", "Online Learning" and "Future Universities" [10]. BSE Aalborg received input from 24 students from 19 universities on the topics of "Future of Project Based Learning" and "Continuous Learning and Valuable Working – Employability". This event hosted the session "How will digitalization shape the future (Global and Collaborative) university" facilitated by an Associate Professor of Aalborg University [11].

The data presented in the next sections is collected from participants with different methodology. The most common type was group discussion, where students were divided into four to six groups, either clustered randomly and equally or according to similar field of study. Besides, answers from open questions and on-site questionnaires were also analyzed.

3 ADAPTATIONS OF YOUNG GRADUATES TO DIGITALIZATION: SKILLS NEEDED IN INDUSTRY 4.0

Industry 4.0 is a name given to the current trend of automation and data exchange in manufacturing technologies. It is commonly referred to as the fourth industrial revolution. Along with the changes in the industry, education has to be adapted in order to fulfil the needs of the future market. At BSE Lisbon 2018, students' opinions on which skills are most needed in the Industry 4.0 were gathered, and it was compared to what they are learning in their current curricula [9].

Firstly, participants were asked what kind of skills they think they will need in Industry 4.0. They were not given specific options when answering. All of the 21 participants agreed that a good knowledge of the English language and operating systems, being able to write reports, as well as the efficient use of email are important skills to master. Moreover, all of them stated that mathematics, multidisciplinarity and programming play an important role.

Students were asked if they have a possibility to gain hard skills, defined as abilities that are acquired and enhanced through practice relevant for Industry 4.0 in their curriculum. 85,7% of students gave a positive answer, 9.5% replied that they are not sure, and 4.8% argues that their university curriculum does not provide possibilities to gain hard skills which are relevant for Industry 4.0.

When asked if there is a sufficient amount of time dedicated to the acquisition of these skills in their curricula, 52% of them gave a positive answer. Results are shown in *Fig. 1.*

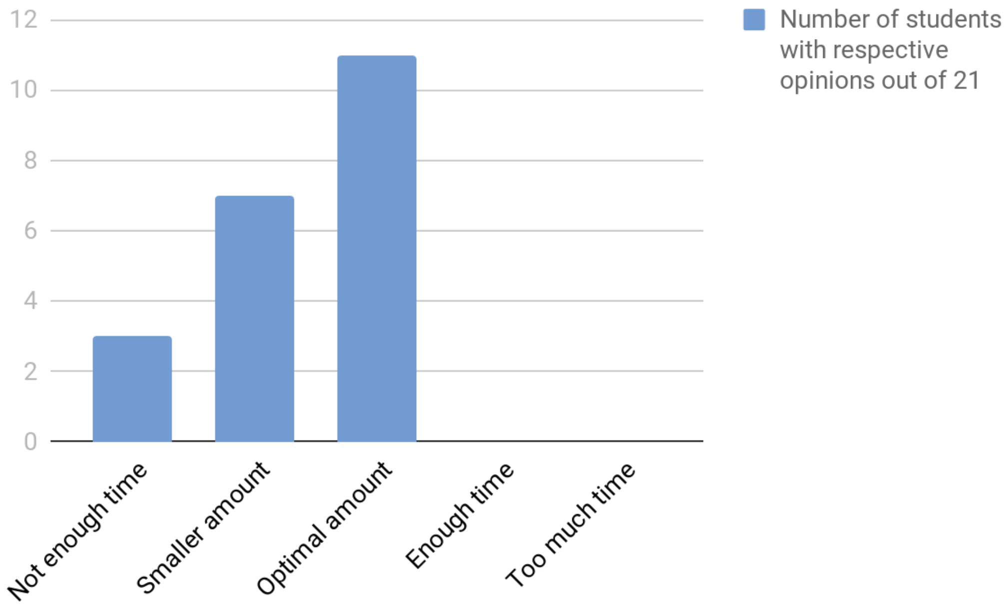

Fig. 1. Students' opinions on the currently allocated time for developing skills relevant for Industry 4.0 in their university curriculum

Finally, students were asked if they can acquire specific hard skills relevant for Industry 4.0, out of a given list, in their university curriculum and if not, how they acquire them instead. Results are given in *Fig. 2.* and *Fig. 3.*

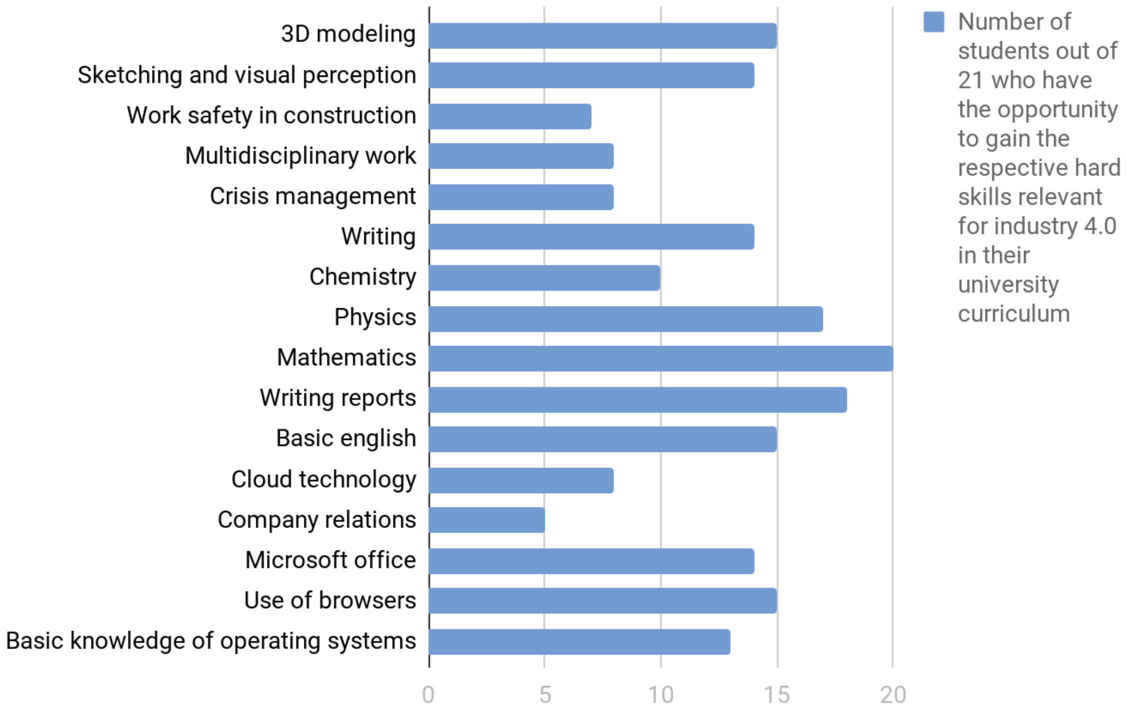

Fig. 2. Hard skills relevant for Industry 4.0 which students can gain in their university curriculum

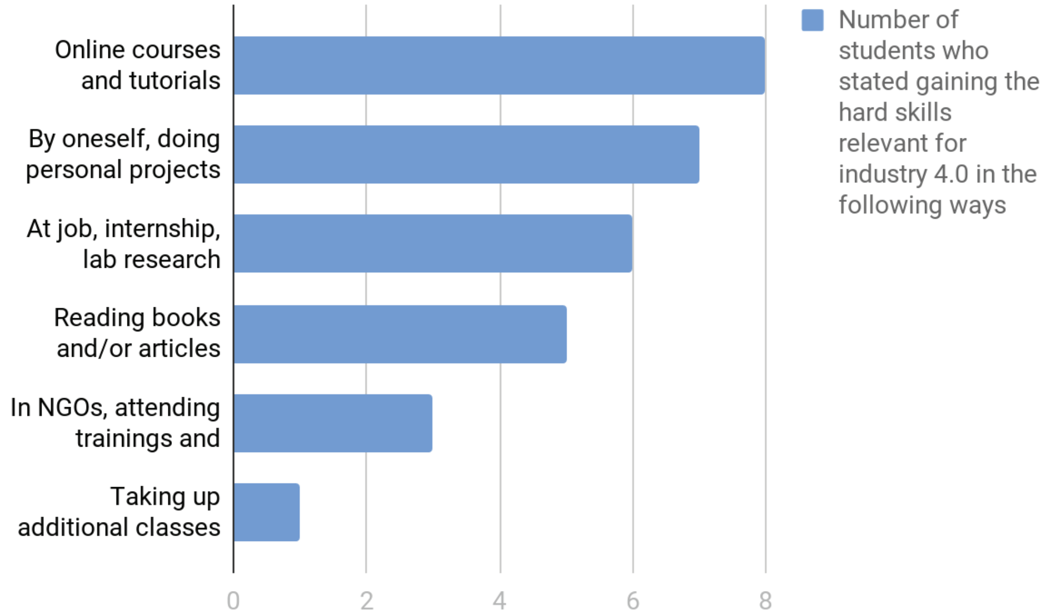

Fig. 3. Ways in which students gain or have gained hard skills relevant for Industry 4.0 outside of curricula

Results show that some students feel that university programs are not up to date with the current business needs and trends. Moreover, some state a lack of multidisciplinarity and contact with companies. Therefore, students often resort to online courses or materials to complete their education and gain new skills. In this regard, students' opinion on the matter of adaptation of teaching methods to the universities' digitalization should be studied.

4 ADAPTATION OF TEACHING METHODS TO THE UNIVERSITIES' DIGITALIZATION

4.1 Flexibility of study programs

Most of the universities nowadays offer a specific study program for each speciality that usually doesn't change for years. At the same time, the world is changing rapidly. Specialists required today need to be not only good in their field of study, but also flexible enough to foresee and adapt to the innovations and current trends.

At BSE Krakow 2018 [10], students were asked the question "In your university, can you select subjects you want to pick up?". Most of the students gave a positive answer, though some of them mentioned that the own selection of subjects is possible only in Master's programs or particular universities. The next question was, "Does the university offer enough options to choose from?". Only 38,5% of students replied that they are satisfied with the provided options for classes while 61,5% would like to have a bigger variety. Some students pointed out that the variety of subjects to choose from might depend on a study program.

In the students' opinion, the main advantage of having a choice in subjects in curricula is an increase in the motivation in learning. The current situation can be improved with the influence of business in the academic field, experts' opinion on the matter can be addressed to encourage universities. Students suggested that the experts from companies can be involved in creating curricula and deliver courses that are relevant for the market needs, which leads to increasing the demand for university graduates, and directly makes the university itself more prestigious. Another solution is online courses provided by academic and business experts [10]. This is also a point where digitalization can be very a significant benefit.

4.2 The development of online learning

Online classes are direct results of digitalization. Their accessibility made them popular all around the world. At the same time, online courses cannot replace traditional classes. At BSE Krakow 2018 [10], students were asked what key factors make an online course successful. The results of the survey are shown in *Fig. 4.* The students' replies are presented on the horizontal axis, the percentage of people who agreed with the idea is on the vertical axis.

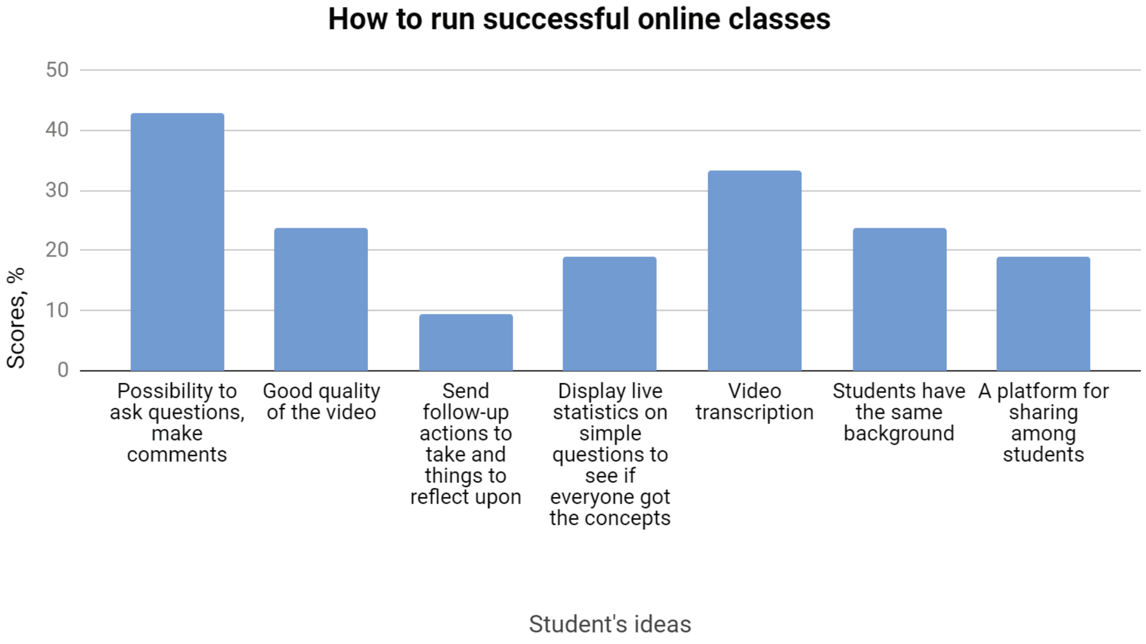

Fig. 4. Students' answers on the key factors of successful online classes

In the students' opinion, the most important factors to make an online course successful are:

- possibility to ask questions, make comments, speak up
- video transcription
- ensure that all students have the same background
- good quality of the video

Along with the development of technologies, online classes will probably transform. In *Fig. 5.* the brainstorm on the idea of online learning transformation is shown. The students' ideas are presented on the vertical axis, the percentage of people who agreed with the idea is on the horizontal axis. The ideas that received the highest support are: the development of laboratories through virtual reality and a 3D holographic professor.

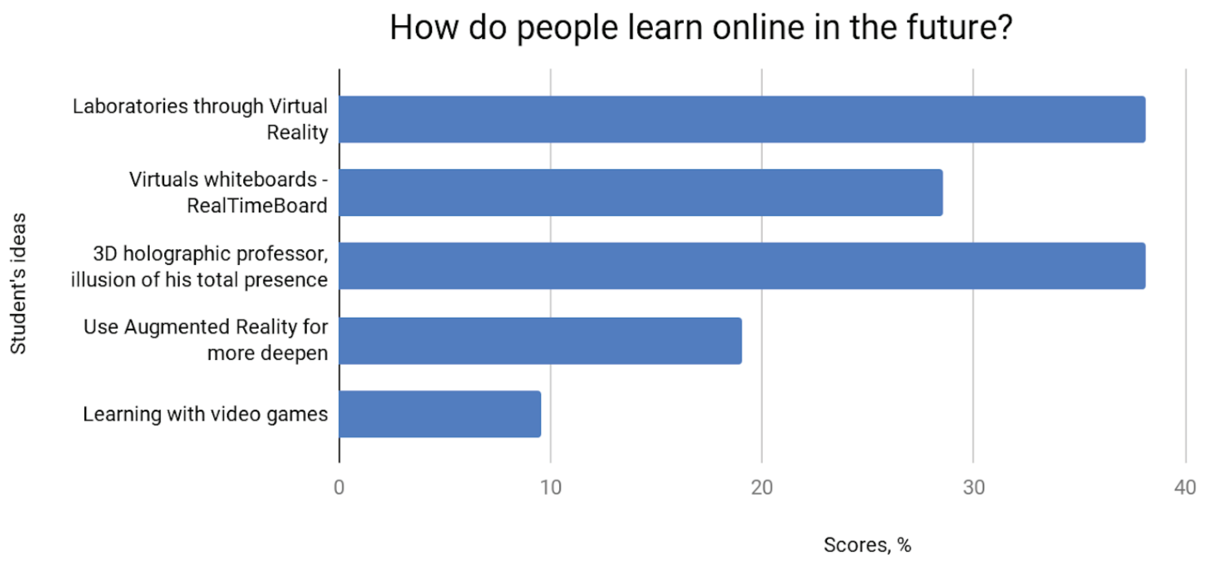

Fig. 5. Students' ideas on the online learning transformation

All participants agreed that online learning can be the future of learning if the balance between online tools and social interaction is established.

5 THE WAY DIGITALIZATION WILL INFLUENCE THE FUTURE OF UNIVERSITIES

Independently of the other two BSEs, the session held at BSE Aalborg 2018 [11] corroborates the rationale of the abovementioned new skills, flexible study programs and online classes since students stated these as a consequence of digitalization. Students were divided into six different groups, were asked three questions and were given time to discuss them.

The first question was "What opportunities do you see in further digitalization of education?". Five out of the six groups mentioned that the possibility to create online content through digital means increases the flexibility of studying and renders access to information easier, not only for students of the university, but also others not studying at university. Furthermore, three groups explained that online education is cheaper than going to university, thereby giving access to high-quality material to a broader audience. Finally, half of the groups mentioned the possibility to adapt the lecture materials to each student and make it more interesting than traditional ex-cathedra lectures.

The second question was "What disadvantages do you see in the digitalization of education?" The main concern expressed by every group was the lack of socialization of students that follow all their courses through their computer. According to them, the students' dependence on their digital devices is likely to increase, which could have negative repercussions on health as well as their learning experience. Indeed, a student might not see the reason to be physically present at university if he can benefit from the same information online, thereby missing out on all the social interactions and group dynamics university has to offer. Four groups mentioned a large amount of time and resources needed to adapt and maintain the infrastructure for the new technologies. Some also warned about possible misuses and the possibility of hacking.

The final question posed to the students was "What actions should universities take to realise the opportunities while minimizing disadvantages and risks, and what roles do students have?". All groups agreed that universities should keep in mind that technology is an addition to the current state of higher education, but it should not be a goal itself. Therefore, students suggested mixing digital content and traditional ex-cathedra classes as a possible way of approaching teaching in universities in the future. Furthermore, the idea of a trial period was mentioned, in order to verify if the proposed changes are efficient and students react positively, by giving them the possibility to give feedback.

6 CONCLUSION

The fast pace of technological breakthroughs and their evolution, constantly require students to develop flexible skills that allow them to adapt to the new working methods. In the perspective of STEM students, curricula development has to be balanced between hard skills, required to understand and keep up with the fast development of technology, and soft skills that allow students to learn how to adapt to changing market needs and opportunities.

Students believe that universities need to incorporate digitalization into their educational system. However, concerns are raised regarding possible repercussions on the social aspects of the learning process. Universities are not only the place to learn hard skills, they also play an important role in the self-development path of an individual. Full digitalization can have a strong impact on social interaction, group dynamics, and soft skill development. To prevent this scenario, digitalization should be used as a tool to complement and facilitate education, instead of a complete substitute for traditional teaching methods.

Along with complementary work, this paper could lead the way towards defining practices that maximize the beneficial effects of digitalization on higher engineering education and minimize its downsides. In addition, future BSEs can be the platforms to further investigate the STEM students' point of view on the effects of digitalization, taking into consideration the results of this paper.

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Rediscovering Visualization –

Towards an up-to-date conceptual framework for promoting learning of Mathematics in engineering education

Nárcisz Kulcsár[1]
Széchenyi István University
Győr, Hungary

Éva Feketéné Szakos[2]
Budapest University of Technology and Economics
Budapest, Hungary

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Keywords: visualization, higher mathematics, textbook, curriculum, adult learning

ABSTRACT

Students in engineering education need tools to gain insight into the ever-increasing complexity of engineering problems and possible solutions in the 21st century (e.g. seeking the reasons for the recent bridge-collapse in Genova). One of these tools could be the utilization of mathematical knowledge and skills – but many engineering students are undermotivated in studying mathematics.

Not only Comenius but our digital age also prefers visualization over textual comprehension, as the Net generation is visually literate. Newer interdisciplinary research findings in brain functions and brain maturation are worth to be integrated into the pedagogy of teaching mathematics to engineers.

Methodologically, in order to improve the quality of teaching Mathematics in engineering education at a Hungarian university, both findings in brain-research as well as theories of adult learning have been analysed from the perspective of visualization. The other direction of the work was focused on different types of visualization in Mathematics (according to Guzman), particularly in textbooks for engineering students. Ten textbooks, (among them the newly developed „Mathematics 1" at the Széchenyi István University), available both in print and online in Hungary have been compared from visual aspects. The current Curriculum of the subject „Mathematics 1" has also been analyzed from visual aspects. Findings show the need for a wider variety of visualization.

Systematically detailing all of the above-mentioned perspectives and findings of data-processing contribute to developing an up-to-date conceptual framework for improving the quality of teaching Mathematics in engineering education at a Hungarian university, and it might be useful for other universities as well.

[1] Nárcisz Kulcsár, kulcsar.narcisz@math.sze.hu
[2] Éva Feketéné Szakos, fekete.e@eik.bme.hu

1 INTRODUCTION

Experts of many engineering disciplines were shocked by the news on the recent bridge-collapse in Genova. A highly unlikely interrelationship of very complex ageing processes in an artificial, human creation – a large scale mechanical structure – along with rare weather circumstances (processes of nature) led to the appalling catastrophe. It was a real challenge for engineers to find the reasons for that surprising event, and to elaborate solutions to avoid similar crashes in the future.

It would be impossible to gain insight into the ever-increasing complexity of engineering problems and possible solutions in the 21st century without utilizing the tools of Mathematics. This paper wishes to contribute to the development of the quality of teaching Mathematics in engineering education by shedding light on the ever-growing importance of visualization in our digital age.

2 CONTEXT OF THE PROBLEM AND AIMS OF THE ANALYSIS

According to the predictions of the World Economic Forum (2019) [1], *Complex Problem Solving, Critical Thinking and Creativity* are leading the list of *Top 10 Skills*, needed by the workforce on the labour market in the future. New elements among the Top 10 Skills are *Emotional Intelligence* and *Cognitive Flexibility*. Mathematics is one of the subjects of engineering education, which offers an opportunity for developing all of the above-mentioned skills. However, teaching methods and the context of the tasks need to be revised and updated continuously. It is expected by society that the theoretical knowledge along with the practical skills of engineers should be adaptable and still produce high quality solutions in different context as well (see United Nations' Sustainable Development Goals, 2015) [2]. That is why engineering education itself needs to reflect these expectations and teach global and adaptable guidelines.

In spite of these ideal goals, many engineering students are unsuccessful and undermotivated in mathematics, do not pass the exam in Mathematics and it is a dreaded or dull subject for them. That is why we decided to take steps in order to reduce the proportion of these students in engineering education.

The Net generation prefers visualization over textual comprehension [3], so our work targeted to analyse the inner nature of learning and motivation of engineering students on the basis of adult learning theories and findings of brain research from the perspective of visualization. Our other goal was to investigate whether the learning materials available in Hungary for the students along with the Curriculum of the subject *Mathematics 1* take the specialities of visual learning into consideration.

3 THEORETICAL BACKGROUND

3.1 Adult learning

According to Dewey's classical learning theory, learning takes place when one is doubtful about how to go on, how to act in the future [4]. That disorienting dilemma, or disjuncture is well-known at the beginning of solving a mathematical problem, and appear as a starting point in the theories of Jack Mezirow [5] and Peter Jarvis [6] as well. Mezirow thinks that to be able to understand and solve the problem (e.g. a mathematical problem), a *transformation* in the adult's personality is necessary. The basis of the positive progress of a person is the development of a critical change of perspective. This process can be assisted through social interactions, by learning from each other, - and by visualization.

Both of the transformative learning theories of Mezirow and Peter Jarvis's concept lie on a *constructivist* basis [7,8]. The aim of constructivistic teaching is to widen the repertory of possibilities in thinking and acting. Learning is not determined by teaching, but rather by the cognitional and emotional structures of the learner's mind. These structures are connected to biographical experiences, in the particular case of Mathematics they may be linked to preconceptions (prejudices) about the subject's learnability and to previous experiences in learning it.

Jarvis uses the term "Life-world" defined by the German Horst Siebert as a construction or a meaning schema which "is built up of our knowledge, beliefs, interpretation patterns, permanent themes and includes our action plans, … and our forgotten or repressed contents of conscience" [9]. We think that these contents are visualized constructions. The sustainability or unsustainability of a construction depends on its viability (in constructivist terms). From the student's perspective, a new knowledge is viable if it suits him/her and helps him/her achieve his/her goals. That is why it is crucial to make the goal of studying mathematics for the engineering students clear. The viability of a construction may cease in time. For instance, a construction of solving a mathematical problem may become destructive, meaning that it does not help to pass the exam, and as a result, it has to be reconstructed.

Informing or communicating in a learning community on mathematical problems means offering an opportunity for the participants to make connections (that is compatibility) between different constructions on solving a problem. In other words: offering the opportunity for them to build more structured, more complex and better informed „mind maps" than they had before. With the broadening of metacognitive (reflective) knowledge [10], the necessity of conceptual change may become more apparent. Metacognition supports and makes self-directed learning easier, which is the precondition of lifelong learning.

Similarly to Mezirow, Jarvis also emphasises the transformative characteristics of learning, particularly the transformation of people through new experiences. How people interpret their experiences (see social constructivism) depends on the social and cultural context as well [11]. Perception and the physical, biological processes are significant in learning. That means that the perceptions of figures and an inner visualization of the problem may help or hinder the learning process. According to Jarvis, the essence of learning is that the initial feeling of absence or confusion transforms into knowledge, competence, attitude, value, emotion, etc. This transformation can occur by thinking, by taking actions, in an emotional way or in any combination of all three of these. Emotions have a significant effect on our way of thinking, motivations, attitudes and values as well. As in the course of learning meaning schemas are being transformed, in this case the visualization of meaning schemas can support the process of transformation. Different types of visualization can approach challenging problems and/or solutions in new ways.

Comenius was the first in the history of didactics, who highlighted the role of sensation in learning and teaching in his Didactica Magna published in 1657, and in his illustrated textbook Orbis Pictus (1658). Our digital age [12] also prefers visualization, as the Net generation is visually literate. Many youngsters use the internet and their mobile-phone to seek challenging visual experience instead of reading texts [13].

Newer investigations in the motivational profiles of adult learners [14] show that some of the adults with lower levels of academic self-concept and lower use of deep-learning strategies, (who would also supposedly have difficulties in learning mathematics,) might have experienced academic failure(s) with negative images in their life history.

Brain researches pay attention to a special process in the brain called myelination which starts before birth but ends until late adolescence. In this process myelin sheath is not fully formed until around ages 24-26 which causes that adolescence and young adults learn differently. Consequently in these ages visual representations can contribute to a wider and deeper understanding [15].

3.2 Typology and other approaches of visualization in mathematics

Miguel de Guzman, a Spanish mathematician created a typology for visualization in Mathematics. His typology contains 4 different types of visualization based on a certain level of abstraction, more precisely the strength of the relation between the object and its visual mapping. We have to keep in mind that he does not use this typology in a clear way all the time: many visuals cannot be put into only one category or even not into any of them [16].

In Mathematics, two structures are isomorphic if there is an isomorphism from one to the other - which means that they are elementarily equivalent. Although the two structures look different, their elements are basically the same, while they have different names. So in *isomorphic visualization* a strong relationship can be found between the visual elements and the initial Math problem. That is why this category is the most frequently used in education. On the other hand it requires a specific sign system (which can depend on traditions, cultures, ages, …) which is known by users. (*Fig.1.)*

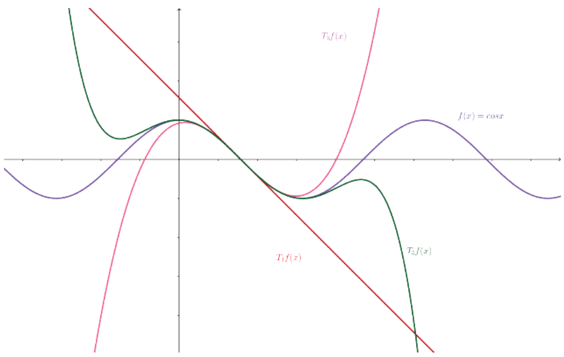

Fig. 1. Example for isomorphic visualization (Taylor polynomial)

When we look at two homeomorphic structures, the bases of the structures look similar, but the elements and operations are presented in a different form. In *homeomorphic visualization* the focus is on relationships: abstract objects can be depicted this way in order to have guesses or lead to proofs. Here, one cannot a find direct relation between the content and the visual presentation. That is why sometimes it is not easy to understand this structures, as it can often be subjective. (*Fig.2.)*

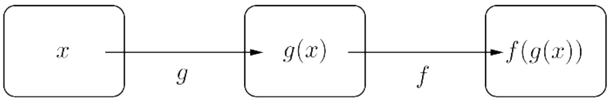

Fig. 2. Example for homeomorphic visualization (composite function)

The visualization which needs the most advanced understanding of abstraction is *analogical visualization*. In this case we swap the object mentally with another object that relates in an analogous way in order to work with it in an easier way. Nowadays this kind of visualization is rather rare, but Archimedes used it as an effective discovery method. (*Fig.3.)*

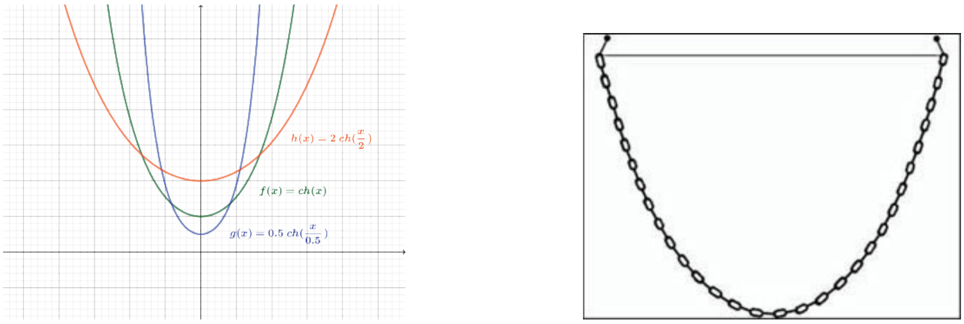

Fig. 3. Example for analogical visualization (catenary curve)

In the fourth category, diagrams are used to represent the relationship between mental objects. *Diagrammatic visualization* is frequently used in number theory and in probability. (*Fig.4.)*

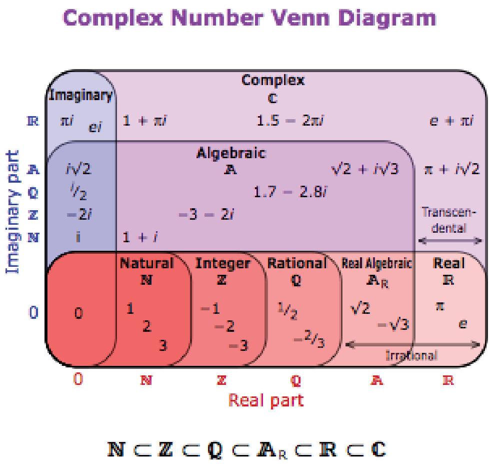

Fig. 4. Example for diagrammatic visualization (set of numbers)

Weinbrenner provided a complex model for textbook researches: he distinguished three categories: process-oriented (how a textbook is realized), product-oriented and impact-oriented (meaning what kind of effect a textbook has on culture, society, social norms). Here we focus on product-oriented textbook research in which textbooks appear not as a product on the textbook market but as a tool in education and visual communication. Comparative analysis can be performed in 4 dimensions: dimension of science theory, dimension of scientific disciplines, dimension of didactics and dimension of education. [17] Based on textbook researches, several didactical standards can be specified. Without completeness, textbooks should call for problem solving, call for action, fit to the psychical nature of students, be lifelike, and contain various kinds of methods. To continue the list we have to pay attention to the changed visual culture of students. Some recommendations for visual contents are listed by Dárdai [18]: the preferred ratio between visual and textual parts should be between 30-50%. At first this ratio may appear high but when we consider our digital age, visuals dominate in every aspect of our life.

3.3 Mathematics curriculum from visual aspects

The European Society for Engineering Education (SEFI) published A Framework for Mathematics Curricula in Engineering Education which aims to provide guidelines for universities and educators in the topic of general mathematical competencies for engineers, content-related competencies, knowledge and skills, teaching and learning environments, and assessment [19].

The document of SEFI highlights two main areas where visualization can appear effectively. Among 8 general mathematical competencies which are essential for engineers we can find the following competencies: representing mathematical entities, making use of aids and tools. Since mathematical entities can be represented in several ways (numerical, symbolic, visual, graphical, verbal, material objects), it is crucial to know their relationships and to be able to switch between them. Hence, a visual and graphical representation can depict phenomena from different aspects but it is worth to be aware of its limitations as well. On the other hand visual aids and tools can contribute to a deeper understanding of a complex concept or processes if the teacher utilizes their potentials.

Generally, visuals are created to explore, present relationships, data, results of some experiments, show statistics, but contrarily they can explain different processes and concepts as well. The former can appear in presentations, while the latter reinforces explanatory visualization. The method of presentation is more frequent in everyday life. Sometimes the difference between them is very slight. However the main aim of explanatory visualization is to educate, to enhance understanding. It focuses on theory and processes, the connection to other principles and interactivity is its own [20].

4 THE METHODOLOGY OF ANALYZING VISUAL ASPECTS IN MATHEMATICS TEXTBOOKS AND IN A CURRICULUM OF MATHEMATICS 1

Based on Guzman's typology and Dárdai's recommendations we investigated 10 textbooks [21-30] which were written for engineering students in higher education. The chosen books were written by Hungarian authors for Hungarian students. The subject of each book was Calculus which is a basic subject for each engineering student in the Bachelor level. Engineering Mathematics education has not changed in the past decades dramatically: the basics of the content in calculus remained the same, so it was suitable to analyse from a visual aspect. Older and newer textbooks were involved in our investigation in order to recognize some changes in visual representations. The newest book was written at Széchenyi István University after a curriculum development. With the exception of two textbooks - which are available online - they all have been printed versions. We used both qualitative and quantitative methods as well to recognize the nature of visualization.

Based on the framework of SEFI, on local needs (what does other teachers teach in other engineering subjects, time limit) and on learning outcomes theory we prepared new curricula in mathematics. We chose our new curriculum in Mathematics 1 for the investigation, which is taught in the first semester for all engineer students (vehicle-, logistic-, civil-, infrastructural-, computer science-, mechanical, electrical engineers, technical manager, architect) with the same learning outcomes.

5 FINDINGS ON VISUAL ASPECTS IN MATHEMATICS TEXTBOOKS

Firstly, we investigated the number of visual elements in the books which shows a very low number of explanatory visuals. Except two books, less than every second page contains a picture, the textual parts dominates on the pages. This finding does not satisfy the Dárdai's proposed minimum ratio which means there is a huge lack of pictures. In some ways it is astonishing because calculus can be visualized very easily through functions in contrast with other more abstract topics. Textbooks can be divided into three category based on content. In the first category textbooks contain theoretical background of the topic with some examples which are solved [23, 25]. In the next category books contain only examples for individual practice [26, 29] and in the last category books contain theory, solved examples and examples for individual work as well [22, 24, 27, 28, 30]. This was important to mention in this context because there is a big difference between these categories in visualization. Those books which list only examples for individual work they almost do not contain visuals at all. In these books there were only few examples which required visuals to solve the problems, and there was any examples which presented a picture that students have to analyse in some way. In the other two categories books used more times pictures to illustrate the solution process or the solution. Only one book [30] uses pictures in that way students have to interpret, analyse or read some information from it. This leads to the conclusion that images are used to explain the meaning of a theory, or to visualize the solution of an example but students are not taught in the investigated textbooks how to interpret an image which would presume a deeper understanding from them.

Secondly, images investigated by Guzman's typology do not show a wide range of variety in visualization. We could find schemas how they visualize a content, theorem. As Guzman mentioned, the most frequently used type of visualization is isomorphic visualization in which there is a strong relation between the math content and image. That is the reason it can be understood easily in most cases. Then homeomorphic visualization was the second most common, while we could find two examples for diagrammatic visualization and only one for analogical visualization. In addition to mathematical tasks, each book has engineering-related tasks as well. These technical tasks often use figures to illustrate physical changes. E.g. work, power, torque, magnetic field, electrical consumer, movement, spreading of sound, light can be presented mostly in homeomorphic way which need more abstract thinking skill. *Table 1.* lists which content was visualized with which type of visualization.

Table 1. Content and the connected type of visualization

Type of visualization	Content
Isomorphic visualization	Graph of a function, function transformations, inverse function, monotonicity, local extrema, convexity of a function, inflection point, limit of a sequence, meaning of index n_0, limit of a function, prove a notable function limit, tangent line, secant line, meaning of derivative, definition of continuous function, intermediate value theorem, approximation with Taylor polynomial, Rolle's theorem, geometrical examples to find local extrema, definite integral as the limit of a sum, area under a curve, area between two curves, volume of revolution, technical problems
Homeomorphic visualization	Domain, range of a function, how to create a composite function, an inverse function, approximation with iteration, technical problems
Analogical visualization	Work as area under a curve
Diagrammatic visualization	Venn diagram of composite function, diagram of continuity, differentiability, integrability and boundedness

We conclude these findings jointly with the findings of the Curriculum analyses at the end of this paper.

6 FINDINGS OF A CURRICULUM DEVELOPMENT FROM VISUAL ASPECTS

In the subject Mathematics 1, main topics are calculus and coordinate geometry. Some topics are more abstract than others but these topics can be easily visualized. In *Table 1.* we highlighted that part of the curriculum which details the acquired knowledge and skills during the subject. We made some visual suggestions connected to the listed knowledge and skill elements and specified those visual representations which can be supported by presentation or explanatory visualization. If we base the mathematical knowledge from different aspects at the beginning well, it is easier to build on it later. Visual aids can contribute to deeper comprehension that is why we must not forget the potential of visualization.

Table 1. Learning outcomes with the connected visual representations

Knowledge	**Skills**	**Presentation (P) or explanatory visualization (EV)**
As a result of learning this subject the student should …	**As a result of learning this subject the student should be able to …**	
know the concept of spatial vector, operations with vectors (addition, subtraction, multiplication with scalar), product of vectors (dot product, cross product, triple scalar product) and their properties	solve tasks related to analytic geometry	discover the relationship between spatial element with the help of some sketches (P, EV)
know the equation of line in space and equation of plane		
know the interrelationship of spatial elements, the methods of calculating the intersections of spatial elements		

know the calculation of distance between spatial elements		
know the calculation of angle enclosed by spatial elements		
know the theory of complex numbers, the rectangular and polar form of them	convert between different forms of complex numbers	complex numbers among set of numbers (P) sketch complex numbers in complex plane (P)
know the operations with complex numbers and their properties	calculate the roots of real and complex polynomial solves different types of equations among complex numbers	sketch the meaning of different operations with complex numbers in the complex plane (EV)
know the real univariate functions and their properties	determine the composition and inverse of real univariate functions	sketch the graph of functions (P)
know the concept of composite functions and inverse of real univariate functions, inverse of elementary functions		sketch the inverse function from the original function (reflect over the y=x axis) (P, EV)
know the graph, domain and range of real univariate functions	determine the domain of real univariate functions, determines the range of a function from its graph	determine the domain and range of functions from their graphs (P)
know linear transformations and their effect on the graph of real univariate functions	sketch functions by linear transformations	understand how linear transformation alter the graph of function (P)
know the concept and characteristics of limit of sequences, the limits of the notable sequences, the critical limits, and the concept of index n_0	calculate the limit of sequences, examines convergence, divergence	explain the visual representation of limit (EV) and the concept of index n_0 (EV)
know the concept, properties and meaning of limit of real univariate function	calculate analytically or read from the graph the limit of real univariate functions	present the illustrative meaning of limit of functions, meaning of convergence, divergence (P, EV) prove notable special limits through geometry (EV)
know the concept, properties and meaning of continuity of real univariate function	analyse continuity of functions	present the illustrative meaning of continuity of functions (P)
know the basic concepts of differential calculus and differentiation rules , derivatives of elementary functions	calculate the derivative of a function, the higher derivatives of a differentiable function	explain the derivative of a function as the instantaneous rate of change (EV)
know the geometric meaning of derivative of univariate real functions, the equation of tangent line	write the tangent line to a given function	explain the connection between secant, tangent line and derivatives (EV) draw the tangent line to a function (P)
know Taylor Polynomial and Maclaurin Polynomial	approximate differentiable functions with the help of Taylor Polynomial and Maclaurin Polynomial	present the graphical approximation with Taylor- and Maclaurin Polynomial (P)
know the L'Hospital rule	apply the L'Hospital rule when calculating limit values	
know the concept of monotony, local and global extremes and relationship with the first-order derivative	apply differential calculus to determine the shape of a function and local extreme values	draw the function based on the calculated properties (P)

know the concept of convexity, inflection point and its relation to the second derivative	apply differential calculus to determine convexity and inflection points	
know the following concepts: parity, zero, intercepts, monotony, convexity, asymptote	examine functions from different aspects in order to graph the function finally	
know Riemann integral, the meaning of definite and indefinite integral, fundamental theorem of calculus	calculate definite and indefinite integral of integrable functions	explain the idea of a definite integral as the limit of a sum (EV)
know the most important methods in integration		
know the most important geometric applications of integration (area, volume of revolution)	use integration in vocational subjects to determine areas, volumes and center of gravity	draw the calculated area (P) explain the calculation of volume with the method of cylindrical shells (EV)

7 CONCLUSIONS AND FUTURE PERSPECTIVES

In our visualized, digital age the Mathematics teaching needs to be innovated. With analysing the relevant and fresh interdisciplinary literature (including adult learning theories, findings in brain research, visualization and new guidelines for curriculum development of SEFI) we conclude that according to our described conceptual framework, a research-based implementation of as many types of visualization as possible in teaching Mathematics in engineering education would reduce the proportion of unmotivated and unsuccessful students in Maths. Visual aids can offer extra help in understanding especially for visual type of learners. The current generation is visually literate so visualization can contribute to a deeper and better comprehension in mathematics for them. Moreover, our approach can provide extra motivation for engineers because later in real life visual communication skills can support communication with specialists from other fields as well.

We can create a new term of "visualization-diversity" expressing focuses on visualization-oriented, revised and innovated textbooks and curricula (including visual, auditive and animated digital learning materials with all 4 types of visualization of Guzman typology), utilising videos on tablets, smart-phones and other devices which are available for the engineering students. Nowadays mathematics software programs make visualization easier but so far we have not used of their full potential in education. A further opportunity for smart learning could be along with self-directed learning the collaborative learning of virtual communities if students (and teachers) are involved in creating and discussing new learning materials to support the learning of all participants.

The above-mentioned perspectives and the detailed findings of this work can contribute to developing an up-to-date conceptual framework for improving the quality of teaching Mathematics in engineering education at a Hungarian university, and it might be useful for other universities as well.

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Use of team contracts as a reflexive tool in an interdisciplinary project-based learning context

M Laperrouza [1]
EPFL
Switzerland

Conference Key Areas: New Notions of Interdisciplinarity in Engineering Education

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ABSTRACT

The paper discusses the use of team contracts as a reflexive tool in the framework of a 9-month interdisciplinary program run across 3 institutions – the China Hardware Innovation Camp (CHIC). The program has the particularity of having teams composed of engineering students (3), design students (2) and business students (1) affiliated with one of the 3 institutions and working together to develop a connected device.

Given the limited number of students participating in the program each year (10-12 engineers and 10-12 non-engineers), emphasis is put on a qualitative assessment of the learning outcomes. This takes the form of several reflective notes due throughout the program covering teamwork, project management and intercultural management.

The paper focuses on the dimension of teamwork. It presents the underlying pedagogical scenario and the protocol related to the use of team contracts as a reflexive tool. It compares the proposed template with the contracts drawn up by 4 teams and analyses the evolution of the contracts during the program. It discusses the reflexive notes of students within a team and across/within teams and disciplines. Finally, it compares the evaluation by the students with the use of team contracts in another setting.

[1] Corresponding Author
Marc Laperrouza
marc.laperrouza@epfl.ch

1 PROGRAMME OVERVIEW

1.1 Brief description of the programme

The CHIC program proposes to go “from idea to functional prototype in 30 working days”. Teams receive a blank sheet of A3 paper at the beginning of the program and have 3 semesters to conceive, develop and prototype an IoT device.

The high-level learning outcomes of the program have been divided into:

- Disciplinary: define functional requirements of a connected device, apply a structured approach to product development and realize a functional prototype;
- Transversal: communicate effectively with professionals from other disciplines, write a scientific or technical report, identify the different roles that are involved in well-functioning teams and assume different roles, including leadership roles, apply fast prototyping techniques and technologies, pitch a product in front of different audiences, communicate effectively across different languages and cultures.

The nature of the program implies that students are exposed to various management issues, including project management, teamwork and meeting management. In short, the program is project-based, interdisciplinary, inter-institutional and student-driven. It can be assimilated to new product development project-based programs [1]. As such it builds on a growing trend of product development programs in multi-disciplinary settings [2].

1.2 Motivation of the use of team contracts

Whereas the program tends to be highly appreciated by the students, they often point out the challenges related to working in interdisciplinary teams. As put forward recently by one participant: “*I was told it would be difficult but I never imagined it would be that hard*”. Such issues with cross-boundary collaboration are not surprising. Edmondson and Harley show that teaming across knowledge boundaries can be difficult in practice, and innovation is not always realized [3]. Heikkinen and Isomöttönen show that learning experiences are not fixed, as team spirit and student attitude play an important role in how students react to challenging situations arising from introduction of the multidisciplinarity [4]. At the same time, Borrego and Newswander identify a number of characteristics of successful cross-disciplinary engineering education collaborations [5]. Reflexivity—the extent to which teams reflect upon and modify their functioning—has been identified as a possible key factor in the effectiveness of teamwork [6].

A number of reasons motivated the use of team contracts:

- In previous editions of the program, students were asked to write reflexive notes on project management and meeting management. The quality of the notes varied significantly between the students. Individual differences aside, one hypothesis was that they were lacking a common reference point to reflect upon;

- While team contracts have been used in the economics literature with the aim to optimize efficiency [7, 8], other authors have proposed the adoption of team contracts to initiate team learning [9]. The latter approach seemed more suitable to the learning environment;
- As noted above, previous assessment of transversal skills related to teamwork consisted of individual reflexive notes due by the engineers (and only the engineers) as part of their assessment of transversal skills [x]. Decision was made to extend the reflexivity related to teamwork to all the participants on two grounds: 1) all participants tended to agree that some of the key learnings from the program laid in teamwork and 2) limiting reflexivity to engineers sent the implicit message that it was (simply) an exercise rather than a tool to improve collaboration. A team contract seemed an ideal vehicle to gather all participants, give rise to discussion and collaboration around a common document.

2 PEDAGOGICAL SCENARIO[2]

The team contracts were introduced as part of a broader workshop on teamwork that all participants followed at the beginning of the program. As a final activity of the workshop, teams were tasked with drafting a draft version of the contract. To do so, students were given a template[3] and time to work individually and then in their team to identify some of the questions deemed important. The elements of the contract referred to 4 dimensions: 1) goals 2) work norms, 3) meeting norms and 4) decision-making. Students were then mixed outside of their team to compare the important questions with students from other teams. Additional time was given for the students to bring back their discussions into their team and draft an initial version of the contract. If an agreement could not be found rapidly on one item, the different views would be noted, the discussion suspended and teams would have to move to the next item. Teams were encouraged to use their upcoming meetings to revisit, complete and/or amend the draft team contract. It was also made clear that the team contract would accompany them during the whole program and that it could be amended at any point in time. To ensure that students treated the contracts seriously, they became part of the deliverables.

The overall scenario included both group work and individual on the team contracts over the first 30 weeks of the program (see Table 1).

Table 1. Timeline of deliverables (group and individual)

	Week 2	**Week 6**	**Week 11**	**Week 15**	**Week 30**
Group	Draft version	1st version		2nd version	3rd version
Individual			1st reflexive note		2nd reflexive note

Source: Compiled by author

[2] The use of team contracts and of reflexive notes has been shaped by discussions with Dr. Emmanuel Sylvestre from the University of Lausanne's Centre de Soutien pour l'Enseignement (CSE) and Dr. Roland Tormey from EPFL's Centre d'Appui pour l'Enseignement. The workshop on team work was conducted by Dr. Jean-Philippe Maître (UNIL, CSE). I am very grateful for their ideas and guidance in developing the pedagogical scenario and accompanying material.

[3] These categories and questions have been taken and modified from an outline found online in a resource for a course of software construction given at the MIT : http://web.mit.edu/6.005/www/fa15/projects/abcplayer/team-contract/#team_contract

3 COMPARISON OF CONTRACTS

3.1 Comparison of template with teams' contracts

Whereas the high-level elements of the 4 contracts are more or less identical – by-and-large they follow the template at their disposal – one can identify initial differences within the items (see Table 2). For instance, workload features in each contract but estimation vary from 16 to 20 hours per week. Akin, expected meeting lengths vary between 60 and 120 minutes. Regarding decision-making (including on contract amendments), certain teams opted for a majority system while others favoured consensus, followed by 2/3 majority in case of no consensus being reached.

Table 2. Comparison of contracts across teams

	Goals and obstacles	**Work norms 11 items**	**Meeting norms 6 items**	**Decision-making 3 items**
Team 1	Goals: device and program-related Obstacles: mistakes, time management, values, MVP	(11) workload, division of work, deadlines, failure to comply, team contract revision, quality of work, communication, data storage	(6) frequency, location, length, note-taking and absence	(3) contract amendment, approval and non-agreement
Team 2	Goals: quality of work and agreement	(11) workload, division of work, failure to comply, deadlines, contract revision, disagreements, diversity, communication, data storage	(3) frequency, length, absence	(3) contract amendment, approval mechanism and rate
Team 3	Goals: device-related and individual objectives	(11) work load, division of work, deadlines, contract revision, disagreements, communication, data storage	(5) frequency, location, day, length and absence	(2) contract amendment, approval mechanism
Team 4	Goals: teamwork-related, learning Obstacles: schedule conflicts, disagreements	(11) workload, division of work, deadlines, absences, documentation, disagreement, communication, data storage	(5) frequency, location, length, note taking and absence	(2) contract amendment

Note: Numbers in parenthesis indicate how many of items are covered by the contract for each dimension.
Source: Author's data.

3.2 Evolution of contracts during the program

At the time of writing, the program is not over. One can nonetheless note that relatively few amendments were made between the draft, 1st and 2nd versions. A number of reasons can explain this: 1) the team contract covers all the situations and needs no amendment, 2) there are few frictions and disagreement in the team requiring to go back to the contract, 3) the contract is not considered as useful to ensure cross-boundary collaboration or to solve the existing frictions or 4) the team contract is (once again) seen as an exercise and not a tool for collaboration.

Some of the amendments made to date relate to meetings. For instance, no longer having a fixed meeting day/time or to take meeting minutes, a better equilibrium of meeting location, attribution of individual responsibilities. In one case, the amendment consists in the addition of a section regarding what takes place once team members no longer all work together on the project. More specifically, it addresses questions related to fairness and representativeness between team members as well as eventual financial compensation on the basis of working hours if there is money involved. The latter is particularly interesting since no project in the past ever resulted in a financial transaction (as this is not the objective of the programme). However, it shows that the team envisages such an eventuality and deems it sufficiently important to amend the contract.

4 REFLEXIVE NOTES

Reflexive notes have been chosen as the *de facto* mechanism to assess the learning outcomes pertaining to transversal skills. They are due at the end of each semester (on week 11 and 30 of the program) and shall not exceed 500 words. Students have the choice to write their reflexive notes on 7 topics: 1) creative thinking, 2) communication in meetings, 3) meeting management, 4) project documentation, 5) management of convergence and divergence, 6) user-driven and solution-driven approaches, 7) team contract. They are asked to collect evidence specific to that process and conduct an individual analysis. The analysis is then discussed within the team before the drafting of the reflexive note. In other words, it follows an individual-group-individual cycle. Each note must include a summary of the initial individual analysis, a summary of the team input and discussion, a link with the team contract, learnings pertaining to team and project management and (eventual) individual behavior change.

4.1 Comparison of reflexive notes within and across teams and disciplines[4]

6 reflexive notes (out of 23) pertained directly to “team contract”. As a reminder, students are free to choose which of the 7 types of reflexive notes they want to work on. Only “project documentation” totalled a similar number of reflective notes. One team had no reflexive note covering team contracts while the 3 others teams had 2 such reflexive notes each.

Table 3. Comparison of reflexive notes

	Communi-cation in meetings	Convergence-divergence	Creative thinking	Meeting manage-ment	Project documentation	Team contract	User-solution driven	**Total**
B	0	1	0	0	2	1	0	**4**

[4] At the time of writing, one (of two) reflexive note per person has been handed in.

D	0	0	1	2	1	2	1	**7**
E	1	2	1	2	3	3	0	**12**
∑	**1**	**3**	**2**	**4**	**6**	**6**	**1**	**23**

Note: B=Business, D=Designer and E=Engineer; one student did not submit a reflexive note
Source: Author's data

As part of the note, students where asked to link their comments to the team contract. Not all notes made such an explicit reference. Those who did covered elements such as responsibilities added to the contract, organization of documents, or decision-making. It goes without saying that the 6 notes relative to team contracts made explicit references. In one case, the student questioned to what extent the contract was to be taken literally (i.e., as a legally binding contract) or as a guideline.

Table 4. Selected quotes from reflexive notes on team contracts

Team$_2$	**Team$_3$**	**Team$_4$**
(E_1) When we first wrote the team contract we kind of anticipated a lot of issues and norms but few of them were respected. We faced some issues that are written in the team contract, but we never needed to go back to it to resolve those problems. However, we also faced some issues that could maybe have been avoided if there were clearly written in the team contract. In the beginning, the team contract was not important for what was written on it but for the process of discussing the main points of group dynamics and be sure that everyone was on the same page. I learned that for a project as big, a good team dynamic is necessary and a team contract really helps in this aspect. In my opinion is not an immutable text but more a tool that helps the group to organize itself and guide us through all the steps of the project. Even if we don't use it very often, it is always in our mind.	(E_1): Go through initial contract and compare. One aspect to revise pertained to allocating more time to decision-making. Two aspects to add pertain to collegiality and ownership in case of incorporation. On the basis of a group discussion, some students propose to update the contract; one student sees the contract as useful when future problems will arise. (D_2): Team contract as important piece in team dynamics in particular when things become tough. On the basis of the group discussion, a change is proposed regarding meeting length (upwards) and an addition regarding managing deliverables.	(B_1): The contract was a good start to understand how the members are willing to work on the project. Some additional details have been added since we wrote the contract but nobody thought of updating it. (E_3): We interpret the contract more as a guideline and not word by word as a legally binding document. Another proposition was to regularly check the contract and adapt/revise it.

Note: B=Business, D=Designer and E=Engineer
Source: Author's data

As a general rule, students seem to have followed the process to discuss their note within their team. This resulted in some form of congruence (at times overlap) between the notes in teams. At the same time, in only one team did half of all the students work on the same note (3 out of 6).

4.2 Comparison with US study

Smith provides an interesting comparison point when it comes to how student perceive team contracts [10]. A similar questionnaire was given to the participants of the CHIC program after Week 20. One can see that except for individual performance, the CHIC participants fall within the undergraduate and graduate students sampled in Smith's study (see Table 5). Likewise, the question on which there is the most disagreement relates to their own performance. That said, on average, the participants tend to agree with the fact that the contract improves/enhances elements pertaining to collaboration (accountability, commitment and expectations).

Table 5. Comparison of team contracts studies (means)

Questions	Under-graduate (n=15)	Graduate (n=32)	CHIC program (n=17)
The use of team contracts increased my sense of responsibility to the team	4.13	3.16	3.59
The use of team contracts increased team members' overall sense of responsibility to the team	4.13	3.13	3.29
My performance was improved because of the team contract	3.73	2.44	2.35
My team's performance was improved because of the team contract	4.07	2.75	3.00
My satisfaction with the team project was improved because of the team contract	3.87	2.75	3.18
The team contract increased my sense of accountability to the team	4.13	3.03	3.29
Fairness of team process was enhanced by using the team contract	4.40	3.16	3.76
Fairness of team results was enhanced by using the team contract	4.20	3.09	3.47
Sense of overall commitment was enhanced by using the team contract	4.27	3.31	3.35
Task-specific commitment was enhanced by using the team contract	4.33	3.28	3.29
Clarity of expectations was enhanced by using the team contract	4.47	3.41	3.59
Overall effectiveness was enhanced by using the team contract	4.53	3.09	3.24

Note: the questions followed a Lickert scale 1-5 with 1=Strongly disagree and 5=Strongly agree
Source: Adapted from [10] and author's data

5 DISCUSSION AND CONCLUSION

5.1 Lessons learnt

A number of lessons can be derived from the team contracts and first reflexive notes:

- The understanding of "contract" may need to be clarified so as to avoid being misunderstood

- The frequency and quantity of amendments remains low; Many teams see their contract as something "in the background" that does not really need regular revisiting
- The contract is considered as a vehicle to discuss and get group dynamics kick-started rather than a tool that accompanies the team along its journey
- It remains difficult for the teams to project themselves in the long-run (*"We did this contract without thinking of the long-term"*)
- When compared to previous editions, one notices less variation in the quality of the reflexive notes – this may also be due to a much more structured of the deliverable
- When looking at the statistical comparison, the program participants do not significantly differ from the sample of graduate students which is not surprising since 2/3 of the participants are graduate students

5.2 Levers for improvement and final thoughts

Among the ideas for improvement, one could:

- Make explicit from the beginning that the contract is in no means "legally binding" and it should be seen as a set of guiding principles
- Formally require the contract to be amended at each milestone (i.e., once per month during the academic calendar)
- Draw attention on the "tricky" items of the contract – this will be much easier during the next edition of the program

While slightly more than halfway through the edition, the use of team contracts appears to provide a good reference points for the reflexive notes and, more generally, the assessment of transversal skills in the program.

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Communication Activity Implementation over 3 Engineering Universities: Values and Challenges

M. Leandro Cruz
TU Delft
Delft, The Netherlands

D. Carthy
TU Dublin
Dublin, Ireland

S. Craps
KU Leuven
Leuven, Belgium

Conference Key Areas: Engineering skills, Curriculum development

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ABSTRACT

The urgency to stimulate transversal competencies is evident and acknowledged by accreditation commissions and institutions. For this reason, higher engineering education has developed practices and implemented in the engineering curricula elements that stimulate these competencies. However, educators find difficulties in developing and implementing them due to lack of time or experience, space in the degrees, or lack of institution support. This study describes a communication activity created and implemented over three engineering education institutions as part of a European knowledge alliance project and presents the values and challenges experienced by the universities after its implementation. Students carried out a short questionnaire at the end of the activity and the data from the three institutions were compared. The findings of this study showed that students perceived that this communication activity helped them to understand the importance of communication skills, and because of its nature of *plug and play* it was easily transferable to the three universities. This study provides educators with a new educational practice easy to implement and effective to stimulate student reflection on their communication skills.

Keywords: Curriculum elements, engineering education, communication skills, values, challenges

1. INTRODUCTION

Transversal competencies have gained importance in the engineering curricula in the last decades. Accreditation bodies such as the ABET Engineering Criteria in the US and the European Network for Engineering Accreditation in Europe and higher education institutions emphasized the incorporation of transversal competencies into engineering education curricula to allow students a smoother transition from education to employment. Engineering students equipped with transversal competencies are deemed more capable to enter the labour market [1]. Both industry [2] and academics [3] agree that transversal competencies such as planning and time management, problem-solving, communication, teamwork, lifelong learning, taking initiative, and creative and critical thinking are important for engineers. This study will focus on communication skills.

Communication is an essential skill for engineers' professional life. Novices engineers reported that they spend 32% of their time using verbal communication with other people and 28% in writing [4]. Another study [5] showed that engineers spend on average 57% of their working time on active communication such as writing e-mails and reports, making phone calls and having meetings. Also, young engineers spend a great part of their time listening [4]. Moreover, Lappalainen [6] argues that, in technology sectors, engineers are constantly exchanging information between other engineering fields and society. They need to communicate effectively to show their vision, to put plans into practice, and to stimulate feedback mechanisms. This importance of communication for engineers rises the need to integrate communication skills in the engineering curricula.

The development of communication skills in engineering curricula is mostly in the form of oral presentations [7] and written reports [8] in project-based learning courses. However, communication extends to informal listening and speaking which are rarely addressed in engineering curricula. Therefore, this study investigates the implementation of a communication activity that was developed to create students' awareness and reflect on effective verbal and visual communication. This includes actively listening, describing information, effectively answering, asking questions, and drawing images.

This study will compare the results of the implementation of this communication activity in three engineering universities, partners in the European project PREFER. Additionally, values of this activity to students perceived by the implementers, and challenges of its implementation will be reported.

The following research questions are addressed in this study:

1. How do engineering student groups perform during the communication activity?
2. How do engineering students perceive the activity?
3. How do educators perceive the activity?

2. METHODOLOGY

This study took a mixed quantitative and qualitative approach utilising a case study methodology to answer the first two research questions.

The performance of the group was analysed based on the scores of the outcome drawings produced by each group during the communication activity. The rubric, present in [9], was used to score the drawings for example on the amount, position, and colour of the objects.

A paper and pencil questionnaire delivered at the end of the communication activity collected information on students' perception of their communication performance in the activity (“*How was your communication skills in this activity?*” and “*Explain briefly why.*”), on points of improvement (“*What do you feel you can improve?*”) and importance of communication skills (“*Do you feel that this activity helped you to understand the importance of communication?*”). The themes that emerged from the analysis of the students’ explanations are presented as quotes. They are in italic and are associated with the role and university of the correspondent students.

The third research question was explored qualitatively through feedback responses of the implementers of the activity in the three universities. The purpose of this approach was to find out the values and challenges of the activity in the implementers’ perspectives.

Ethical approval was granted for this study and participants have consented to be part of this research.

3. COMMUNICATION ACTIVITY DESCRIPTION

3.1. Learning outcomes

At the end of this communication activity, students will be able to:

- Experience effective oral and visual communication by means of active listening, describing images, effectively answering, asking questions and drawing images
- Understand the importance of effective oral and visual communication for engineers

3.2. Design of the activity

The communication activity is based on the children’s game, the Chinese whispers. Its objective is to pass around the message to draw an image similar to the original image provided (*Figure 1*). Due to this difference between the original game, it is named Chinese Whisper wi*th a Twist*.

This activity has a duration of one hour and allows students to practice their communication skills by actively listening, describing information, effectively answering and asking questions. It is performed in groups and each group is divided into three roles (A, B and C). The rules and dynamics of this activity are shown in *Figure 1*.

3.3. Implementation

Data were collected between March 2018 and April 2019 in three European engineering universities (*Table 1*), known as TU Delft (The Netherlands), KU Leuven (Belgium) and TU Dublin (Ireland). The same vector image (see Figure 1 in [9]) was used in the three universities. This image was chosen so that it could be used in all university contexts.

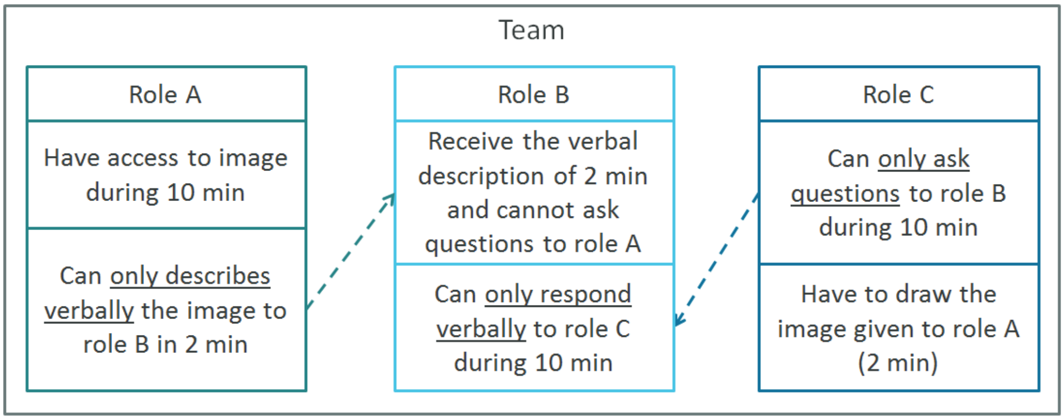

Figure 1 - Rules of the communication activity per role of each team.

Table 1 – Summary of information about the three participant universities.

	TU Delft	KU Leuven		TU Dublin
Implementation	March 2018	September 2018	April 2019	March 2019
Number of participants	20*	17	10	6
Roles per team (A-B-C)	4x (2-2-1)	2x (2-2-2) & (2-1-2)	2x (1-1-1) & (1-1-2)	(3-2-1)

*Of the 20 participants, one did not return the final questionnaire.

The communication activity at TU Delft was integrated into the Forensic Engineering course at the faculty of Aerospace Engineering and was delivered to international first-year Master students by the two-class lecturers in March 2018.

The activity at KU Leuven was implemented twice. First in September 2018 in a one-week summer school with international Master students of KU Leuven and FH Dortmund, and second in April 2019 with Master students of different KU Leuven campuses.

Finally, the activity at TU Dublin was carried out in March 2019 with a group of first-year Bachelor students in a project-based learning course.

The activity was conducted in English, except during the second implementation in KU Leuven that was in Dutch.

4. RESULTS

4.1. Group performances

Over the four implementations of the communication activity in the three universities, eleven drawings were produced as an outcome of each group. These drawings were measured with the rubric previously mentioned. The groups and the corresponding drawings' scores per category (objects, amount, colour, position and details) present on the rubric are present in *Table 2*. In this, we can observe which aspects the groups focused on and as a result how well they performed during the activity.

The results showed that the flow of communication between the participants within the roles worked very adequately in two groups (group 4 of TU Delft and group 1 of TU Dublin). They strategically and efficiently communicated by conveying information, attentively listening and carefully drawing the image.

> *"I tried to convey information as efficiently as possible by visual (charades) and descriptive (talking) means."* (Student in role A, TU Dublin)
>
> *"Listened for most details."* (Student in role B, TU Dublin)
>
> *"I didn't start drawing until I understood exactly what and where everything in the picture is."* (Student in role C, TU Dublin)

These groups met most of the aspects present in the picture. They identified all the objects, colours and positions, but also small aspects such as the *ears of wheat* (see Figure 1 in [9]).

On the other hand, some groups (e.g. groups 2 and 3 in KU Leuven 2018) struggled with their communication skills and consequently, their group scores were lower. They missed several aspects in the picture such as objects and their colours and amount, as well as most of the details.

> *"Didn't listen/take into account the suggestion of another team player "C". And paid attention to some details, but did not ask about the main feature - background colours/amount of trees in total."* (Student in role C, group 3, KU Leuven)

The average groups met more than half of the aspects of the picture. They performed well on the identification of objects. While some groups focused on the colours of the objects (e.g. TU Delft group 1 and KU Leuven 2019 group 1), others neglected them (TU Delft group 3 and KU Leuven 2018 group 1). Only one group (KU Leuven 2018 group 1) was able to identify more than half of the details in the picture.

Table 2 - Drawing scores per team assessed through a rubric (see Figure 1 in [9]). The maximum score is 43 points.

University	Groups	Rubric Scores					
		Objects	**Amount**	**Colour**	**Position**	**Details**	**Total per group**
TU Delft	1	6	4	6	4	7	27
	2	5	4	4	4	5	22
	3	6	4	1	4	8	23
	4	7	4	7	7	11	36
KU Leuven 2018	1	6	4	2	4	9	25
	2	4	3	1	4	5	17
	3	3	3	3	3	5	17
KU Leuven 2019	1	6	3	6	4	7	25
	2	5	4	4	3	7	23
	3	6	4	3	3	8	24
TU Dublin	1	7	4	7	6	9	33
Total per rubric		**7**	**5**	**7**	**7**	**17**	**43**

4.2. Students' perceptions

Over the three universities, a total of 52 engineering students completed the questionnaire delivered at the end of the activity.

Students were asked to rate their communication skills and to provide an explanation for their responses. The findings show that 86.5% of students in the three universities perceived they were very good or good communicators (*Figure* 2). The majority of students in role A stated they described the image in a precise and structured way and conveyed information well. Students in role B indicated they attentively listened and clearly answered the questions with the information received. Finally, students in role C asked general and in-depth questions to draw the image.

> *"…We broke it* (the image) *down to elements (objects, shapes, colour, positioning) and we were able to provide all the information"* (Student in role A, TU Delft)
>
> *"I was clear and got lots of detail."* (Student in role B, KU Leuven)
>
> *"Based on the role, I felt that the communication skills shown by me were met, having answered all the questions satisfactorily."* (Student in role B, TU Delft)
>
> *"Asked both in-depth and broad, general questions."* (Student in role C, KU Leuven 2018)

A small percentage of students (13.5% who responded *neither good nor bad*) realised that their communication could have been better.

> *"I tended to rush and forget important details/clarification."* (Student in role A, TU Delft)

> *"My questions could have been more to the point (and same goes for drawing skills)"* (Student in role C, TU Delft)

> *"Forgot to ask a lot of detailed questions because I assumed a lot like a sunset: orange, cow drawn in this way…"* (Student in role C, KU Leuven 2019)

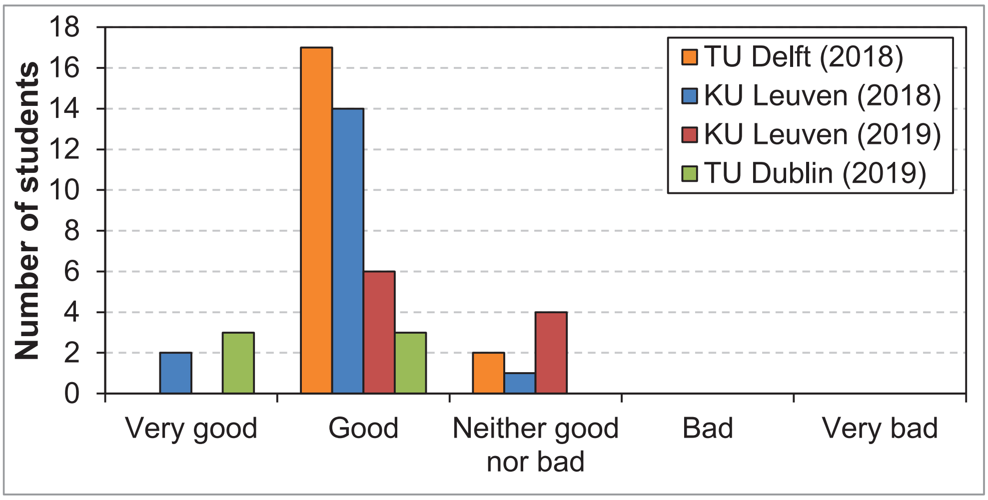

Figure 2 – Communication skills perceived by students (n = 52) on a 5-point Likert scale (very good, good, neither good nor bad, bad, and very bad).

Also, students, who considered that their communication performance was adequate, recognised they could still improve their communication skills, especially to pay attention to details.

> *"After seeing the original picture, we got pretty close. We missed some details and maybe, I personally didn't analyse why the trees were slack."* (Student in role C, TU Delft)

> *"Apart from some minor details, I think we explained it very well."* (Student in role A, KU Leuven 2018)

Overall, when students were asked points of improvement (*Figure 3*), students in role A indicated skills as *describe information* and *pay attention to details*, in role B *write down information*, and in role C *ask questions* and *pay attention to details*.
Another result from the questionnaires shows that 86.5% of the students from all the three universities strongly agreed and agreed that the activity has helped them to understand the importance of communication (*Figure 4*).

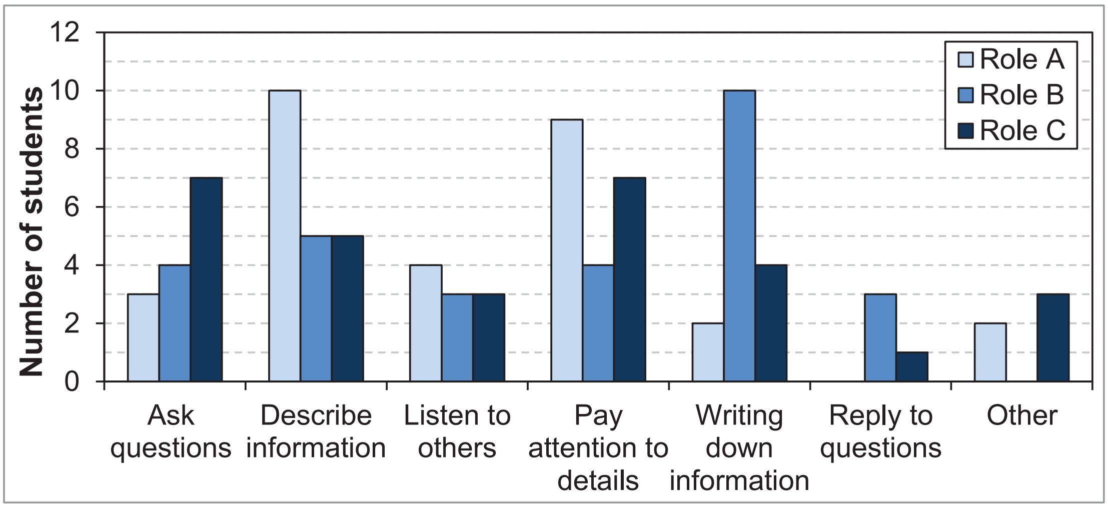

Figure 3 – Points of improvement perceived by students (n = 52) per role after the communication activity.

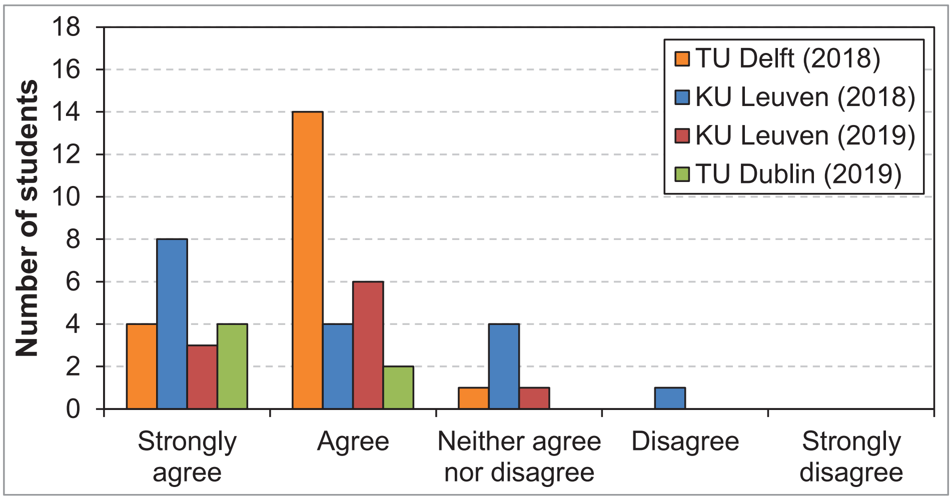

Figure 4 - Perception of students (n = 52) on whether this activity helped them to understand the importance of communication on 5-point Likert scale (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree).

4.3. Perspective of three universities

The implementers of the communication activity in the three universities provided with feedback on the activity. The feedback of the TU Delft lecturers was used to improve the implementation of the activity and it is described in a previous paper [9]. Overall, the implementers of the three universities considered the activity a fun and ice-breaker exercise, and easy to implement. Moreover, although implemented in different courses and contexts they indicated that the activity is adequate to experience and reflect on the importance of communication.

> *"In the context of a session on pitching, it was a fun exercise to let the students experience the importance of efficient communication."* (Implementer at KU Leuven)

"The value of the activity in this context is that it got students to think about the importance of communication, which is certainly of value when one is acting as a project manager on a design project." (Implementer at TU Dublin)

"I think with the activity they learned a lot about the communication aspects, so I guess on that side I really like the activity. It was a really good activity." (One of the lecturers at TU Delft)

A challenge in the implementation of the activity pointed out is when the class groups are large. This requires better organisation in the sense that larger or more rooms are needed as well as assistance to supervise the groups during the activity.

5. DISCUSSION & FUTURE WORK

This paper presents the findings from the implementation of a communication activity over three different European engineering universities.

The data from the three universities illustrated that most of the students perceived that their communication skills were good. The scores of the drawings showed, however, that some groups experienced some difficulties in communicating. A very interesting finding was that difficulties arose mainly with students who did not know each other (they just met in the one-week summer school), and were from different (e.g. Belgium and German) cultural backgrounds. On the other hand, the communication skills of the English native speakers (TU Dublin) worked really well. These results may indicate that the intercultural aspect played a role in the communication performance of the groups. Though, we believe that culture was not the only factor playing in the activity, but also the approach taken by the students when communicating their messages to draw the image. For example, students in group 4 of TU Delft were from different nationalities and not English native speakers, but they approached the exercise very strategically. They described the image by sections giving directions, sizes and colours, paid attention to most details, and asked first general questions and then more detailed questions to draw the image. A similar strategy was adopted by students in TU Dublin. Then the organisation of the group and how communication was transmitted was an important factor for effective communication. The factors (e.g. cultural and approach) that influenced students' communication may be investigated in a future research.

Overall, this activity seemed to stimulate students' reflection on their communication skills, including strengths and points for improvement, as well as to provide students with awareness for the importance of communication. Moreover, the implementers of the activity in the three universities stated that they value this activity because it stimulates students' reflection on their communication skills. Therefore, we believe that this research provides engineering education with an activity that may help students to reflect on their communication strengths and aspects to develop and to gain awareness of the importance of effective communication necessary for the engineering labour market. An additional advantage of this activity is the ease of its implementation in different contexts.

Self-assessment tools are convenient instruments to measure students' competencies because they are easy to develop and implement. Nevertheless, they are subjective to people's bias. To overcome this research limitation, in future work, as complementary exploration, interviews will be conducted to evaluate students' experiences during the participation of the communication activity and how that may change the way students view or experience effective communication.

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Experiences from collaborative online education for degree and further education on circular economy

M.M. Leppänen
Tampere University
Tampere, Finland

P.H. Kuula
Tampere University
Tampere, Finland

Conference Key Areas: Open and Online Teaching and Learning, Lifelong Learning

Keywords: online teaching, circular economy, continuous learning, cooperative learning

ABSTRACT

Life-long learning has been recognized to be a powerful route to meet the transient competence needs. The education during employment gives a chance to renew competences and skills.

Circular Economy (CE) is one topical issue pushing us to update our skills and competences. To promote and accelerate the necessary and disruptive change in a culture, we should educate both future and present professionals. To focus on specific perspective in all applications rather than general design, a novel course on circular economy of infrastructures was created in co-operation with industry.

In this paper, experiences from two CE courses are discussed to point out the special questions in lifelong learning especially considering the cooperative learning and student diversity.

The participants with different backgrounds, i.e. the young degree students and further education students, were mixed together in co-operative learning schemes. The adult learners were supposed to provide their practical working experience and holistic approach, and the undergraduates in turn their modern learning and information retrieval skills.

The course has been organized twice, at two universities simultaneously. The course consists of six contact teaching days. The lectures were recorded and available on line through Adobe Connect (AC). The tasks and quizzes were distributed in Moodle. The project work was done in groups composed of various participants. In latter implementation, the flipped learning methods were applied.

Based on the feedback, the participants were very satisfied with the course. However, the low commitment of further education students shown as drop-outs and various delays caused problems especially in group work, thus overloading the degree students.

1 INTRODUCTION

1.1 Education of Circular Economy

Circular Economy (CE) has been one of the key targets of the Finnish government [1]. In the national road map to CE, one important measure is introducing the circular economy perspectives to teaching in all education levels [2]. According to a recent study [3], the education for sustainable development is still not integrated in all engineering education in Finnish universities despite committing to the sustainable development in their strategies. To implement the strategy, a cross-disciplinary module on CE, bringing together engineering and business perspectives, has been established in Tampere University.

Infrastructure construction is a very material and energy intensive sector. The use of recycled materials and the design of the structures are in a key role in promoting CE in infrastructure construction. The environmental legislation and public procurement methods create boundary conditions on the implementation of CE. The inquiries and discussions with the experts, contractors and authorities have also shown that the lack of knowledge is one of the major obstacles for the utilization of recovered and secondary materials in earthworks and infrastructure projects. Therefore, the industry was very interested to support the education of CE for infra engineering students and professionals.

1.2 Co-operative learning

Based on the variety of students and complexity of the subject, the chosen pedagogical approach for CE courses was co-operative learning. Co-operative learning is an effective method in problem-based learning, providing a possibility to practice and learn useful meta skills such as team work, negotiation, argumentation and presentation.

In co-operative learning the learners are working together to accomplish shared learning goals and complete jointly specific tasks and assignments. The groups are typically heterogeneous, especially in terms of achievement motivation and task orientation. The longer a cooperative group works together, the more caring their relationships will tend to be, the greater the social support they will provide for each other, the more committed they will be to each other’s success, and the more influence members will have over each other. [4]

1.3 Lifelong learning

Oosi et al. (2019) are stating that “learning is becoming a key asset when we are answering to various social and economic challenges”. It has been recognized that to agilely adapt to the future challenges caused by the megatrends, such as, among others, digitalization, urbanization, robotics and climate change, there is a need for re- and further education. Life-long learning, also called continuous learning, could be a solution for reskilling, upgrading skills or developing the skills required by the changing working life. [5]

1.4 Student diversity

When degree students and adult students are combined, the student diversity should be considered. To be able to provide student-centered teaching you need to know who your students are. Students are coming from a range of diverse backgrounds and have differing aspirations, levels of motivation, attitudes towards teaching and learning and responses to learning environment and teaching practices. Especially adult learners are having diverse knowledge, perspectives, bias and life experiences. *Fig. 1* summarizes the main key dimensions of student diversity that may affect learning and teaching. [6]

Fig. 1. Some of the key dimensions of student diversity. (UNSW is referring to UNSW Sydney, i.e. the University of New South Wales, one of Australia's leading research and teaching universities.) [6]

1.5 On-line learning

On-line or distance learning, i.e. learning through an internet connection, has been considered as a solution especially for further education of working adult learners. On-line learning can be either synchronous or asynchronous. Synchronous means “at the same time” and typically the learners meet and work online in a virtual classroom. Especially asynchronous e-learning offers working professionals a flexible alternative to upgrade their knowledge, since the schedule of learning is free.

On the other hand, on-line learning requires higher self-direction and better self and time management skills than traditional class room learning. The instability of Internet and software problems may cause difficulties especially in synchronous teaching.

2 COURSE CONTENT, LEARNING OUTCOMES AND ASSIGNMENTS

2.1 General description

Two universities were jointly organizing two course implementations on circular economy in infra construction, *Course 1* carried out in academic year 2017-2018 and *Course 2* in 2018-2019. The *Course 1* was designed and realized together with industrial and institutional partners, such as Ministry of the Environment, Finnish Transport Agency and consulting office Ramboll Finland Ltd.

Both courses were aimed to the university degree students and to the professionals. The courses were designed to 5 credits ECTS, which means 133 h of studying. All the lectures were given in Finnish. In *Course 1* the participants from companies paid a small fee. In *Course 2*, there was no fee thanks to a small financial support received from the Finnish Innovation Fund Sitra. To promote the information on potential of by-products, the municipal and environmental regulators were invited to follow the lectures online for free in *Course 1*.

The core of the courses consists of six intensive days organized once per month. The lectures were sent online by AC and recorded. In *Course 1*, the content and lecturers were designed together with the industry producing potential by-products. As for the *Course 2*, the content was planned mainly by the university based on the experience from *Course 1*. The topics of the both course implementations included e.g., material requirements for typical applications, properties of various secondary materials, such as demolition wastes and ashes and slags from energy and steel industry, legislation, environmental risks and permission processes and design criteria.

In *Course 1*, lectures were given either in Tampere or in Pasila outside the university campus, and participants and lecturers were travelling to the lecturing location. In *Course 2*, the lectures were given either in Tampere or Espoo, or from any location the lecturer chose, and distributed online to participants sitting in a lecturing room either in Tampere or Otaniemi, at their working places or at home.

The learning outcomes of the course on *Circular Economy in Infrastructures* were derived from the experiences of Finnish UUMA2 demonstration projects and discussions with experts. The aim was to provide a wide knowledge on recycled materials and their influence on the design and performance of the infrastructures.

2.2 Participants

The interest for the courses was high. The total amount of participants of *Course 1* was 162, of which 40% were authorities, i.e. municipal or provincial regulators or officials, participating through an on-line connection. In contact learning the actual number of students was 98, of which 80 completed the course (81.6%). At the beginning of the academic year the total amount of participants in Course 2 was 68. The actual number of participants completing the course was 47 (69.1%).

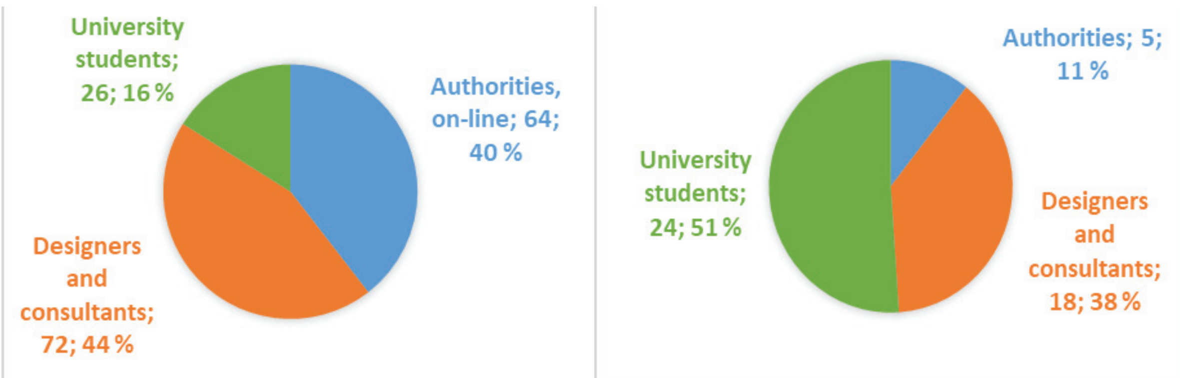

Fig. 2. Background of participants on two courses on circular economy, *Course 1* 2017-2018 on left and *Course 2* 2018-2019 on right.

The division of the participants on these two courses into three main groups, 1) university degree students, 2) authorities, and 3) designers and consultants, is presented in *Fig. 2.*

2.3 Learning assignments

A learning platform Moodle was used for communication and to distribute the information and links to AC recordings. At the beginning of each contact day a multiple-choice test based on lectures of previous day was organized in Moodle to assess and motivate the learning. There was no final exam.

In order to get the credits, the participation to contact learning was compulsory during the *Course 1*. In *Course 2*, the on-line participation controlled by a password, was also accepted as participation. If the participant was missing the lectures, it was possible to compensate it by doing substitute tasks, e.g. writing a learning diary based on lecture slides and the lecture recordings. Diaries were returned to Moodle.

The participants were divided into groups. The groups were pre-formed in order to mix the degree students from different universities and adult students to promote the information sharing and cooperative learning. In the *Course 1* the groups were quite big (max 12 participants) due the large number of participants. In the *Course 2* the groups were a bit smaller (max 8 participants).

One of the main differences between the two implementations was the activation of the students. In *Course 2* the students prepared in groups a compact material card and a 30-minute presentation about a given secondary material. The presentation was performed to all, either online through AC or as a pre-recorded video, and an expert from industry were commenting the student presentations.

The core part of the course was a project work, where the groups searched and gathered information about given secondary materials, selected a suitable material and designed the structure for a factual application. The applications used in both courses were real cases from public infra construction projects of which enough public information was available for design. The results of the design work were presented to other students as a poster. The other students evaluated the posters in an electrical form. In the *Course 1* the posters were printed and presented in a poster walk. In the *Course 2* the posters were presented as pdf-files in Moodle.

3 RESEARCH METHODS

3.1 Evaluation of learning activity

Learning analytics from Moodle was used to evaluate of the activity of the students. Unfortunately, the detailed analytics from the *Course 1* were no longer available at the time of this study. The data from the *Course 2* was analyzed with quite simple methods using Microsoft Excel.

The reports of AC provide data on number of participants on each "meeting", as they are called in AC, and detailed information when each participant has created and ended a connection. This data was used to assess the online participation activity.

3.2 Feedback questionnaires and interviews

The feedback was collected in the *Course 1* after every contact day by a Webropol questionnaire. The focus of the questionnaire was on the content of each day and the practical management of the course. In *Course 2*, a common Webropol questionnaire was sent to everybody after the course. In addition, separate feedback surveys were made to the university students at the end of the course. Besides, during the *Course 1*, three students were interviewed by a professional magazine.

In addition, fifteen participants representing both courses and various backgrounds were chosen for a personal interview by email. The questions involved the affect of participants with different background on one's learning.

4 RESULTS

4.1 Activity in Adobe Connect

The number of online connections and number of actual online participants during lecturing days in *Course 1* and *Course 2* are shown in *Fig. 4*. The opening day on *Course 2* was divided into two parts, hence the morning program was together with parallel course on circular economy in house construction.

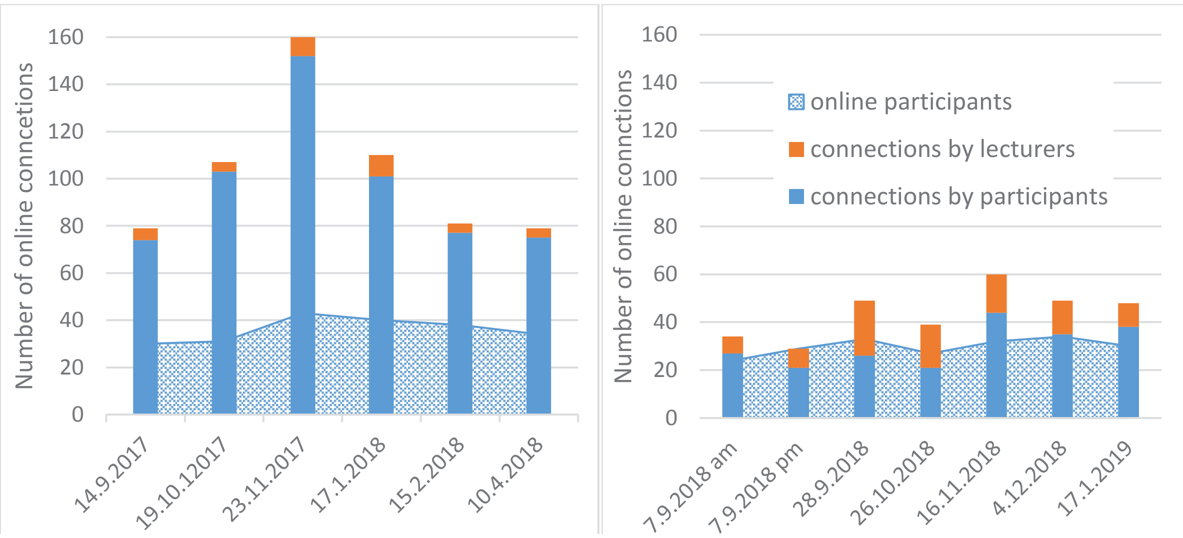

Fig. 4. Number of online connections in AC during the lecturing days on *Course 1* (left) and *Course 2* (right).

During one lecturing day, a participant could have started several online connections, especially if any technical problems have occurred. In some cases, there were several persons using the same connection, especially during Course 1, where the municipal and provincial officials were invited to follow the lectures online for free.

On *Course 1* there were significantly larger number of connections due to unexperienced users and technical problems in internet connection. Also, the number of online participants were a bit higher than on *Course 2*. In average, there were 36 online participants on *Course 1*. One connection from a municipality or a Centre for Economic Development, Transport and the Environment typically corresponded two to four online listeners. The most popular day among the authorities was the third day concentrating on the renewing environmental legislation.

On *Course 2* the lectures were presented alternately from two or three places and lecturers of both universities were online, increasing the connections of lecturers. The number of online participants varied between 24…34 on *Course 2*.

4.2 Activity in Moodle

The detailed data from the activity of *Course 1* were not available. The general activity based on monthly Moodle records presented in *Fig. 4* shows that the activities were typically the highest in the beginning of the course and an increase in activity is noticed shortly before and during the contact days.

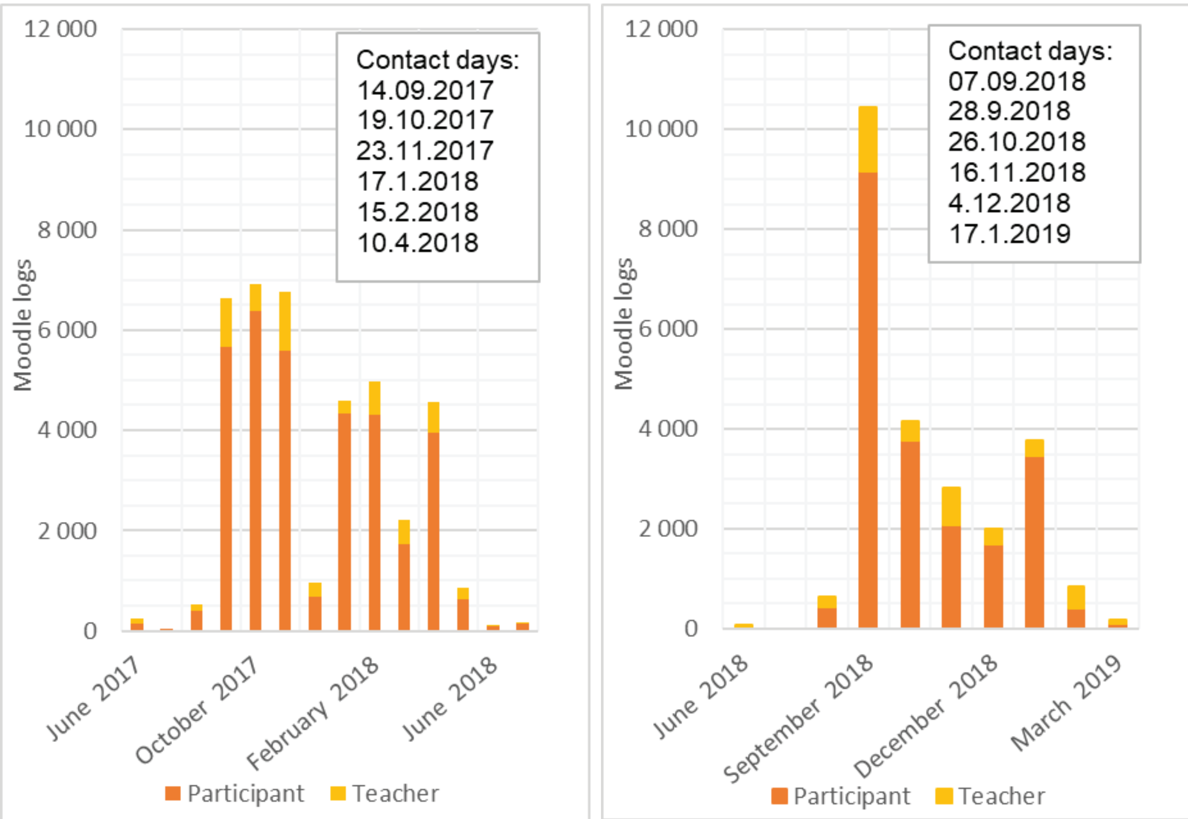

Fig. 4. The monthly summary of the activities during the Course 1 on left and on Course 2 on right based on Moodle records.

The activity in the *Course 2* decreases during the course more than in the *Course 1*. In fact, the lowering of the activity in the *Course 1* was only 20% as in the *Course 2* the decrease was 60%. The total amount of logs in the *Course 1* was naturally higher because of the higher number of students. Based on the logs, the most visited point in Moodle were the assessments: the results of exams and the grading of the group work.

The Interactions in Moodle can be divided in six different groups according to Gómez-Aguilar et al (2015): *learner-learner*; *content-content*, *learner-content*, *teacher-teacher; learner-teacher; teacher-content* [7]. In both courses the main interactions may be classified to learner-content interactions. Learner-learner interactions, such as discussions were not so popular, when a post to discussion forum or starting a discussion were considered. The groups used other media, e.g. WhatsApp or Microsoft applications to interact. Therefore, the Moodle logs are not representing the teamwork activity and the commitment of the group.

4.3 Learning results vs activity

Drop out percentage in the *Course 1* was 18% and in *Course 2* 30%, in the average. In the latter course, 50% of the authorities starting the course dropped out; in other words, they didn't take the Moodle quizzes or participate to the group work. However, they could be following the lectures online. Based on these results, the formal learning requiring student activity is not as attractive for working learners as passive listening, especially if there is no external motivation such as participation fee. On the other hand, most of the degree students passed all the learning assignments, even though the course was not compulsory. In addition, the high drop-out rate on *Course 2* added the work load of the remaining students.

When the activity of a single student in *Course 2* is compared to the grades or success in the course, a clear difference is discovered: the activity of the student with low points (total amount of activities 360 in Moodle) is only 50% from the activity of the best student (total amount of activities 711). The student with lowest grades visited Moodle only during contact days. Also, the group which got the highest grades from the group work, had higher number of activities (total 2225) than the group with lowest points (total 2026). However, there is no clear correlation between the logs and grades, since the purpose, outcome and type of the activity are affecting on the learning results; just the number of clicks is not telling about the quality of the activity.

When the adult learners and degree students are compared, the difference in Moodle activity is evident. The degree students are experienced and effective Moodle users needing less clicks to find their way, resulting lower number of logs, while the adult learners are less experienced and clicking more often (see *Fig. 5*).

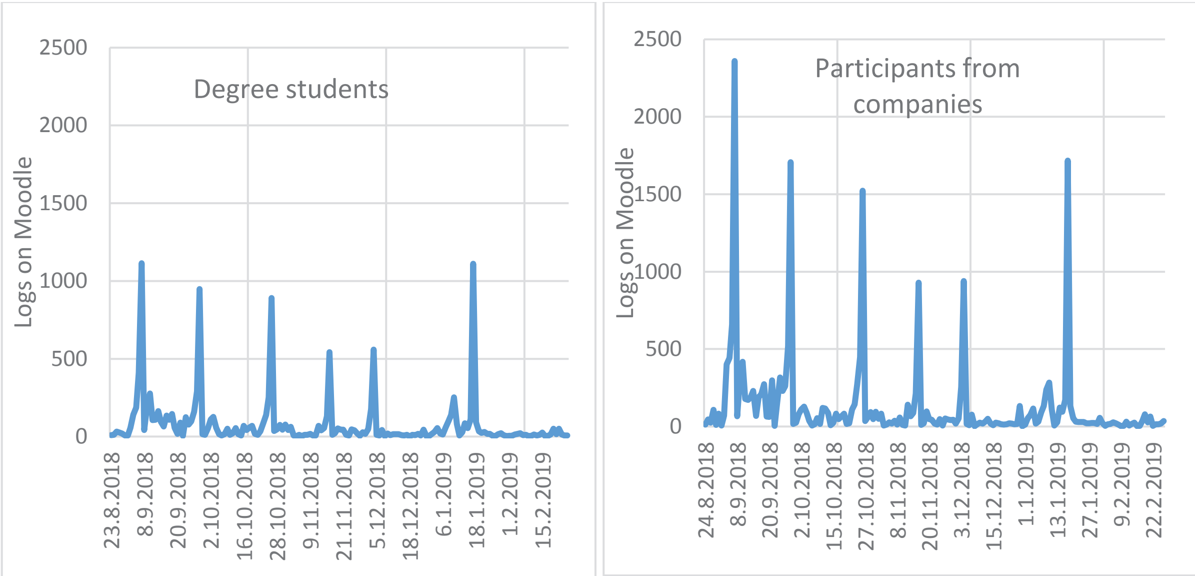

Fig. 5. The summary of the Moodle logs of the degree students on the left and the participants from companies on the right based on Moodle records during *Course 2*.

4.4 Feedback analysis

The feedback of the *Course 1* has been described briefly in reference [8]. In general, the feedback of both courses was very positive. Based on the questionnaires, the participants were especially content with the topicality of the course content and the lectures given by experts with practical experience. Most of the respondents considered the learning assignments beneficial for their learning. For example, in *Course 2* over 60% of 21 respondents considered that the material card, presentation and design project supported their learning and gave additional value. All respondents would recommend the course.

In general, the online connection was good. There were some minor problems with voice (mentioned by 6 of 11 answers). The major difficulty was the group work: there were problems with the division of the labor, partly due to the lack of face-to-face contact in Course 2, resulting uneven workload. However, the co-operation between degree students and working learners was considered beneficial (*Fig. 6*).

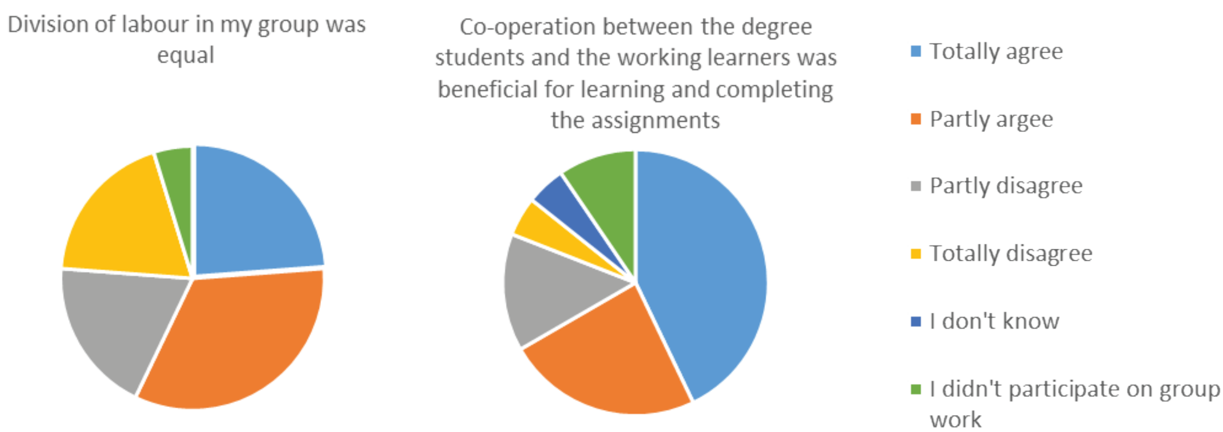

Fig. 6. Some results from the feedback questionnaire on Course 2.

5 DISCUSSION

The information the Moodle analytics is providing on student activity seems promising. However, it doesn't tell the whole truth since the learners were using other communication and co-operation platforms, such as Google Docs and WhatsApp. The main interactions were learner-content interactions.

Co-operation learning is beneficial for motivated learners. However, the achieving of active co-operation in online course requires much more effort than in contact teaching with possibilities to face-to-face contact during e.g. lecturing brakes. Especially older students are used to passive listening of lectures instead of active involvement and learning by doing.

In addition, the inadequate e-learning skills limited the student activity, especially among the further education learners. This should have been considered in course planning by organizing either extra activities or compulsory face-to-face group meetings.

The learning results depend strongly on the motivation, both internal and external, of the learner. The drop-up rate was much lower among degree students, even though the course is not compulsory. A fee is also a motivating factor to attain the lectures, but not strong enough to urge to work between the contact days. Especially voluntary, working further education learners are unprepared and unwilling to participate in group work and other learning tasks requiring activity outside the lectures, mainly due to the lack of time. Free education without credits results high no-show and drop-out rate.

These two courses on Circular Economy involved over 300 people, including the lecturers. This is a significant figure considering the size of the Finnish infra construction sector, both demonstrating the need for education and launching a necessary disruptive change towards CE.

The increasing need for lifelong learning is recognized by the Finnish universities and decision makers. The collected experience will be used in development of future courses, where the degree students and further education learners are combined, to achieve cooperative and continuous learning.

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Simulation of Research-Grade Physics, Chemistry, and Engineering Experiments in LabVIEW as a Flexible Template for Remote Laboratories

R J Lewis[1]
School of Physics and Astronomy, Cardiff University
Cardiff CF10 3AT, UK

T D Drysdale
School of Engineering, The University of Edinburgh
Edinburgh EH9 3FG, UK

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Keywords: Remote Laboratories Simulation Education Authentic

ABSTRACT

We propose to repurpose sophisticated experimental simulations used for testing of control and analysis software as the foundation for flexible, realistic, and robust remote access-simulated-resource-type [1] project-based learning in higher education.

It is impractical to implement undergraduate projects or laboratories directly on “big science” experiments by virtue of their uniqueness, rarity, and running costs. By implementing simulations we can take advantage of the benefits of scalability and reduced running costs [2] in addition to the unique affordances of simulations such as zero acquisition time, enhanced opportunity for iteration of technique, and learning outcomes adaptability [3], all while maintaining a realistic learning experience.

There is a danger with virtual laboratories that students “act before thinking” as opposed to “thinking before acting”, with potentially negative effects on their learning and the realism of the experience [4]. In order to minimise this effect and to ensure as realistic an experience as possible, we propose embedding the interaction with simulations within a facsimile of a research group environment which includes time budgeting and peer accountability.

We demonstrate the practicality of this concept by implementing a LabVIEW-based simulation of the KATRIN TILO (Karlsruhe Tritium Neutrino Experiment Test of Inner Loop) tritium gas assaying system [5] which can be adapted for physics, chemistry, and engineering projects. Multiple simulations run at different physical scales and variable timescales, taking advantage of LabVIEW's inherent parallelism, including the quantum mechanics of Raman scattering, isotope exchange mechanics, transmission efficiency of the light collection system, and a realistic interface for controlling the laser, gas handling, and spectral acquisition.

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1 Corresponding author: LewisR54@cardiff.ac.uk

1 SIMULATIONS IN RESEARCH AND EDUCATIONAL ENVIRONMENTS

1.1 Simulations in Research Environments

In experimental physical sciences and engineering, simulations are routinely constructed by practising professionals at scales / levels of depth from fundamental physical interactions, through individual experimental components, to comprehensive simulations of entire experimental set-ups. It is beyond the scope of this paper to provide a comprehensive review of such simulations; the following examples from physics serve only to illustrate the depth, sophistication, and universality of simulations in the physical sciences.

At the fundamental level of physical processes, one encounters highly context- and application-specific single-use simulations in fields as diverse as the particle physics of hadronic showers [6], simulation of muon backgrounds for detector commissioning [7], and gravitational waveform simulations for black hole binary merger searches [8]. Multiphysics suites do exist, however, and are also widely used. Notable examples include COMSOL [9] and ANSYS [10].

At the application level of entire detectors or elements of detectors, one encounters more frequent use of general-purpose multiphysics and simulation tool-kits such as GEANT package, applied for example to calibrate calorimeters [11] or muon flux through the KATRIN main detector [12].

Such simulations and iterative comparison with experiment are a vital part of the design and evaluation process for devices of all scales, from portable neutron flux detectors [13], to large satellites [14], to entire "big science" experimental set-ups and facilities [15], [16]. This practice is nothing new in engineering and industry, however; aerospace have long used simulation- and hardware-in-the-loop [17], [18], and it remains a central pillar of modern engineering practice [19].

In summary, simulations in research and industrial environments are vital and ubiquitous. Their implementation is usually thoroughly planned, often highly complex, cover every conceivable time, energy, and length scale and are iteratively linked to experiment / implementation by design. As a consequence of their application, such simulations are restricted to use by the host research group / institution / company, and are very rarely adapted for wider use.

1.2 Simulations in Educational Environments

When considering the use of simulations in higher education in physical sciences and engineering, the concept of the "virtual laboratory" is commonly encountered [1], [2]. This term hints at the inextricability of a simulation from its educational context. In the field of physics education, for instance, the importance of learning concepts by means of constructing models is emphasised [20]. Formal modelling frameworks have been developed which emphasise the students' engagement as practising researchers and the iterative nature of model construction [21], construction of models in a mixed-reality setting [22], and the effect of the blurred boundaries between physical and virtual laboratories [23]. Indeed, the dividing line between what a practising scientist might consider a simulation and a virtual environment is itself blurred.

The blurring is further complicated by the module- / programme-level framework into which the laboratories are embedded; examples include realistic "practice-centred" project-based learning frameworks with time budgets, peer-accountability, and the real possibility of failure [3], and more traditional discrete "learning units" closer in form to typical undergraduate laboratories. The latter appears to be the dominant form; educational simulations / virtual laboratories are rarely "large scale", in both the sense of operational complexity and breadth of the underlying concepts. Rather, simulated experiments are often virtual versions of simple undergraduate experiments [24]–[29]. This is in stark contrast to the research and industrial simulations already discussed.

Within the educational context, simulations / virtual laboratories are instances of active learning, which are well-known to have an overall positive effect on student learning [30]. Virtual laboratories have a number of potential enhancements over physical laboratories, what Nolen and Koretsky refer to as the "affordances" of the virtual environment. Affordances in turn influence the instructional design of a virtual laboratory, such as the overlaying of visual representations of invisible phenomena on a user interface (UI) [3].

Potkonjak et al. neatly summarise the advantages of virtual laboratories such as lower operational and maintenance costs due to the lack of physical equipment, ease of reconfiguration, and multiple, simultaneous (perhaps remote) access, balanced against disadvantages such as the necessity of (possibly large) computer and software resources, the typical lack of (often instructive) "bad" outcomes in a "safe" virtual environment [2]. Interestingly, Potkonjak et al. state that "the final stage in training … requires real equipment" [2]. The use of the word "training" suggests a predefined idea of the purpose of virtual laboratories. In the context of physics virtual laboratories this is debatable, since understanding of underlying fundamental concepts is likely the intended learning outcome, rather than mastery of a particular experimental set-up.

In summary, the operating context of simulations as part or the entirety of a virtual laboratory is very different to that of research simulations, and are typically restricted (although not always) to small-scale defined-concept implementations, although they are evidently very effective in this role.

2 PROPOSAL: BRIDGE THE GAP BETWEEN THE RESEARCH AND EDUCATIONAL REGIMES

We observe that there is a gap in the educational application of simulations in virtual laboratories that lies between the simple, small-scale virtualisation of traditional laboratories, and the simulation / computer operation of large-scale experimental set-ups in research environments. More specifically, there is little opportunity for undergraduate students to experience operation of cutting-edge "large" experimental set-ups, and hence limited access to realistic experience of grappling with the complexities research-grade experimental work.

We propose the use of simulations of practical experimental set-ups as flexible, robust, and, above all, realistic virtual laboratories.
The general principle is either to adapt existing simulation and experimental control software for educational use and / or to develop applications which simulate the operation and physical processes underlying a particular experimental set-up. It is likely that a research group will have several such applications that could be adapted, or existing simulation elements that could be combined within a framework such as a LabVIEW project or a GUI-driven Python application.

An advantage of this approach is that institutions will already have the authors / maintainers of the source software and a team of experts in the field on-site. We note, however, that development time may be significant, so it is likely that a virtual laboratory lead would actually develop the application in consultation with the research group.

Specific implementations will naturally vary between disciplines and in light of the intended learning outcomes of the planned activities. In this paper we suggest one possible specific implementation in order to illustrate the general principle; the development of a simulation of a subsystem (TILO) of a large experiment (KATRIN), based in large part on repurposing existing code. We suggest, without prescription, the use of the LabVIEW development environment due the relative ease of UI development and inherent parallelism. We further suggest how this proof-of-principle implementation can be adapted for multiple disciplines (physics, chemistry, engineering), and adapted and scaled for use in a remotely- and multiply-accessed virtual environment.

2.1 General Simulation Requirements

A simulation of an educational experimental set-up will consist of several intercommunicating simulation elements, each of which represents a context-consistent “unit” of the simulated system. The simulation as a whole should satisfy the following requirements to meet the requirements of flexibility, robustness, and realism, bearing in mind the specific local and educational implementation contexts:

Modularity and user interaction: individual elements of a simulations should be able to combine and scale with other elements in a natural way. Each simulation element should run within its own process in parallel and communicate with other elements via a standardised interface. As a consequence, a top-level application will be necessary to coordinate communication between simulation elements and to handle user input.

Timescale compatibility: physical, chemical, and mechanical processes will occur on different characteristic timescales. Depending on the time budgeting and complexity required in a specific implementation, one or more of these timescales will be dominant. A simulation should therefore account for the possible requirement to average / integrate the observables of faster processes within a slower dominant timescale, or to reliably and realistically schedule slower processes within dominant fast processes. Ideally, this scheduling should be configurable to allow for efficient code re-use.

Time budgeting configurability: not all simulations can, or need to, run in real-time. Simulations should allow for the configuration across the spectrum of “instant” results, “instant” results with a time budget cost, and “real-time” operation. This spectrum broadly aligns with the requirements of undergraduate concepts-first teaching, problem- / project-based teaching, and system training, respectively. Time budgeting configurability allows both for efficient code re-use and flexibility of deployment.

Adjustable complexity: simulations of physical processes typically rely on assumptions and approximations, which can be progressively relaxed and refined to achieve the desired precision of an observable. The Raman scattering of light from diatomic molecules, for instance, can be simulated with increasing precision by modelling a diatomic molecule as a rigid rotor, a non-rigid rotor, including vibration-rotation interaction, including centrifugal distortion, and so on [31].

Realism: simulations should present a coherent UI which reacts realistically to user input, taking into account the local educational requirements and the time budgeting and complexity configuration of the implementation under consideration. This requirement does not prescribe absolute verisimilitude with a research-grade interface (although this might be appropriate in context), but rather that the essential character and layout is adequately captured [32]. A parallel here can be drawn with the design choices of flight simulator interfaces as implemented on consumer PC hardware.

Appropriate use of affordances: a degree of overlap exists with research-grade simulations and control applications, which can use visual, audio, or other cues to allow efficient user interaction. Examples include: the use of highlights to show whether a fluid is present and / or flowing in a vessel, colour highlighting to allow at-a-glance estimation of temperature of components, and overlays to increase the contrast of edges in low-contrast images [3]. Context and practicability will determine which affordances could be implemented, with prioritisation determined against development resources available.

3 LABVIEW AS A MODULAR SIMULATION PLATFORM

While it is not essential that LabVIEW be the programming language in which simulations are implemented, for virtual laboratories it has a number of features which make it particularly suitable:

Ubiquity: LabVIEW is often used to implement main control applications, auxiliary supporting applications, and system prototyping in physics [33]–[39], chemistry [40]–[44], and engineering [45]–[49] research and industrial contexts. LabVIEW is also prominent in higher education in physics (usually control of simple table-top experiments) [24], [25], [50]–[52], chemistry (particularly common since a surge of interest in the 2000s) [26], [27], [53], [54], and engineering (often NI ELVIS-based, usually problem- or project-based learning) [28], [29], [55]–[57]. It is worth noting here that the engineering education LabVIEW implementations are clearly the most integrated into existing curricula and best-supported overall. In all three disciplines, a large corpus of code is already in-place.

Inherent parallelism: LabVIEW implements the "G" dataflow language [58], whose visual design allows a "natural understandability of dataflow diagrams", as noted by Kodosky et al. [59]. In G code, data flows between nodes by means of wires. If two sections of G code are not dependent on each other under the rules of dataflow, they are in parallel, and will run as separate processes. This dramatically simplifies the top-level architecture of simulation applications, and allows a large degree of modularity.
As of April 2018, the latest version of LabVIEW is LabVIEW 2018 [60], which is the version of LabVIEW used in this work. Note that there is also a parallel, mutually incompatible version of LabVIEW (LabVIEW NXG). Although LabVIEW NXG can be deployed successfully in an education environment [61], LabVIEW 2018 is used here as it is currently more mature, stable, and has better driver support [62].

3.2 Implementing a Modular Simulation in LabVIEW

A modular simulation can be implemented very straightforwardly in LabVIEW. The inherent parallelism of the language allows each simulation element to reside within its own for loop, which can run asynchronously with respect to other loops. Communication between loops can be achieved by means of queues, although notifiers (essentially lossy, single-element queues) or files might be more appropriate in different contexts. Dedicated state machines, also residing within their own for loops, handle UI monitoring and time budgeting accountancy.

The desired level of complexity and per-loop clock can be set either by controls on the front panel (UI) or by reading configuration settings from a file. The UI is monitored by a dedicated event-driven state machine which can communicate to loops and update UI elements programmatically. A dedicated time budgeting loop synchronises and logs the duration of user interactions and processes, particularly important in the "instant results with a time budget cost" operation mode.

The requirements of "realism" and "appropriate use of affordances" are primarily addressed by careful context-specific UI design, and in the manner in which the simulation activity is embedded in the module- and programme-level activities.

4 TILO PROOF-OF-CONCEPT: A REALISTIC LABORATORY SIMULATION

Having discussed the general motivations, simulation requirements, and a general LabVIEW template, we apply our proposed approach to a concrete example, TILO.

The Test of Inner Loop (TILO) experimental set-up was a mock-up of the Windowless Gaseous Tritium Source (WGTS) inner-loop gas handling system for the Karlsruhe Tritium Neutrino (KATRIN) experiment [5].

Hydrogen isotopologue mixtures are circulated around TILO's gas handling system and a Raman detection system measures their relative abundances. Dissociation of hydrogen isotopologues can be achieved by passing gas mixtures through a heated permeator. The TILO system was capable of observing changes in the relative abundances of hydrogen isotopologues passing through the permeator with an acquisition time of about 100s. A schematic layout of TILO is shown in Figure 1.

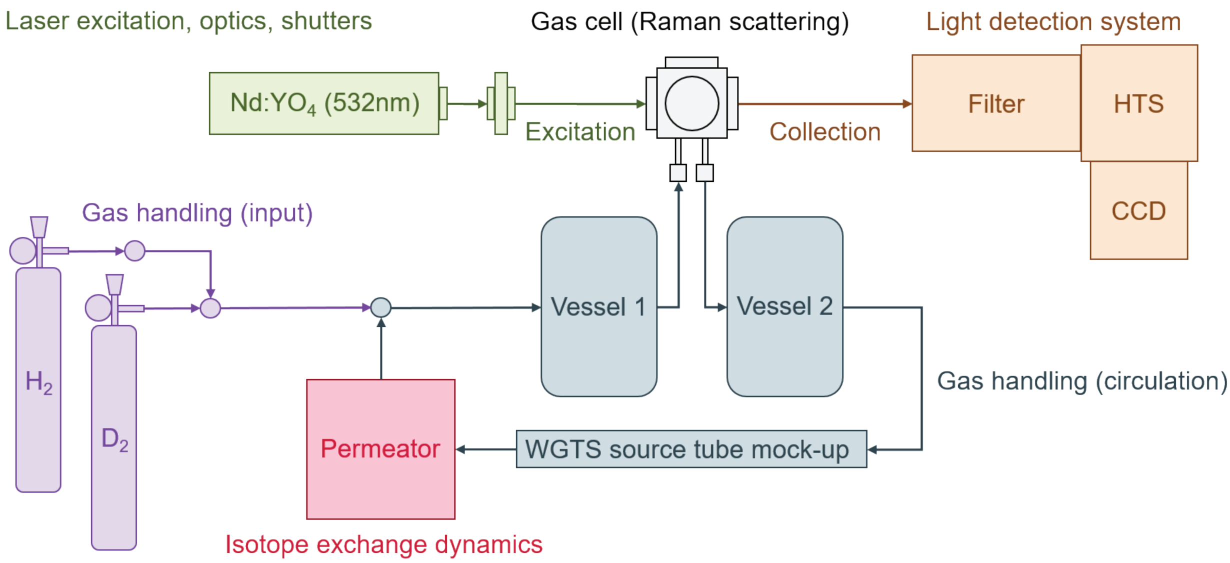

Figure 1. Schematic layout of TILO's principal experimental components. Note that principal components broadly map onto simulation elements. Adapted from [5].

TILO is a particularly useful example of an experimental set-up that contains multiple interacting elements. Simulation of TILO requires multiple mutually-interacting elements modelled at different physical and time scales, as summarised in Table 1. Simulation complexity would need to chosen to suit local context. TILO's dominant timescale is >1s, primarily due to the long exposure times for the CCD detector, requiring integration / averaging of faster simulation elements.

Table 1. Principal simulation elements for the realistic simulation of TILO. Note that these simulation elements broadly map onto principal experimental components.

Elements	**Basic timescale**	**Primary complexities (not exhaustive)**
Raman scattering	10^{-14} to 10^{-13}s	Scattering model depth, polarisation
Gas handling systems	10^{-3} to 100s	Connectivity model, diffusion, equilibration
Permeator vessel	1 to 100s	Isotope exchange dynamics, temperature
Light detection system	1 to 1000s	Transmission efficiency, noise, aberrations
Laser excitation	1 to 5000s	CW laser line shape, warm-up, mode hops
Safety infrastructure	$>10^{-6}$s	Interdependence of simulation elements

UI monitoring	Asynchronous	Implementation of simulated failures
Time budgeting	Asynchronous	Synchronising to dominant timescale (>1s)

The simulation elements summarised in Table 1 reside in separate for loops running in parallel. The UI monitoring loop is an event-driven state machine monitoring the front panel and acting as the master loop. Individual elements are state machines, slaved to the master loop. Inter-loop communication is via queues. A flexible, tab-based GUI provides a realistic, colour-coded, focussed view of the simulation, shown in Figure 2.

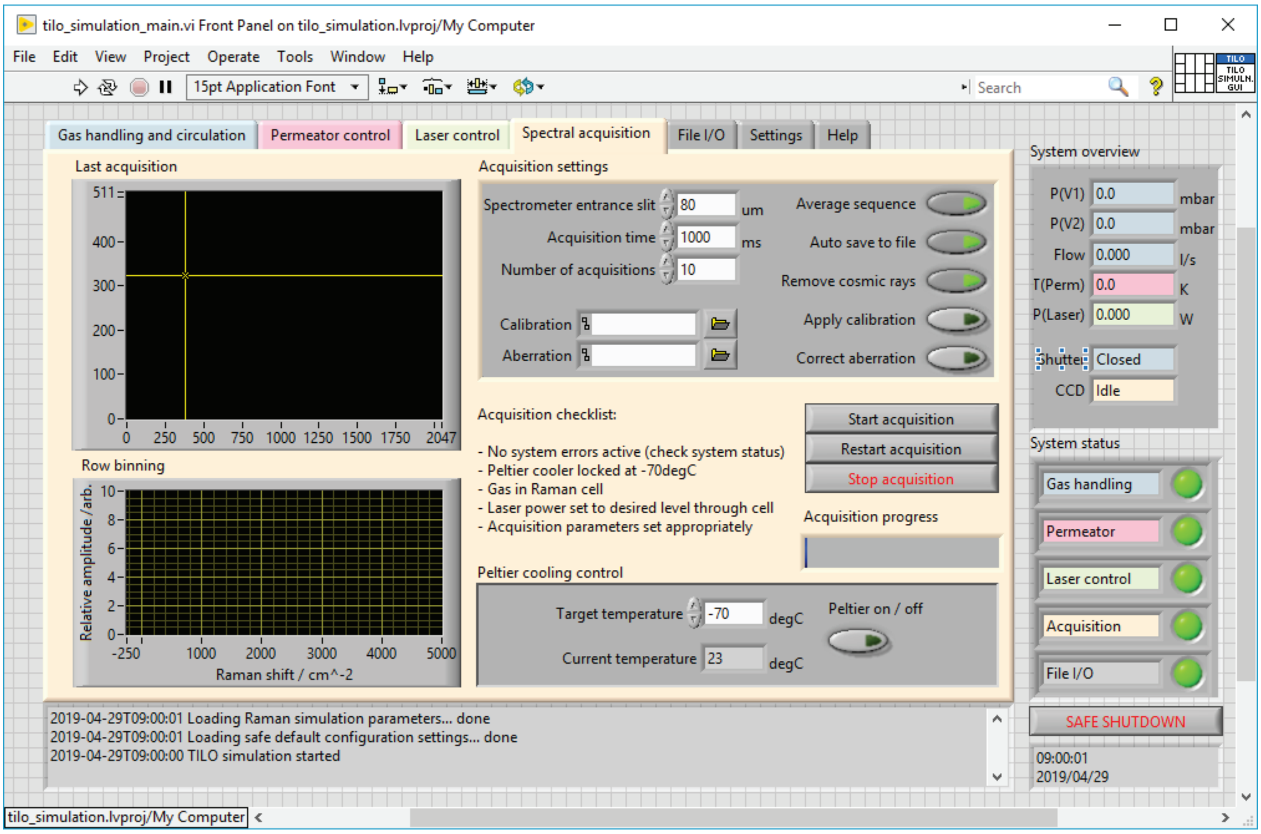

Figure 2. Tab-based GUI for the TILO simulation, with "Spectral acquisition" in focus.

4.2 Possible Operational Contexts for the TILO Simulation

The TILO simulation outlined in this work could be deployed appropriately in a number of educational contexts. Keeping the same UI and using the three time budgeting models outlined in Section 2.1, one can envisage the following three prototypical use cases:

Undergraduate problem-based learning (instant results): this model emphasises exploration of concepts and rapid iteration. Students would work in pairs or small groups. Activities would centre around correctly feeding in partial pressures of gas mixtures and finding a S/N optimal acquisition time / number of acquisitions for the Raman system. Measurements with / without gas circulation would be compared with fundamental calculations made off-line. Interactions between students would be primarily concerned with protocol, data I/O, and data analysis. Active learning and quick, iterative interactions with the simulation, together support developing an intuitive feel for the fundamental processes at work.

In this use case, complexity would be limited to the desired precision of the gas mixing and Raman scattering. While the light detection system would respond realistically (with noise, etc.), behaviour such as unstable system temperatures and unstable laser wavelengths would not be modelled. Session time: circa 2 to 5 hours, including analysis

Postgraduate (Master's) project-based learning (instant results with time budget): this model emphasises group interactions, peer-accountability, and project planning. A programme of system characterisation and optimisation, gas mixing regimes, and investigation of "unknown" gas mixtures would form the basis of a relatively long-term research-style project (several weeks) Students would be prevented from "acting before thinking" by the presence of a time budget – while results are instantaneous, the "real" generation time would be logged, and a time budget accordingly reduced. Students would meet weekly (or more frequently) to report progress and to suggest next steps.

In this use case, complexity can be increased over the undergraduate model to include the need to follow the actual system set-up and operational protocols. Behaviour that requires on- or off-line correction, such as spherical aberration in a transmission-based spectrometer would be included. Depending on the intended learning outcomes of the project, educational "booby traps" could be programmed into the simulation. For example, a failure of the Peltier cooling system for the Raman system's detector could be coded to occur during a particular week. Students would not be warned in advance, and their response and reaction to this occurrence could be worked into an educationally highly valuable reflective discussion in a group meeting. Such occurrences should be kept to a minimum, however, and require sound pedagogical justification and careful input from the academic supervisor.

This use case is the envisaged target for our proposal in most circumstances, bridging the gap between small-scale simulations and research-grade implementations in an educationally valuable way. While this implementation of simulations can support learning of fundamental concepts, it is assumed that students operating at this level already possess a working facility with the concepts.

Research student system training (real-time): this model emphases realism in all aspects. Depending on the training regime, complexity could be gradually ramped up, or present in full force from the beginning of a student's interaction. Interactions require the time they would have in a physical implementation of the set-up.

This use case is not likely to be used in an educational setting since the primary objective in training is for a student to have some simulation experience with running a particular experimental set-up. Set-ups that are inherently fast to operate, however, could directly implement a full simulation for the project-based learning case.

4.3 Extension of Proof-of-Concept to Remote Laboratories

In an era of swiftly evolving concerns around online security, adherence to standard security practices is of the utmost importance in developing distributed educational systems [63]. Unfortunately, full support in this area is lacking in the LabVIEW ecosystem [64], presumably as a result of limited demand from the traditional customer base. It is not a simple situation to rectify, because cryptography libraries are notoriously difficult to get right [65], while Autobahn-compliant WebSocket servers and clients are not trivial to build and maintain [66]. It is not practical or advisable for individual users to attempt to implement cryptographic solutions for TLS (to support https:// and wss:// connections) since they are vulnerable to attack via numerical implementation details.

Other web-native languages excel in this area, however, with open-source possibilities including Python, Golang and Rust. Python is the most widely used by scientists and engineers, but if embarking on a major project there are significant benefits in the cleanliness with which Golang handles asynchronous programming. Golang applications can also be distributed as a single executable on all platforms, including Windows [67].

In order to hybridise with LabVIEW, the LabVIEW code needs to implement a simple unsecured WebSocket client, which is protected by the PC's firewall. That client logs into a custom-built WebSocket proxy running on the same PC (coded in Python, Golang, Rust or other web-native language), that takes care of securing and encrypting communications with the outside world and managing the communications logic of the remote lab system. A variation of this approach was used successfully in the OpenEngineering Lab at the Open University, which offered large scale remote access to ELVIS II+ boards via secure WebSockets [68].

5 DISCUSSION

Our proposal to re-purpose / adapt / re-implement research-grade simulations and control software for educational purposes would provide a much-needed bridge between the small-scale, limited-scope simulations of the typical undergraduate virtual laboratory and realistic experience of a research-grade operational environment.

We suggest that this addresses a number of criticisms levelled at virtual laboratories, particularly the "virtual laboratories are too safe" criticism of Potkonjak et al. [2], which we contend could be easily addressed in the project-based learning (instant results with time budget) use case by programmed system failures / anomalous behaviour along the lines of similar functionality already present in flight simulation software.

Additional advantages include: re-implementation of existing software bases, availability of local expertise, and the ability to relatively easily scale / adapt simulation software to a wide range of educational use cases. Although simulations are not without cost in terms of computing resources, expertise, security, and system maintenance, in the context of realistic research-grade simulations, they are much more robust, far cheaper to implement, easily modified for different use cases, and much easier to maintain.

Our proposal is not without potential disadvantages. The time and effort required to develop a realistic simulation might prove to be significant (although offset by existing software and local expertise), the necessary educational logistics (course resources, academic supervision, etc.) must be put in place, and careful thought must be put into the embedding course / module design. While the startup costs are significant, previous experience with large scale remote laboratories [68] suggests that the payback for implementing robust, autonomous systems is significant. It allows the academics to concentrate on the usual academic matters [69] rather than continually trying to coax along a less well-developed system. Having said that, it is not an easy task and so there is great need for the academic sector to work together to share a common infrastructure so as to allow academics to focus on content development, rather than continually resolving the same delivery mechanism issues [70].

In conclusion, we have identified a gap in the educational application of simulations which we propose to address by repurposing research-grade simulation and control software to provide robust, scalable, and realistic virtual laboratories.

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Agile Learning in Continuing Education

Learning Structures and Materials for Work Based Learning

J. Longmuss
Sustainum Institute
Berlin, Germany

B. Hoehne
Beuth University for Applied Sciences
Berlin, Germany

Conference Key Areas: Lifelong Learning, Continuing Engineering Education

Keywords: : Agile Learning, self directed learning, work-based learning

ABSTRACT

With the "Agile Learning" concept, competences required in a company are acquired in the processing of real-life problems from the learner's own field of work. This means self-directed learning of teams in short stages, supported by coaches and reviewed by a "project owner". There are already experiences from 4 different companies with this new learning concept. Characteristics are:

- Learning new skills in the work process: no transfer losses
- Real projects, real work, no training simulation: no loss of time.
- Collegial consulting and reflection in the team: no loss of experience

After a short introduction into the learning concept, two methods to support agile learning projects will be discussed:

1. The learning card format

2. Enhancements of the Kanban principle

. These methods are not only suitable for use in companies, but also for project-based teaching methods at universities.

1 INTRODUCTION

Shorter innovation cycles in work require an increasing frequency and intensity with which lifelong learning is required and employees have to train themselves further and acquire new competences (see e.g. [1]). However, there are hardly any suitable continuing education formats for this need to date, since classical forms of qualification (e.g. seminar courses, further education courses) do not fit the individual competence requirements precisely enough and also react too slowly to the dynamics of change in companies.

Three requirements must be fulfilled for in-service competence development under these conditions:

- High scalability to make qualification measures from a few to several hundred hours possible;
- Adaptability of content in order to be able to take up new topics as quickly as possible;
- Connectivity to existing organizational structures and software infrastructure in order to be able to start with little effort.

In order to implement such competence development in companies, the "Agile Learning" approach was developed [2], which is based on the principles of research-based learning [3]. Its aim is to enable learning directly in the work process and on the basis of real tasks and thus to make competence building and knowledge transfer sustainable components of the company organisation.

1.1 Learning on the job at real tasks from practice

For a targeted development of competences that are needed in the company, it makes sense that the employees do not learn from general tasks or case studies from another environment, but rather from real problems from their own field of work. This means that

- first, the new competencies that are relevant for the employees or will become relevant in the foreseeable future ("learning topics") are precisely determined, then
- suitable tasks from company practice, in which these competences are needed ("learning causes"), are identified and finally
- these tasks are carried out exemplarily with technical and didactic support.

This learning directly at and in real practice has several advantages:

- The employees learn exactly what they need for their work and not what is offered in general seminars. The contents as well as the tools used (computer, software, etc.) are directly applicable in everyday life.
- The usefulness of each learning step is immediately apparent. It is not learned "in advance" in the hope of being able to use it one day.
- The learning topic becomes more accessible for the employees, because they have to provide significantly less transfer performance.
- In addition, the employees remain in the work process and are not completely off-site for longer training.

1.2 Organization of agile learning

Learning from real tasks from operational practice needs three types of actors:

- A person who represents the content of the learning topic, i.e. defines the objectives of the competence development project and accepts the results of the learning process: the "project owner".

- The employees, who work on this learning project as a team in stages, present the results to the project owner and reflect the process.
- The "coaches" (see figure 1) are accompanying persons who supervise the learning process from a technical, organisational and didactic point of view.

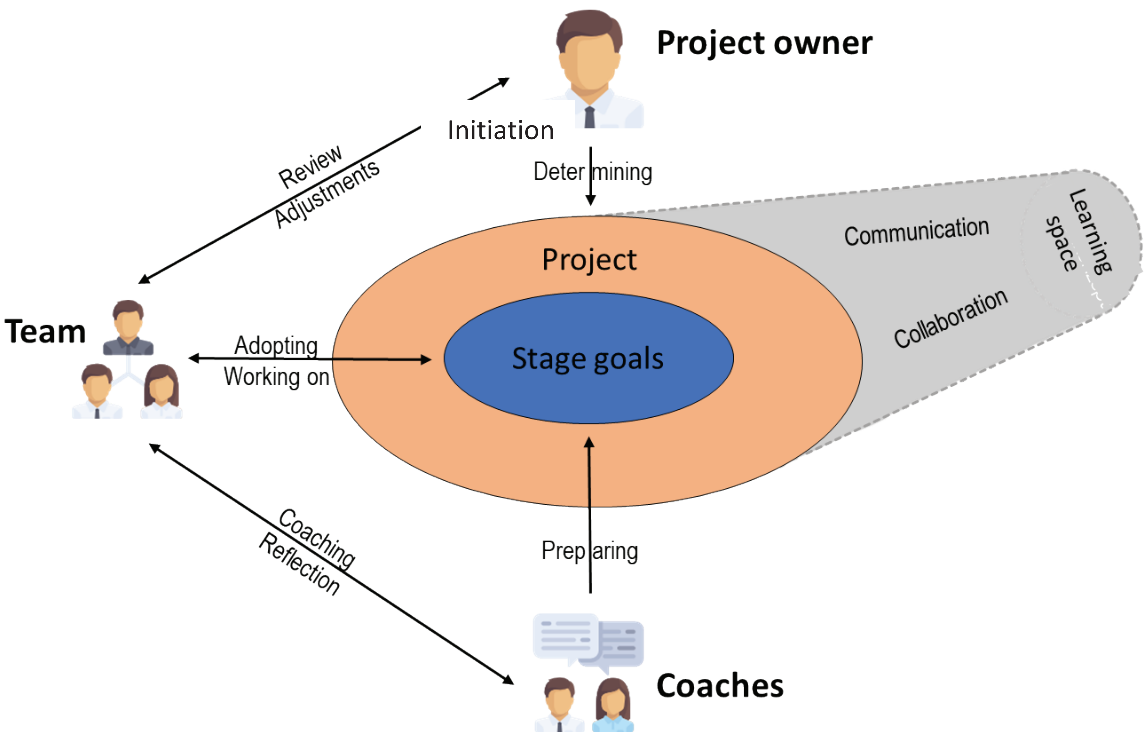

Figure 1: Roles and interactions in the agile learning project

The work on the learning task takes place alternately between individual and group work, with each phase of the individual work being followed by a stopover at which results are exchanged and compared in the team. At longer intervals - the learning stages - the learning progress is presented to the project owner and accepted by him/her or necessary reworking is made clear. This is followed by reflection on the learning process and an adoption of goals and procedures for the next stage (see figure 2). The coaches rather play the role of a learning facilitator or a supporter than of a traditional teacher.

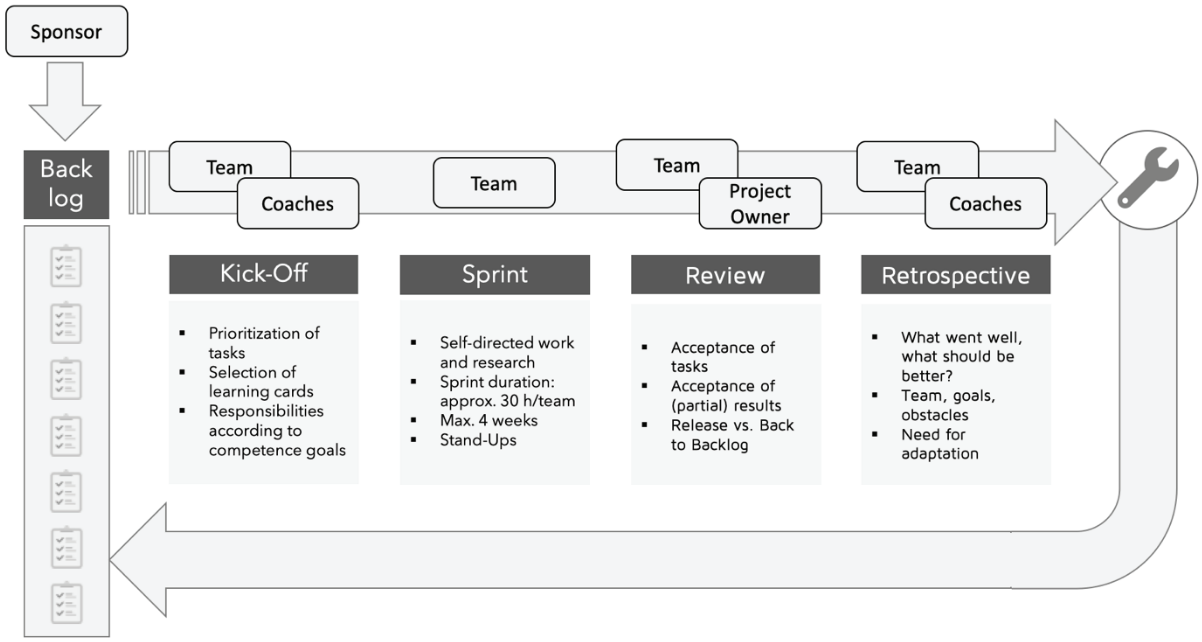

Figure 2: Stages of an agile learning project

This form of learning – in stages on the basis of tasks from one's own practice in interaction with a project owner and coaches – has been established in the last years in about ten German companies, from start-ups to big international enterprises and with learning topics ranging from project management or spread sheets to communication techniques (for details see [11]). It is mainly named "Agile Learning", although other terms are used, too (e.g. [4], [5], [6]).

Agile Learning has a structural similarity with agile methods of project management, especially "Scrum" (e.g. [7]). There are several differences, e.g. the team members are not yet experts for the tasks to be done in agile learning. Nevertheless, in many cases the extensive methodological toolbox developed for Scrum can be used to support a working process with the above mentioned roles.

2 METHODS TO SUPPORT AGILE LEARNING

Although IT-tools like SharePoint, Jira or Trello may support the general cooperation of the team both internally and externally, it does not take into account the special requirements of Agile Learning. To this end, the authors have developed various approaches, two of which will be presented in more detail here, as they particularly support Agile Learning in practice. These are

1. Learning Cards: A format specifically developed for the transfer of knowledge and
2. Kanban: the adaptation of a common method of work organization in Scrum.

2.1 Learning cards

Learning on the basis of practical tasks reverses the usual form of continuing education – and also the usual teaching at universities. There the teaching form of the "course" ([8]) prevails: First, a defined canon of knowledge is presented (in a lecture or in a script), which is then - in the best case - to be applied in more or less practice-oriented tasks. In agile learning, the practical problem is the starting point. The learners have to work on it, similar to Problem Based Learning (PBL, see e.g. [9], [10]), following the steps

1. Define the problem first
2. Develop solution strategies
3. Research the required knowledge
4. Develop solutions

This poses two questions for the coaches who prepare the learning:

- Which contents should be conveyed within the framework of competence development?
- How are the contents made available to the team?

In contrast to PBL at universities, for example, the knowledge required for processing should not first have to be researched in general sources. University libraries, etc., are usually too extensive to find specific information in a timely manner, and online searches often lead to sources of low trustworthiness. This leads to loss of time and to uncertainty, which is difficult to justify in a job-integrated competence development.

The task to be completed should therefore be prepared by the coaches in a form that is adapted to the goal-oriented, step-by-step process. For this purpose, the authors developed the digitally supported format of the "learning card". These are knowledge units whose processing usually takes no more than 30 minutes. This makes them easy to use even when learning at work, because they do not block long periods of time.

For these learning cards, this structure has proven to be effective:

- Name the occasions (e.g. "moderation of a small group") when it is necessary / helpful to process the learning card,
- Give exemplary results (e.g. "Can create a schedule for a work meeting") that can be achieved with the application,
- Present and explain the relevant content, and finally
- Set assignments in which the content must be applied.

These tasks should be formulated in such a way that the processing of the learning card also means a direct progress in the processing of the learning task, e.g. "List the work packages necessary for your project" or "Determine the communication strategy for your next stakeholder meeting?". In this way, the processing of the entire learning card as a whole or a single task from it can be integrated directly into the work planning of the learning group.

On the website https://academy.agile-learning.eu you may find some examples of learning cards which meet these requirements and are used for agile learning projects. For a better understanding, figure 3 shows a sketch of the structure – without graphics and content. This format is also suitable for other activating teaching/learning formats in which learners are to acquire knowledge on their own.

Burn Down Chart

Occasions

You want to visualize continuously,
- how much effort is still required to complete a project,
- how fast it's coming along and
- when it is likely to be completed.

Results

The learner is able to determine:
- The effort still needed to complete a project
- The pace at which the work is progressing
- The work status (ahead of schedule or behind schedule)

Burn Down Chart

A "Burn Down Chart" shows ...

For example, a burn down chart can look like this:

Insert graphic ...

Variants

The burn-down chart is available in two variants ...

Assignments

- Select one of your current projects, which you have an approximate overview of ...
- Estimate as carefully as possible how much effort is involved - measured in working hours, working days or task packages etc. - and mark the starting point on the vertical axis.
- Decide for on-schedule or resource-faithful planning and define the end date.
- Create a burn down chart for this project and draw the idealized process as a straight line ...
- ...

Links for further studies

A detailed presentation of the requirements and details of burn down charts can be found at ...

Figure 3: Sketch of a learning card

2.2 Kanban / Kanboard

Kanban (Japanese for “card”) is widely used in production systems and is a simple way to divide the work on complex projects into smaller tasks and visualize them. The principle is well suited for agile (learning) projects, because at the beginning of a learning project not all tasks are already known and priorities may change. In its simplest form, a Kanban board consists of three columns (To Do, Doing, Done) in which the tasks are organized, one card per task. For the organisation of an agile learning project it has become established to work with four columns (To Do, In Progress, Check, Done). The check column is introduced to signal that a task has been completed from the team's point of view. If the result was approved in the review meeting, the card with this task can be moved to Done.

Learning cards can easily be integrated into the work with a Kanban board. They are sorted as individual tasks under To Do. Shifting it to Check and then Done indicates the content has been processed. Thus, for the project owner, the status of the acquisition of knowledge is clear at the same time as the work status of the team.

If an analogue Kanban board is used, it should be visible and easily accessible to all team members and be updated regularly. If the status of the tasks cannot be seen "in passing by", regular stand-up meetings should be held between the team members (approx. 15 minutes) to inform all participants about the status of the processing. The team members have to take care on their own that they remain informed about status changes.

An alternative to analogue Kanban is the introduction of a digital Kanban board. This makes it possible to implement an automated notification in case of a status change of tasks, to allow comments on the status or to upload documents to the cards. Commercial tools such as Jira or Trello are often too complex for learning projects. In the project MeDiAL4Q (Media Competence in Digitisation - A New Agile Learning Culture for Part-time Qualification), the open source tool "Kanboard" was developed especially for use in agile learning projects (see figure 4) and is already in use in several companies.

It is a lightweight, digital Kanban solution that is structured by stages and stories, allows task-specific comments and uploads of final documents. It also clarifies responsibilities for tasks and To Dos. It gives a quick overview and eases implementation of learning projects alongside everyday business.

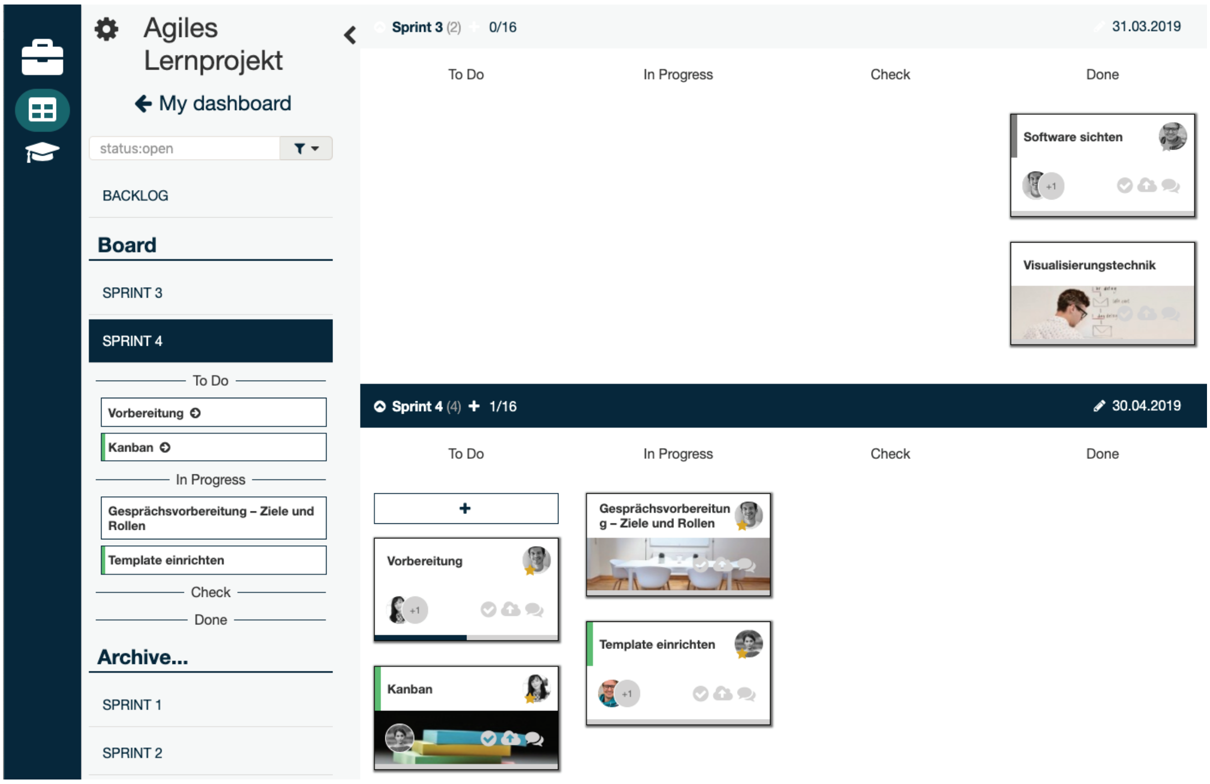

Figure 4: Screenshot of a KANBOARD page

3 PRACTICAL EXPERIENCE

The authors have now been able to use the concept of Agile Learning in several companies, some of them extensively, for the development of professional competencies. The concept had been evaluated using a broad variety of methods from interviews with participants, project owners and coaches over learning diaries and comprehensive reflections to standardised checklists to determine the degree to which the learning objectives were reached. In this, Agile Learning as a format has proven itself throughout [11], [12].

For the methods introduced here, the learning cards as a form of pre-structuring of knowledge and the Kanban board as an agile organizational form, some specific results have emerged:

Learning cards

- Learners are often focused on completing the learning task and try to avoid anything that is not directly related to it. Therefore, a learning card must facilitate and support this path directly and not be perceived as a detour. If the card does not bring a learner closer to her/his problem solution, it is unsuitable and will be disregarded.
- Playful elements such as a quiz increase interest and motivation.
- Further web links and possibly literature stimulate, once the interest is aroused, surprisingly often an additional occupation with the learning topics.

Kanban

- The simple visualization of tasks and their progress is very well received. In some cases the participants of learning projects have built themselves a Kanban board for their everyday tasks.
- Each card with a task that is currently to be processed must also contain a responsible person - who can change during processing. Otherwise it happens again and again that a task is ignored by the whole team.
- The board is only helpful if it is used continuously. If the work status recorded there is frequently not up to date, it is no longer observed.

4 RESUMEN

The combination of these two tools of support for Agile Learning has been successful in the companies were it was applied. The learning progress became more visible and transparent, in particular for the project owner. It made it also easier for the coaches to direct the process. This is an encouraging experience we would like to continue.

At the moment it requires still considerable time and effort to have the learning cards ready on time when required by the learning process. However, once more cards have been produced (within the next months there will be around 60, mainly on different aspects of project management and communication and all under an open licence), it will be easier to work with them because most cards can be used in many learning projects.

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Studying innovation with patents and machine learning algorithms: a laboratory for engineering students

R. Manzini[1], L. Ponta, G. Puliga, C. Noè
LIUC Università Cattaneo
Castellanza, Italy

L. Oneto
Università di Pisa
Pisa, Italy

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Keywords: Patents; Machine learning algorithms; innovation management; teaching.

ABSTRACT

Teaching innovation management to engineers is becoming increasingly relevant. However, it can be difficult to involve engineers in a discipline in which technical competences do not represent the core whereas professional and soft skills play a critical role. For this reason, adopting the proper teaching approach is key to capture the students' attention and interest. In our study, we propose a laboratory for teaching innovation based upon two elements that are very closed to the engineering mindset: patents and machine learning algorithms.

The laboratory proposes the application of machine learning approaches to patents data, for studying the innovation activity of companies. Three machine learning algorithms, Least Squares, Deep Neural Networks and Decision Trees are exploited. Their application is proposed to capture the relationships between relevant patents output variables (such as, for example, the number of forward citations, as proxy of the company's innovation capability) and the related input features (such as, for example, the number and type of patent technological classes).

By practically using this approach, students can be introduced to some relevant topics in innovation management, such as investments, protection, market identification, cumulation of knowledge.

[1] Corresponding Author
R. Manzini
rmanzini@liuc.it

1 INTRODUCTION

Teaching innovation management to engineers is becoming increasingly relevant. However, it can be difficult to involve engineers in a discipline in which technical engineering competences do not represent the core and professional and soft skills are more relevant. For this reason, adopting the proper teaching approach is key to capture the students' attention and interest.

2 LITERATURE BACKGROUND

2.1 Teaching innovation management to engineers

The literature on teaching innovation to engineers has received a great attention in the last years, as engineers very often are key actors in innovation processes, both in public and private organisations. Therefore, the educational role of engineering schools is increasingly relevant [1], as they have the task to train such (future) engineers with the proper set of skills and competences. To this aim, technical competences are to be complemented with managerial competences and with soft and professional skills, such as team-working, leadership, creativity, curiosity, autonomy [2]. Integrating this complex mix of technical, managerial and professional competences and skills is not easy: there is a pedagogical issue there, concerning the need to change the focus from theory to practice [13], to care about "how" to teach and not only about "what" to teach [14], to match with the learning style of today's generations [15]. An important suggestion found in the literature to answer to this pedagogical issue is the adoption of active learning approaches, such as, among others, problem-based learning and project-based learning. In fact, these approaches stimulate the acquisition of inquiry skills and the integration of theoretical knowledge, by engaging students in solving ill-defined, open-ended, interdisciplinary problems [3]. More recently, also simulation-based learning (SBL) has been proposed to teach innovation, as engineering students may strongly benefit from the involvement in a real-world environment [4]. For the same reason, the literature suggests the direct involvement of the industry when teaching innovation management to engineers, in order to propose managerial issues in their technological context. For example, Costello [4] suggests bringing entrepreneurs to work together with students within courses on innovation management and shows that this is very much appreciated by students. In summary, three main suggestions come from the above literature: the adoption of active learning approaches, the involvement of actors from the industry environment, the need for multidisciplinarity.

2.2 Patents and innovation management

Patents represent a rich and valuable source of information concerning invention and innovation at a global level. Furthermore, patents represent a relevant source of information because of public availability, limited cost of retrieval, reliability, formalization and standardization of the data and information embedded, historical data availability, rich content. For these reasons, patents have been widely studied in literature not only as tools for protecting innovations, but also as tools for investigating the innovation activity of public and private organizations [5] [9], [7]. In this last case, the literature usually refers to the concept of “Patent Intelligence”. Patent Intelligence can assist innovation managers in decision making processes, providing useful information and data concerning the technological and competitive environment, in terms of threats and opportunities. Given the wide, historical, standardized availability of patents data and information, patent intelligence can exploit even sophisticated, quantitative typologies of elaborations and analyses [5]. This is especially true in the era of the 4th Industrial revolution, in which sophisticated algorithms, such as machine learning ones, able to analyse complex, nonlinear and noisy data, are becoming widely diffused, thanks to the increased computational capacity and to the availability of Big Data. Neural networks are well suited tools to extract significant and useful information from that kind of data [6]. Recently, the use of these tools has been extended in the field of management and especially in the development of business research and innovation analysis, because of their capacity to provide accurate predictions, much better than traditional econometric analyses. Nevertheless, as reported by Lee et al. [7], the application of neural networks in the innovation field is still in an emerging state.

Starting from this background, in this paper a laboratory is proposed, based upon the use of patents and machine learning algorithms, aimed at stimulating the interest of engineers towards the management of innovation and providing them with some of the critical competences and skills in this field.

3 THE PROPOSED LABORATORY ON PATENTS AND MACHINE LEARNING

3.1 The idea

The idea is to exploit patents and machine learning approaches, which are very coherent with the engineers’ technical spirit and values, to teach innovation management, a topic not traditionally included within engineering curricula. In literature, an approach with patents and machine learning algorithms has been proposed recently by Ponta et al. [8]. These authors have employed three machine learning algorithms, Least Squares, Deep Neural Networks and Decision Trees, to a large set of patents data, for studying the innovation capability of companies (IC) and the factors that influence such capability, i.e. the determinants. Patent forward citations are used as proxy of IC (as suggested in [9], [7]), and patent features (e.g., backward citations, number and the type of technological classes) as proxy of IC determinants. IC is taken as the output variable and the patent features as input variables.

The approach proposed by Ponta et al. [8] has been exploited to build a laboratory on the management of innovation, giving the opportunity to discuss with students about some of the most relevant concepts and issues in the management of innovation: the innovation capability and its determinants, how they relate each other and how they can be measured, the role of patents, the investments in innovation, the cumulation of knowledge, the identification of markets for innovation.

3.2 The methodology

The idea described above has been discussed with four groups of stakeholders, separately: teachers of innovation management within an engineering school, students of industrial engineering, engineers working in the field of innovation and intellectual property, and institutional stakeholders, namely the Rector and the Dean of the Engineering School. The synthesis of the discussion process is given in table 1:

Table 1. Building a proposal: stakeholders involved

Stakeholders (n. and type)	**Topics of discussion**	**Needs, issues and suggestions emerged**
2 engineers working in the field of innovation and IP management	What are the competences needed for an engineer involved in innovation processes; how engineers within companies usually behave when involved in innovation processes: positive and negative aspects	Competences needed: IP tools and IP strategy; managerial issues and tools in the innovation process. Need for engagement and culture in IP
4 teachers of innovation management	How engineers usually behave when involved in courses on innovation management: positive and negative aspects; what are the basic topics for an engineer to be able to effectively contribute to innovation processes	Students are lost with qualitative topics; need to mix technical and managerial competences and soft skills; managerial topics are appreciated only when specifically connected to technology. The management of IP is badly perceived, it is considered as a legal topic
3 industrial engineering Students	How students perceive innovation management topics; main problems in acquiring competences in the management of technology; how they perceive innovation management with respect to their main technology studies	IP management is too legal; difficult to connect IP with managerial and technological topics; innovation management is a topic too fuzzy, not enough systematized, too qualitative
2 institutional stakeholders (Rector and Dean of Engineering school)	What is the role of the University and of the Engineering School in training engineers for innovation management; how to integrate technical courses with managerial ones; how to integrate technical competences with professional skills	Need to invest in topics concerning innovation and IP; need for interdisciplinary and soft skills for engineers; experiential learning as a fundamental tool for integration of different competences and skills; need for a direct involvement of companies

After having collected all the comments and suggestions from these stakeholders, a version of the proposed laboratory has been defined and is being proposed to students.

3.3 The proposed laboratory

The proposed laboratory, as resulting after the interaction and discussion with the four categories of stakeholders, is synthesised in table 2. The laboratory is organised around a real case, involving a company responsible for proposing a managerial issue that could be supported by patent analyses. This is important to give students a real ground to play in, with a clear technical environment to delve into. The laboratory could be adapted (and offered) to engineers coming from whatever discipline, by choosing the company and the case in coherence with the students' specific discipline.

Table 2. A laboratory on patents, innovation and machine learning algorithms

Module	**Topics**	**Time (hours)**	**Place**
1	Inventions, innovations, patented innovations	3	A company, in co-teaching with the R&D or Innovation manager and / or with the IP manager of the company
	Using patents as a strategic weapon	3	
2	Patents, big data and machine learning methods	6	University
	Machine learning methods applied in the field of innovation management: the measurement and prediction of the Innovation Capability of companies	6	University
4	Project work: applying machine learning approaches to patents data	8	Working with a company tutor on a specific topic / issue / objective, concerned with innovation management, proposed by the company. For example, predicting the innovation activity of competitors
5	Discussion of the projects results	4	University, inviting the involved companies or the Company
For a 10-15 people class, one "leading company" is involved hosting module 1 and proposing 1 project for applying machine learning approaches to patents and innovation (module 4). Three groups of students are created, competing on the same project: the best project will be awarded after the final discussion that could be held at LIUC or in the hosting company.			

1 or 2 tutors are necessary for supporting students during their project work. A patent database, allowing for efficient data search and download is necessary (e.g. Orbit). A tool for supporting artificial intelligence modelling is necessary (e.g. Matlab).

A first module, lasting 6 hours, is dedicated to the basic concepts of innovation, innovation management and patents, not in general, purely theoretical terms, but applied to the real context of a company. The involvement of the company's R&D or Innovation manager and of the Intellectual Property manager is crucial.

A second module, lasting around 16 hours, is dedicated to the explanation of some (basic) machine learning algorithms and to the realisation of some real applications, as for example those reported in Ponta et al. [8]. It is important here to merge knowledge about the algorithms with examples of applications in the real context of innovation.

The third module, lasting 8 to 16 hours (depending on the availability of the company) is dedicated to an application of machine learning approaches, with patent data, for supporting decision making around a specific innovation problem, proposed by the company. Just to make a few examples:

- The company identifies a set of relevant competitors and asks students to investigate (and predict) the innovation capability of the selected group of companies, testing and evaluating the various appropriate machine learning algorithm(s) in coherence with the type and amount of data available;
- The company identifies a specific patent variable to be investigated (taken as output variable, for example, the number of patents) and asks students to identify the patent input variables able to predict the selected output variable, selecting and applying the most appropriate machine learning algorithm(s) to the most appropriate set of patent data.

The fourth module is dedicated to the presentation and discussion of the students' projects. An evaluation committee composed by the company's R&D or Innovation manager, the IP manager, the university lecturer and the projects tutor(s) must be involved. The best project will be awarded by the Company. The final assessment will be based upon the judgment of the committee, in which different aspects will be considered: (i) knowledge about (and confidence with) the topics of IP, innovation management, application of machine learning algorithms; (ii) presentation ability; (ii) teamworking; (iv) accuracy and precision of the results achieved; (v) coherence and usefulness of the results for the company's needs.

As a whole, the proposed laboratory would introduce students to some relevant topics in innovation management, such as: the relevance and role of patents; the actual use of patents by companies; the use of patents to measure the innovation performance of companies and the drivers of a good innovation performance; the protection of innovation; the companies' investments in innovation and patents; the link among innovation, patents and markets; the effects of internationalisation on innovation strategic decisions; the relevance of cumulation of knowledge for successful innovation.

A beta version of the laboratory will be offered to industrial engineers in academic year 2019-2020, in order to define a final version to be proposed since 2020-2021.

In order to move from the beta version to the final one, a survey will be conducted at the end of the first release, involving all the four types of stakeholders, in order to evaluate the results achieved, the weaknesses and the strengths of the proposed laboratory. The stakeholders will be asked about whether the laboratory has helped in answering to the needs and issues emerged during the discussion (reported in table 1). This first release would also bring into evidence potential issues in group profiling and in group selection, to be considered for the final use of the laboratory.

4 DISCUSSION AND CONCLUSIONS

The proposed laboratory is expected to give positive contributions from both a practical and theoretical perspective.

4.1 Expected benefits for the engineering community

From the point of view of the engineering community, including both students and professionals, the proposed laboratory is expected to:

- stimulate the interest on innovation management and patents, topics recognised in the literature as particularly relevant for future engineers to play their role in society [10], [1];
- provide companies with a professional profile which is very useful and not diffused yet (especially in Italy), characterised by competences on patents and their use for supporting the management of innovation. This important benefit has been underlined with great emphasis by the stakeholders coming from the industry environment, who ask for a larger use of patents among engineers;
- provide an opportunity to strengthen links between industry and university, another key element in the curriculum of future engineers [4], thus offering students the opportunity to create a network with companies, potentially useful for their future professional life;
- improve the students' "soft" and "professional" skills, by engaging them in project-based learning and teamworking, by stimulating them within a competition, by embedding their work in a real-world context, by asking them a formal presentation of their work and by involving people from outside the university environment in their evaluation [3];
- offer students the opportunity to directly exploit systems and tools that are becoming increasingly relevant in the era of the 4th industrial revolution, such as artificial intelligence;

- collect a set of projects and companies' cases, by repeating the laboratory over time, which may represent teaching material to be exploited in future classes on the management of innovation.

4.2 Contribution to theory

From a theoretical perspective, the proposed laboratory will hopefully give a contribution to the literature on teaching innovation to engineers, a key topic for engineering schools [11]. In terms of contents, the laboratory suggests an original integration of innovation topics with artificial intelligence topics, of patents and IT, thus providing for a multidisciplinary approach, which is highly recommended in literature [10]. In terms of methodology, the laboratory is based upon three pillars: (i) active learning approach with a project-based activity, necessary to stimulate students towards an entrepreneurial approach in their work [12]; (ii) teamwork, necessary for developing soft skills such as leadership and relational abilities; (iii) quantitative analyses (with the support of appropriate tools), with a typical engineering approach. The mix of contents and methodology that characterises the proposed laboratory can be considered particularly useful for teaching innovation in the era of the 4th industrial revolution.

A contribution could also be given to the theory on patent intelligence, as new models of analysis and new cases can be developed through the activities conducted by students. This could be particularly relevant because of the exploitation of algorithms of machine learning, which are not yet widely diffused in the field [7].

The applications studied during the laboratory can also be interesting for the scientific community working on artificial intelligence, machine learning, data science. In fact, the analyses conducted allow to understand the advantages and limits of the different methods and tools of AI in a specific context of application: innovation management and patents.

4.3 Limits and future research

The paper presents several limitations that we plan to manage in our future research. First, the background literature on the pedagogical theories could be significantly enriched in order to better position the proposed laboratory and its results with respect to what suggested and discussed in that literature. Furthermore, some other suggestions aimed at improving the laboratory itself could be drawn from that literature.

Second, after the first “beta version” of the laboratory, some other pedagogical aspects of the laboratory could be studied, especially referring to the teaching and learning activities, the learning resources needed, the criteria for selecting and profiling students for groups formation and management, the assessment methods.

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Peer Reflection using an E-portfolio Improves Students' Leadership Behaviour

T. Maruyama [1]
Ehime University
Ehime, Japan

M. Inoue
Shibaura Institute of Technology
Saitama, Japan

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Keywords: Leadership education, Simulated experience, E-portfolio, Reflection

ABSTRACT

Leadership education has been conducted for first-year students of the Master's program at the Shibaura Institute of Technology's Graduate School of Engineering and Science for over ten years. Because students have limited opportunities to learn from hands-on leadership experience, we utilize a simulator to increase students' experience in a safe environment. A student is less resistant to take leadership actions following repeated practice in simulations. The program has five modules: knowledge, training by simulation, real action, reflection, and assessment. Results of previous studies showed that student leadership ability improved. This program was popular among students because of its interesting educational method and high effectiveness. Initially this was an elective subject for a small number of students, but following its success was made compulsory and is now attended by about 80 students. It became necessary to devise a way of reflection to bring educational effects to the larger numbers of students. The e-portfolio was introduced to invite students to review their behaviour. It became difficult for the faculty to provide individual feedback on e-portfolios to so many students. Looking back on experience from others is essential for improving the students' behaviour. Consequently, we introduced peer reflection, which is evaluated in this paper – the students exchanged reflections with each other based on behaviour recorded in their e-portfolios. Consistent with our hypothesis, students who tried to continually apply the new learning obtained by peer reflection in a real situation significantly improved their leadership behaviour.

[1] Corresponding Author
T. Maruyama
maruyama.tomoko.xl@ehime-u.ac.jp

1 INTRODUCTION

1.1. Leadership Education Background

A leadership education program has been conducted in the Master's program at the Shibaura Institute of Technology's Graduate School of Engineering and Science since 2008. In this program, leadership is defined as an ability to grasp the emotion of team members accurately, to collaborate with them, and to appropriately develop human relationships. In addition, leadership is not an ability inherent in a special person, but is rather for everyone to exhibit and develop. The traditional leadership education only gave students' knowledge regarding leadership in the form of lectures. Many students have never been leaders in their social and school lives and a leading role is unimaginable to them. Therefore, how to apply such knowledge through action is a big issue for them. Thus, a new leadership education program was created in order to enhance students' actions, which in turn improved quality of the educational method [1] [2] [3].

1.2. Education Using Simulation

Students who lack experience have huge gaps between knowledge and action and this makes it impossible for them to immediately turn knowledge into action. Therefore, we utilize simulation as a means to bridge these gaps (Fig. 1) [4]. The simulated experiences that students acquire through repetitive practice can provide a smooth bridge to reality.

Fig. 1. Simulation Interface

1.3. Levels of Learning and Educational Achievement Goals

This leadership education has four levels: knowledge, consciousness, action, and mastery (Table 1). In contrast, the traditional leadership education only provided learning level 2, and had no curriculum designed to transform knowledge into action.

Table 1. Leadership Educational Achievement Level

Learning level		Performance goal
4	Master	Establish new behaviour by a process of trial and error
3	Act	Act in the real situation as he/she did in simulated experience
2	Conceive	Realise needs of behavioural change and improvement points of daily action to reflect on oneself through the simulated experience
1	Know	Understand necessary knowledge to show leadership

2. LEADERSHIP EDUCATION MODEL

The leadership education model (Fig. 2) is constituted of five modules: knowledge, training by simulation, real action, reflection, and assessment [5]. At the start of a program, diagnostic evaluation is conducted. Next, a student enters a cycle of skill acquisition. The first step is for students to gain knowledge in the leadership arena through lectures. Then, they utilize simulation to experience leadership actions many times. Simulation provides a safe environment in which they can try many different approaches in taking leadership in various situations. A simulation exercise has the effect of raising awareness of daily improvement and the necessity for new action as a result of self-reflection, all of which stem from the various virtual experiences.

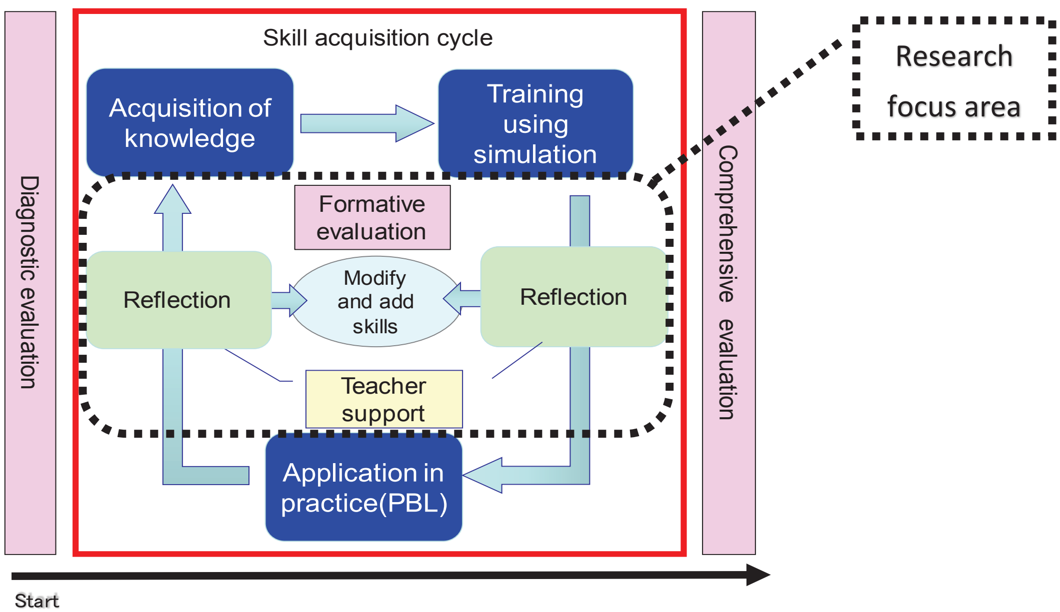

Fig. 2. Leadership Education Model

In the next step, students as a team utilize PBL (Project Based Learning) so that the above simulated experiences can help them to show leadership. Students can apply trained leadership to actual projects, and this increases their leadership skills. It is highly effective to apply conscious leadership to a project aimed at a specific goal in limited circumstances. This education repeats both of the steps above, raising leadership abilities in an upward spiral. Furthermore, the learner reflects on the simulated experience and the action in practice, and identifies the skill correction component and the skill that needs training. In the end, students complete a comprehensive evaluation. This paper focuses on the reflection component.

3. CHALLENGES TO REFLECTION IN LARGE CLASSES

This program is popular among students because of its interesting educational method and high effectiveness. Therefore, after initially being an elective subject for a small number of students, this was introduced as compulsory for many students (about 80) (Fig. 3). It became necessary to devise a way of reflection that would provide the educational outcomes for the increased number of students. The e-portfolio was introduced to invite students to review their behaviour but it became difficult for the faculty to provide feedback to so many students after individually analysing all the e-portfolios. However, looking back on experience from others is essential for improving the students' behaviour. Consequently, we introduced peer reflection – the students exchanged reflections with each other based on the behaviour recorded in their e-portfolios.

Fig. 3. A large-scale class of about 80 students

4. PEER REFLECTION USING AN E-PORTFOLIO

4.1. Effective Use of E-portfolio

E-portfolios (portfolios handled electronically) are used widely in the field of education. Effective use of an e-portfolio allows students to reflect on their own learning and improve their continuous learning practice. This process also connects students' regular lessons and extracurricular activities, and promotes integration of learning.

4.2. E-portfolio and Student Reflection

Students recorded the results of leadership behaviour in simulated experiences and practices in the e-portfolio once a week. This process continued for six weeks. Students performed mutual reflection on the behaviour in the simulated experience and practice described in the e-portfolio in the second week of these classes. The 81 students were divided approximately into groups of six. The flow of reflection was as follows.

Personal reflection

・Describe what happened

・Record your feeling then

・Evaluate advantages and disadvantages

・Analyse what caused this.

Group reflection

・Performed in groups of six people. By taking on the role of facilitator, the group members reflected on each member.

・The facilitator posed a retrospective question on the behaviour of the members. In this case, they asked other members how to do a specific task and generated various ideas.

・From here on, everyone discussed what action to take. Facilitators were required to show leadership so that they explored the possibilities of various actions.

Personal work

・Filled in the e-portfolio with action improvement measures and specific actions to implement in the future.

5. ASSESSMENT

The following assessments were conducted to verify whether student-to-student reflection influenced student leadership behaviour.

Evaluation 1: Change in leadership behaviour frequency

Evaluation 2: Degree of useful reflection between students

Evaluation 3: Relationship between the degree of helpfulness of reflection among students and the frequency of leadership behaviour.

5.1. Evaluation 1: Change in Leadership Behaviour Frequency

Students transferred the training on the simulator to practice in the PBL exercise. Students evaluated how often 12 items of leadership behaviour (Table 2) were performed in practice. They continued this process once a week for six weeks. The behaviour frequency criteria follow: 1, all of the time; 2, some of the time; 3, hardly ever; and 4, never.

Table 2. Leadership Behaviour

#	Items	
1	I can devise my work to contribute to an activity in a project.	Goal setting and achievement
2	I can understand specific situational requirements and encourage project members to achieve their goals.	
3	I can contribute to a project and achieve results through work.	
4	I can share knowledge and technology with a project member positively, and can strengthen a mutual relationship.	Communication and problem solving
5	I can discern the cause of a problem, acquire pertinent information, and determine a solution.	
6	I can carry out activities for the smooth progress of a project.	
7	I can coordinate socially relevant research tasks and	Proposal of

	plant the seeds for scientific innovation.	ideas and planning ability
8	I can propose an idea with confidence in a timely manner.	
9	I can create a plan foreseeing short- and long-term research results.	
10	I can manage my and others' ability to cope with high pressure situations or rapidly changing environmental conditions.	Understanding the situation and building relationships
11	I can engage a project member in conversation, listen attentively and positively, and show sympathy.	
12	I can raise motivation by managing a project member's level of stress.	

5.2. Evaluation 2: Degree of Useful Reflection between Students

Whether reflection between students improved subsequent leadership behaviour was evaluated, using the following criteria: 1, very useful; 2, useful; 3, a little useful; and 4, not very useful.

5.3. Evaluation 3: Relationship between the Degree of Helpfulness of Reflection among Students and the Frequency of Leadership Behaviour

We analysed the relationship between the degree of reflection between students and the degree of improvement in leadership behaviour (Table 2).

6. RESULTS

A number of items in the leadership behaviour shown in Table 2 improved as follows. Seven items improved for students who answered "Very useful", 4.9 items for "Useful" students, 3.7 items for "A little useful", and 3 items for "Not very useful". Students who answered that the other students' reflections were more helpful had more leadership action items with higher scores (Table 3).

We also extracted the first and sixth times from the description of the e-portfolio concerning the behaviour change of students who said that other students' reflections were very useful (Table 4). In the first reflection, these students ended with a description of the activity content, but in the sixth, they mentioned the awareness from the activity and the improvement measures for the next time. As a result of the analysis of the transition of the e-portfolio description over six weeks, the following has been confirmed. The accumulation of small behaviour coordination led to small success and the acquisition of new behaviour. Also, continuous reflection over six weeks showed that students have become accustomed to observe and monitor their cognitive processes. In addition, students learned to actively seek strategies for problem solving. These activities have led students to carefully evaluate their own growth. Furthermore, the implementation of peer reflection gave students a new perspective of self-assessment based on the opinions of others. Students need to maintain motivation for continuous reflection. It is essential for students to acquire knowledge as to the meaning, method, and effect of reflection as knowledge.

Table 3. Relationship between Effects of Student Reflection and Improved Leadership Behaviour

Effects of student reflection	Very useful	Useful	A little useful	Not very useful
Number of students	27 (36%)	38 (50%)	7 (9%)	4 (5%)
Number of improved leadership action items	7	4.9	3.7	3

Table 4. The First and Sixth Descriptions of Students' E-portfolios

	The first description	The sixth description
A	In the project exercises, I expressed the affirmation of the opinion by noting the opinion given by the members. I could encourage project members to express their opinions. However, I thought that it would be necessary to devise new ideas to allow deeper discussions.	In the project, each member worked to improve work efficiency by dividing the work. There was a lot of individual work, but when there was something I did not understand, we discussed this among members. I tried not to move in the wrong direction. As a result, we worked efficiently without going in the wrong direction.
B	As a team leader, I experienced difficulties in judging what the members could do and assigning them appropriate work. I was too attached to one job. Communication with the	I thought that the leader should have the most work, so I initially did not allocate much work to the members. I noticed that work efficiency of the members was bad. However, by

	members was not enough.	allocating work equally to each member, I was able to process tasks quickly and efficiently.
c	I thought that high-tension meetings would not have a positive impact, and I made an effort to move forward in a peaceful atmosphere from beginning to end. However, this lowered the motivation of the other members. It turned out that it was necessary to adjust the degree of tension so that the meetings could be productive.	At the meetings, we focused on what was important and what was to be prioritized. When the members' opinions were divided, we were able to select the agenda at the meeting smoothly by firmly conducting a factor analysis and analysing what was necessary.
D	I focused on firmly understanding all the project members. Not just remembering names and majors but also trying to determine at an early stage what kind of human beings they were. As a result, in group activities, it was possible to work after knowing the other person's situation, thus increasing the probability of success.	When trying to prototype the system considered by the project members, the members' roles became vague. Therefore, to make the best use of the characteristics of each department, we made a place to share knowledge of the field of each member, and all members decided to deepen mutual understanding. Then project progress became smoother.

7. CONCLUSION

Leadership education has been conducted for first-year students of the Master's program of Systems Engineering and Science for over ten years. The program has five modules: knowledge, training by simulation, real action, reflection, and assessment.

This program has been made compulsory and is attended by many students (about 80). It became necessary to devise a way of reflection to produce educational effects for the large numbers of students. Consequently, we introduced peer reflection – the students exchanged reflections with each other based on behaviour recorded in their e-portfolios. Students who tried to continually apply the new learning obtained by peer reflection in a real situation significantly improved their leadership behaviour.

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Effectiveness of Active-learning Methodologies in Math Courses for Engineering Students

Effectiveness of AL in Math Courses for Engineering Students

J. Mendonça, C.M.A. Pinto[2], S. Nicola
School of Engineering, Polytechnic of Porto
Porto, Portugal

Centre for Mathematics, University of Porto[2]
Porto, Portugal

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Keywords: active-learning methods, jigsaw, eduScrum, effectiveness

ABSTRACT

Global changes in Education are a consequence of changing demography, increasing globalisation, emerging demands on sustainability and the rapid evolution of digital era. These issues develop a generation Z of students, which are more independent that their Millennial counterparts. They prepare for their future, have college expectations and use educational technology for their academic progress. This causes a disruption and presents new challenges and opportunities for educators and administrators. Gen Zers, the demographic cohort after the Millennials, expect knowledge to be delivered to them in different ways. They are open to learn in environments where they are active players, where they do research, discuss results, multitask, and decide themselves. Professors have to fully take advantage of these Gen Zers' potential and think of new ways of introducing course materials, both in and beyond the classroom. This will exploit their ability to think critically, be problem solvers, and train their resilience to be prepared for society challenges. Thus, how can teachers involve students more actively in class? Active-learning (AL) methods are part of the answer. In an AL framework, students are directly involved in their learning process, instead of merely listen.

The purpose of this article is to summarize the implementation of AL methods (Jig-Saw, eduScrum, Think-Pair-Share) in Math courses at the School of Engineering of the Polytechnic of Porto. Students' perceptions of the application of AL in class are discussed. We hope to contribute to fruitful discussions of what should be best practices of application of AL methods in Math courses for Engineers.

1 INTRODUCTION

Generation Z is disrupting the way learning takes place. Gen Zers strive to be directly and actively involved in acquiring knowledge. They refuse to passively listen to what the teachers have to tell them. They want to attend classes in a fully engaged way. They don't want to go to classes to merely take notes to memorize, and write them down in an exam later on. Gen Zers tend to be more hands-on, more problem-solvers, they like interactive classes, and social learning environments, over traditional teaching methods. They are used and feel comfortable in studying collaboratively with other students, taking advantage of digital tools, like online forums, chats, amongst others. Moreover, as children of the digital era, the students of today want knowledge to take place at any time and so courses' contents are expected to be available on-demand, easily accessed, and not be limited to the classroom environment. These students are also more career-focused and are themselves driving changes in college curriculum, whenever this possibility is at hand. Thus, Gen Zers are mastering the change in the way they learn. They are pointing to a more learner-centered framework where students are owners of their own futures [1].

Providing our students with more stimulating learning environments and new approaches to teaching is part of a broader Education Strategy. Students are inspired mostly when they feel engaged, and this requires active-learning (AL) methods, to break with the passive way of delivering classes. Moreover, teachers are also requested to adequate teaching options to individuals and groups, as well as addressing students' individual needs [2].

Active-learning techniques promote creativity, cognitive processing, critical thinking, resilience, collaborative work, discussion [3,4].

AL has been steadily taking its own place in the world of Education. Australia was one of the first countries to embrace it, in 1990. New Zealand and the United Kingdom were the next countries in this sequel [5]. Researchers have been focusing on teaching in distinct environments and in new ways [6], as well as in exploring AL impact in improvement of learning outcomes [7]. More recently, in 2018, Holmes focused on the amount of energy, time and resources each student spends, in virtual learning environments, to promote their own knowledge [8].

There are several ways of encouraging AL environments, namely Jigaw, eduScrum, Think-Pair-Share, Problem-Based Learning, Flipped classroom, to name a few. Jigsaw is an AL strategy in which students work in small groups and are directly engaged with the working material. Students learn the topics by themselves and explain them to their peers. This promotes an increased knowledge and understanding of the topics and go against the typical exam-driven learning [9]. EduScrum is an adjustment of the Scrum Project management technique to Education [10]. In companies, Scrum is a technique favoring teamwork between collaborators in a productive and enjoyable way. With eduScrum, students organize and manage their own learning process. The teacher is only a guide, determining why and what to study. This type of collaborative educative process boots student's creativity, mutual collaboration, constant improvement, professional communication, teamwork, and critical thinking [11].

Think-Pair-Share (TPS) is a simple learning tool in which students find the solution to a given proposed problem. This strategy promotes students' oral communication skills, team work, and discussion, since they have to think individually about the problem, and then share their ideas on how to solve it with their peers. This discussion boosts students' participation and engagement in class and deepens the understanding of the reading materials [12].

With the aforementioned ideas in mind, the paper is organized as follows. In Section 2 we review several cases of application of AL methods to teach Math Courses in Bachelor degrees at the School of Engineering of the Polytechnic of Porto, since the academic year of 2017/2018. In Section 3, we discuss results of statistical analyses of students' perceptions of the implementation of these AL techniques in their courses. In Section 4 we conclude this work.

2 CASE-STUDIES OF AL AT ISEP

In this section we will present and describe the pedagogical methodologies and evaluation methods applied to a three case studies at ISEP, on the academic year of 2017/2018, first and second semester. The three case studies were at the courses Linear Algebra and Analytical Geometry (ALGAN) and Computational Mathematics (MATCP) at the Bachelor Informatics Engineering Degree, and in Calculus (CALCL1) at the Bachelor Biomedical Engineering Degree.

2.1 A case study at Linear Algebra and Analytical Geometry.

The first case study where it was implemented the active learning methodologies was on the academic year of 2017/2018, first semester in the course of Linear Algebra and Analytical Geometry of the Bachelor Informatics Engineering Degree at ISEP. This study target 308 students, separated in 5 theoretical lessons (T) with about 60 students each and 10 practical classes (TP) with more or less 35 students each. 'Typical' (traditional) T classes sizes can run from 70 to 100 students, with varying levels of individuals' needs and support, whereas TP classes consist at most of 30 students.

Theoretical Lessons

In the T classes, we implemented a hybrid teaching framework: some classes are taught using the traditional approach (TM), and some are taught applying the JigSaw method of AL methodology. The Jigsaw framework is based on a self-teaching strategy and was applied in 3 T classes. The students of the other 3 T classes were taught by the traditional method (TM), with the usual talk and chalk approach. Implementing Jigsaw in a class is achieved through the following procedure. The teacher must prepare notes for each of the topics, and these notes are made available to all students a priori. In class, the teacher starts by giving information about the global topic and the 4 subtopics which are intended to be learned. Students are then gathered in groups of 4, the so called Home groups. Each student studies one particular subtopic individually. This task may take 10 minutes. Then, all students who have learned subtopic i, $i = 1,2,\ldots,4$, move to an Expert group, for that specific subtopic i. There, they take 10 minutes to discuss between peers the key points of that subtopic and how they will teach it to the other members of their Home groups, when they return. After returning, they have 10 minutes to teach their peers. In the end of this activity, the teacher verifies the degree of understanding of the 4 subtopics by all students.

Practical Lessons

In order to implement the active learning approach with different methods, we applied in the practical classes of the Linear Algebra and Analytical Geometry course, the eduScrum methodology, as a part of an AL process. The 10 practical lessons were also divided in two categories, in 5 of them the eduScrum method was implemented and in the other 5 was used the traditional method. The course consists of 12 weeks. Each practical class of 37 students was split in 6 or 7 groups, of 5 or 6 students each. Every two weeks, students have Sprints, where they have to do a set of proposed exercises and are evaluated accordingly. In this scenario students are exposed to some discussion between their peers and with the teacher, which is an essential part of a mathematical classroom. Students in class are asked
to form groups of 4/5 members each (the team). After forming the groups, students chose a Student Master, who is responsible for distributing the tasks to each member of the group. This procedure ends with a Sprint Review, where the sprint assessment is performed. The latter consists of 3 components: 1) assessment of tasks performed - usually calculating the weighted average of accepted tasks; 2) activities not accepted have a 0; 3) assessing students' individual contribution by analysing the team's Scrum board. In the Sprint retrospective students discuss key points of the solved tasks and make a brief report of what went well, what went wrong, what should be improved in the next Sprint.
Figure 1 shows the distribution of each pedagogical method allocated to each form. In three theoretical lessons (T1, T4 and T5) is applied a self-teaching method, based in the Jigsaw framework. In the other two lessons (T2 and T3) we maintain the traditional teaching method (TD). Concerning practical lessons, these are divided in two categories: a) in 5 forms is implemented the eduScrum methodology; b) in the others 5 forms the traditional method is used.

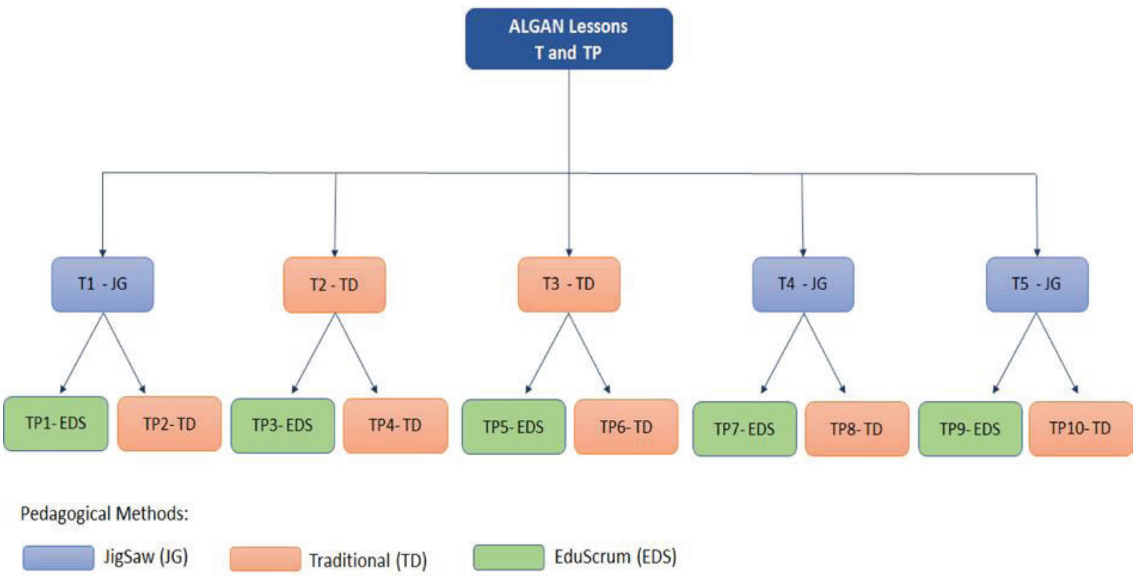


Fig. 1. Distribution of each pedagogical method allocated to each class in ALGAN [11]

The Fig.2 presents the excel worksheet for evaluating the students in the course of ALGAN. For 12 weeks the students had 5 Sprints, where each of them weight 25%, 20%,15%, 20%, 20% respectively. Then the students had two written assignment, with individual assessment each one weight 40% each. The total of Sprints value 20% and the individual assessment 80%.

Fig. 2. Excel Sheet for evaluate students sprints in ALGAN

2.2 A case study at Computational Mathematics.

The second case study in 2017/2018 where it was implemented the active learning methodologies was in the academic year of 2017/2018, second semester in the course of Computational Mathematics of the Bachelor Informatics Engineering Degree at ISEP. This study targeted 384 students, separated in 5 theoretical lessons (T) with about 80 students each, 11 practical classes (TP) and 21 Practical Labs (PL) of 15 students each. 'Typical' (traditional) T classes sizes can run from 80 to 100 students, with varying levels of individuals' needs and support, whereas TP classes consist at most of 30 students and PL runs from 15 to 22 students. Figure 2, shows the distributions of different pedagogical methods (JigSaw, eduScrum and traditional way of teaching) applied to each class. The course has a team composed by 9 professors with more than 20 years of experience at ISEP.

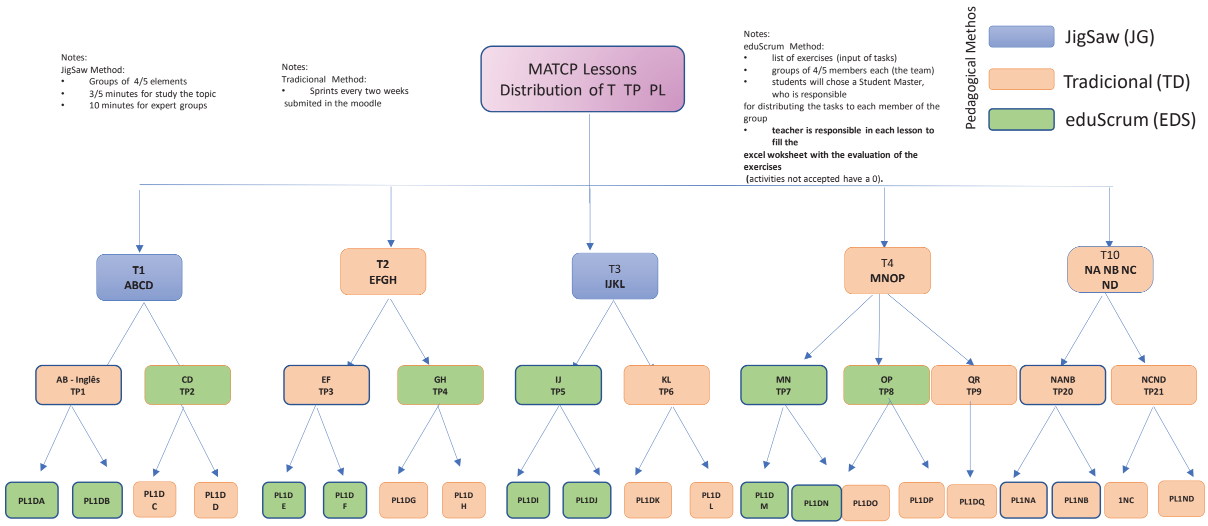


Fig. 3. Distribution of each pedagogical method allocated to each class in MATCP

It was created a table, table 1, where each teacher knew the type of lectures, methodology applied, tasks and evaluation for each class.

Table. 1. Distribution of each pedagogical method allocated to each class.

Teacher	Lectures	Methodolgy	Task	Evaluation
X	T/Practical	Traditional	Blackboard exercises	"---------------------
	Practical Labs	Traditional	Blackboard exercises	Moodle feedback/Excel sheet
Y	Theoretical	Jigsaw	Coach	"---------
		Traditional	Teaching	"---------
	Practical Labs	Traditional	Blackboard exercises	Moodle feedback
		Eduscrum	Coach	Eduscrum/Excel sheet
Z	T/Practical	Eduscrum	Coach	Eduscrum/Excel sheet
	Practical Labs	Traditional	Blackboard exercises	Moodle feedback
		Eduscrum	Coach	Eduscrum/Excel sheet
W	Theoretical	Jigsaw	Coach	"---------
		Traditional	Teaching	"---------
	Practical Labs	Traditional	Blackboard exercises	Moodle feedback
		Eduscrum	Coach	Eduscrum/Excel sheet
K	T/Practical	Eduscrum	Coach	Eduscrum/Excel sheet
		Traditional	Blackboard exercises	"---------------------
	Practical Labs	Traditional	Blackboard exercises	Moodle feedback
		Eduscrum	Coach	Eduscrum/Excel sheet
Q	Theoretical	Traditional	Teaching	"---------
	T/Practical	Traditional	Blackboard exercises	"---------------------
	Practical Labs	Eduscrum	Coach	Eduscrum/Excel sheet
P	T/Practical	Traditional	Blackboard exercises	"---------------------
	Practical Labs	Traditional	Blackboard exercises	Moodle feedback
M	Practical Labs	Traditional	Blackboard exercises	Moodle feedback
		Eduscrum	Coach	Eduscrum/Excel sheet
A	T/Practical	Eduscrum	Coach	Eduscrum/Excel sheet
	Practical Labs	Traditional	Blackboard exercises	Moodle feedback
		Eduscrum	Coach	Eduscrum/Excel sheet

Theoretical Lessons

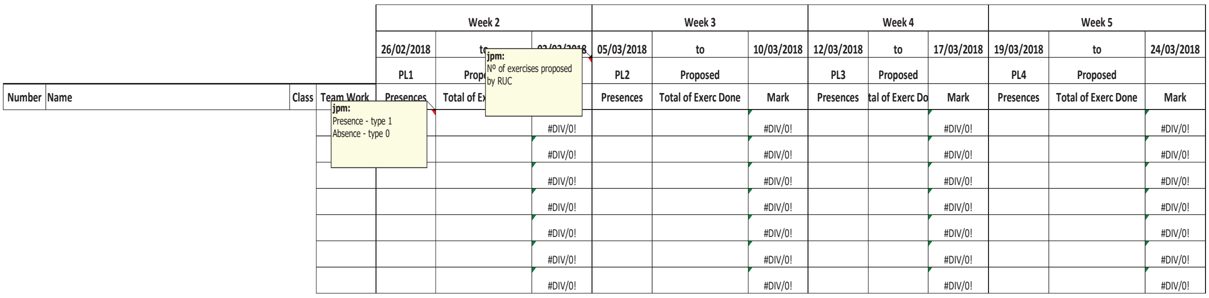
The theoretical lessons followed the same strategy of ALGAN classes. In the T classes, some classes were taught using the traditional approach (TM), and some were taught applying the JigSaw method of AL methodology.

Practical Lessons

To implement the active learning approach with different methods, we applied in the practical classes of the Computational Mathematics course, the eduScrum methodology, as a part of an AL process. The 11 practical lessons were also divided in two categories, in 5 of them the eduScrum method was implemented and in the other 6 was used the traditional method. The course consists of 12 weeks. Each practical class of 37 students was split in 6 or 7 groups, of 5 or 6 students each. Every two weeks, students had Sprints, where they have to do a set of proposed exercises and are evaluated accordingly (please see table1). In this scenario students are exposed to some discussion between their peers and with the teacher, which is an essential part of a mathematical classroom.

Practical Lab Lessons

Practical Lab Lessons were also divided in two models, 13 using the traditional method and 6 of them the eduScrum method. Each PL of from 15 to 22 students were split in 4 to 5 groups, of 4 students each. Every two weeks, students had Sprints, where they had to do a set of proposed exercises and were evaluated accordingly (please see table1). PL where prevails the traditional method, the exercises were done in the blackboard by the teachers and the evaluation of the different topics of the subject were done every two weeks (called sprints). These sprints were done by each student in the Moodle platform in the form of quizzes. The PL classes that prevails the eduScrum method, the role of the teacher was coaching the students. The teacher ask the right questions, to promote greater self-awareness and foster more informed decision making, so that the students can learn something. In this type of lessons is not the role of teachers that will solve problems, but rather, promote discussions, observations, pre-observations to collaboratively promotes the students learning. This will help students to think critically and be a life long learner. Every two weeks, Sprints, they had to present to the teacher the tasks solved and teachers put the evaluation of each student in an excel sheet, Figure 4.



				Week 2			Week 3			Week 4			Week 5		
				26/02/2018	to		05/03/2018	to	10/03/2018	12/03/2018	to	17/03/2018	19/03/2018	to	24/03/2018
				PL1	Prop		PL2	Proposed		PL3	Proposed		PL4	Proposed	
Number	Name	Class	Team Work	Presences	Total of Ex		Presences	Total of Exerc Done	Mark	Presences	tal of Exerc Do	Mark	Presences	Total of Exerc Done	Mark
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Fig. 4. Excel Sheet for evaluate students sprints in MATCP

2.3 A case study at Integral Calculus.

The third case study, where it was implemented the active learning methodologies, was on the academic year of 2017/2018, first semester in the course of Integral Calculus (CALCL1) of the Bachelor Biomedical Engineering Degree at ISEP. This study targeted 79 students with theoretical lessons (T) and 2 practical classes (TP) with more or less 35 students each. In the theoretical classes was applied the Jigsaw technique to deliver the theoretical concepts of the course. With this pedagogical technique students learned in both base groups and expert groups. They actively engage in the learning process and have a better understanding of their learning. The eduScrum methodology defines that incorrect work is not acceptable. In the sprints of the pratical classes, students will work in groups. The groups will have to Peer-review to improve the quality of the work (Peer Feedback pattern). This work tool aims to provide students with information about the evolution of their learning process. In the practical lessons we apply the eduScrum technique in solving problems associated with the contents of the lectures. The students learn in groups. There will be time for questions of students, where they can place and be answered questions regarding the curricular unit.

For 16 weeks the students had 5 Sprints with 30% as total. Then the students had two written assignment, with individual assessment each one value 35% each.

3 ANALYSIS OF STUDENTS' PERCEPTIONS

Students' perceptions of the implementation of AL techniques along the previous referred courses were evaluated from their responses to posed questionnaires. Students' opinions were rated according to the scale 1-Strongly disagree, 2- Disagree, 3-Slightly agree, 4-Moderately agree, 5-Strongly agree. We started in Calculus (50 responses) and ALGAN (209 responses) courses, in first semester of academic year 2017/18. These courses were followed by the MATCP (102 responses) course in the second semester of the academic year 2017/18. The first questionnaire has been updated due to inner characteristics of the different courses, but the main purpose, which was to measure students' perceptions to the AL framework remained unchanged.

The implementation of these methodologies in general has promoted a positive impact in students due to the teamwork approach, and evaluation based on their self-effort. In Fig.4, are shown the results *(mean$\pm$standard deviation)* of students' perceptions on several issues concerning AL, obtained for the three courses. The scale in the x-axis is [1,6], since there are cases of values of the standard-deviation greater than one. As we observe in Fig. 4, CALCL1 is a small dimension course, with a smaller number of students, presenting very positive and with small variability responses. The ALGAN course revealed positive means with higher variability for the same questions.

The questionaries' of MATCP suffered an upgrade in the questions posed to the students, since this course contains different class typologies and requires Excel programming tasks. Moreover, the authors with the experience from the 1st semester notice that the questionnaire should have different questions to gauge and assess more precisely the implementation of new methodologies applied in each course.

The questions on Table 2, "Work in assigned groups to complete homework and other projects" (p=0,002); "Be graded based on the performance of my group" (p=0,000); "Solve problems in a group during class"(p=0,000), "Do hands-on group activities during class" "(p=0,001), present significant differences between the courses. The students in CALCL1 course show higher mean values than ALGAN courses.

In MATCP the authors notice that students have good perceptions on these methodologies, evidenced by the following questions "Discuss concepts with classmates during class"; "Solve problems in a group during class; "the discussion of the topics between peers"; "I consider myself resilient when facing difficulties in some exercises in laboratorial classes " with mean values over 3.5.

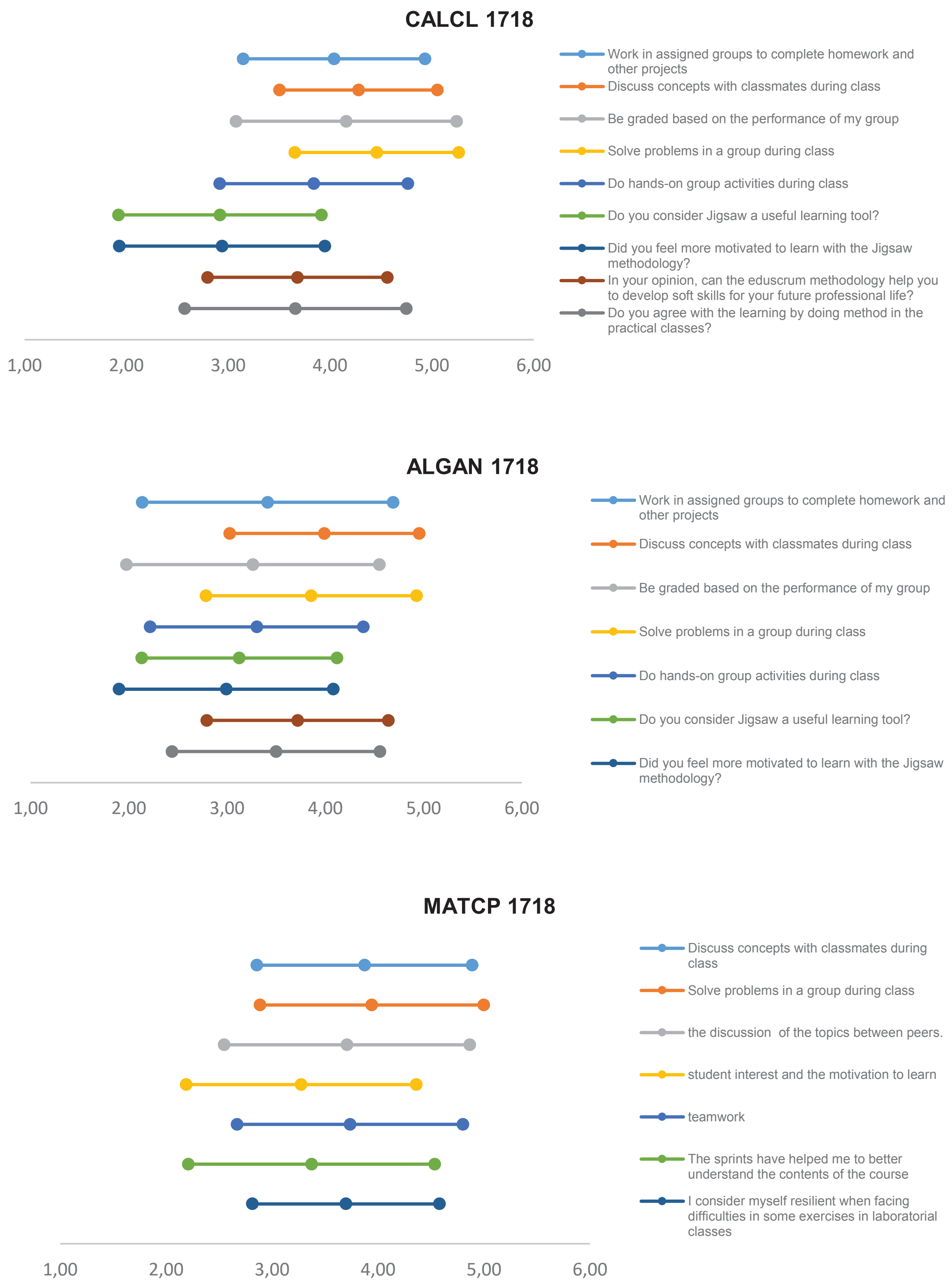


Fig. 4. Mean±standard deviation of Students' perceptions on CALCL1, ALGAN and MATCP Courses.

Table. 2. Mann-Whitney Test -ALGAN vs CALCULUS

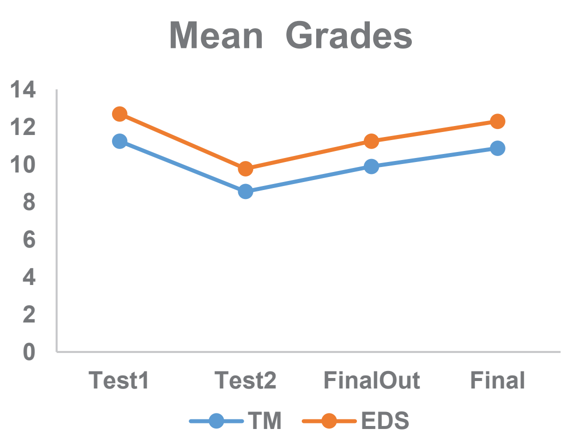
	Mann-Whitney U	p-value
Work in assigned groups to complete homework and other projects	3801	**0.002**
Discuss concepts with classmates during class	4374	0.057
Be graded based on the performance of my group	3056.5	**0.000**
Solve problems in a group during class	3439	**0.000**
Do hands-on group activities during class	3771	**0.001**
Do you consider Jigsaw a useful learning tool?	4650.5	0.206
Did you feel more motivated to learn with the Jigsaw methodology?	5006.5	0.633
In your opinion, can the eduscrum methodology help you to develop soft skills for your future professional life?	5068.5	0.728
Do you agree with the learning by doing method in the practical classes?	4775	0.325

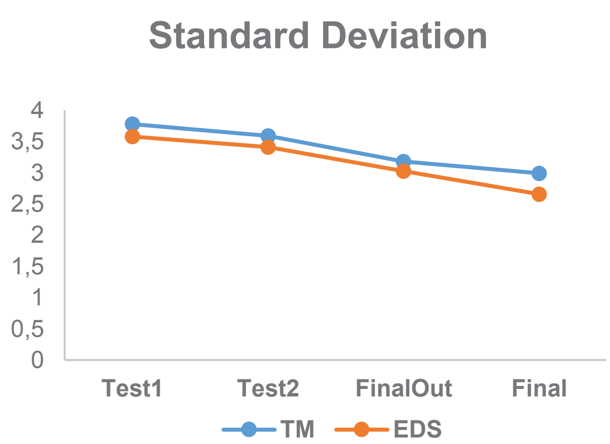
4 EFFECTIVENESS OF THE TWO TEACHING APPROACHES

We present here the analysis of the grades in the course of Computational Mathematics (MATCP). We compared the two groups TM – traditional method versus EDS- Eduscrum method, concerning, Test 1 grades, Test 2 grades, Final grades without Sprints' grades, and Final grades with Sprints. We considered for this study the students who've done all assessments along the course. We observe significant differences between these two groups for all cases as shown by the mean difference t-test results (Table 3).

Table. 3. Descriptive statistics and t-test for the two teaching approaches, TM and EDS.

		Test1 Grades	Test2 Grades	Final Grades without Sprints Grades	Final Grades with Sprints Grades
N	TM	151	151	151	151
	EDS	101	101	101	101
Mean	TM	11.235	8.551	9.893	10.868
	EDS	12.688	9.771	11.230	12.287
Standard deviation	TM	3.776	3.588	3.177	2.990
	EDS	3.577	3.407	3.022	2.655
t-stat		-3.055	-2.701	-3.337	-3.869
p-value		**0.001**	**0.000**	**0.000**	**0.000**





Moreover, from the observation of the mean grades we can conclude that the EDS method seems to produce better outcomes than the TM approach. The standard deviations are greater in the TM method, though not statistical significant by the F-test (variances). These results are in accordance with the ones already available in the literature, concerning assessment of students' of active-learning classes [13].

5 CONCLUSIONS

In this paper, we reviewed case-studies of application of AL techniques in Math courses at ISEP, since the first semester of the academic year of 2017/2018. We implemented stimulating learning environments and new approaches to teaching in different class typologies, namely eduScrum, Jig-Saw. We analysed statistically data from questionnaires given to students of the different courses. Students' perceptions were positive with respect to the application of AL techniques in these courses. Students enjoy working in groups and the increase in the responsibility of their learning process. We have also done a comparative statistical analysis of the students' grades along the semester in the written assessments for one Math course. The results reveal significant differences between the two groups of students, for all cases, as shown by the mean difference t-test results. The EDS approach produces better results, the mean grades are better for EDS students. Altogether, the results from the soft skills questionnaire and from the grades, reflect the boost of cognitive and social students' skills, reported in the literature for students engaging in active-learning frameworks. We highlight student's creativity, mutual collaboration, constant improvement, professional communication, teamwork, and critical thinking.
These novel methodologies have been developed in the scope of an Erasmus+ project, DrIVE-MATH - Development of Innovative Mathematical Teaching Strategies in European Engineering Degrees, which has had its beginning in September 2017, and will end in August 2020 https://ec.europa.eu/programmes/erasmus-plus/projects/eplus-project-details/#project/b1a82053-e093-4526-90d6-aa1efe1c6a1b

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What can be recommended to engineering teachers from the analysis of 16 European teaching and learning best practices?

D. Mesquita[1]
Centro Algoritmi, School of Engineering, CIEC – Research Centre on Child Studies, University of Minho
Guimarães, Portugal

T. Salimova (ORCID 0000-0003-4050-2702)
Economics Department, National Research Mordovia State University
Saransk, Russian Federation

E. Soldatova (ORCID 0000-0002-0318-2386)
Economics Department, National Research Mordovia State University
Saransk, Russian Federation

S. Atoev
Physics, Telecommunication and Technical disciplines department,
Technological University of Tajikistan
Dushanbe, Tajikistan

R. M. Lima (ORCID 0000-0002-7991-0132)
Centro Algoritmi, Production and Systems Engineering, University of Minho
Guimarães, Portugal

Conference Key Areas: another topic relevant to the conference

Keywords: Engineering Education; Best Practices; Active Learning

ABSTRACT

European Higher Education institutions have been implementing active learning strategies in different contexts. In order to learn and disseminate these approaches, it is important to understand how these successful active learning strategies can be implemented in new contexts.

The EXTEND ERASMUS+ project aims to develop Engineering Education Centres in Russia and Tajikistan in order to make a contribution for the development of these countries' schools of Engineering. One of the first steps in pursue of this objective is the study of European teaching and learning best practices and the definition of a set of useful recommendations for the teachers of Engineering schools. A question raised by this approach was what can be recommended to engineering teachers from the analysis of teaching and learning best practices? The objective of this paper is to

[1] Corresponding Author
D. Mesquita
diana@dps.uminho.pt

develop a method for the analysis and recommendations and to present the results of the application of this method in 16 European teaching and learning best practices.

The method was qualitative and developed by brainstorming between experts of the projects from different areas of knowledge. This method included the definition of a glossary, selection of best practices, collection of the information, analysis in relation to the best practices, analysis of maturity levels regarding the current level of partner countries and development of collaborative recommendations.

The main recommendations for the Russia and Tajik contexts are to develop Project Based Learning approaches in interaction with industry, and additionally for Tajik partners to develop entrepreneurial and management competences in engineering students.

1 INTRODUCTION

The Bologna process aims to improve the European Higher Education (HE) system, contributing for a better transition of graduates to professional practice, through the introduction of new or more effective approaches for international mobility, quality of HE systems, and innovative curricula, including teaching and learning strategies inspired by Active Learning. Thus, the modernization of the HE systems has been acknowledged as a core condition for the success of the Lisbon Strategy (2000).

Post-socialist countries are going through dramatic changes in higher education, caused by the transition toward a market-driven economy. HE institutions start looking for new sources of funding and involving teachers / researchers into entrepreneurial activities. Russia joined the Bologna process in 2003 and went through a structural transformation of traditional training for engineers of 5 to 6 years, toward a two-tier system [1]. According to the research conducted in the *National Development Strategy for development of the republic of Tajikistan until 2030* Engineering training is poorly integrated with scientific activities and interaction with the external companies, which adversely affects the quality of training and at the same time reduces the potential of preparing qualified specialists [2]. An EU funded project in the frame of ERASMUS + aims to enhance the capacity of HEIs in Russia and Tajikistan in engineering education. The EXTEND project aims to launch Engineering Education Centres to develop teacher competences and improve the quality of education in engineering disciplines.

As EU universities have a large experience in the creation and implementation of innovative student-centred approaches to teaching and learning activities, the analysis of EU best practices will contribute for the development of useful recommendations for both Russian and Tajik HE institutions. Nevertheless, the analysis of best practices raises questions related to what can be recommended to engineering teachers from the analysis of teaching and learning best practices? The objective of this paper is to develop a method for the analysis and recommendations and to present the results of the application of this method in 16 European teaching and learning best practices.

2 METHODOLOGICAL APPROACH

In order to have a good grasp of the European best practices, there is the need to collect and analyse information about a large set of best practices on teaching and learning strategies. Thus, a list of best practices, based on Active Learning practices or approaches, was created. These were chosen considering recommendations from project experts, availability of information in web sites and publications and available capacity to process the information. It should be noted that this list does not have the intention to cover all best practices, but has the intention to create a good perspective on different innovative approaches being developed in the European context. After defining the list of cases, there was the need to develop a glossary to increase the coherence of the analysis and a form for selection of the most important information to extract from each case. Finally, a maturity model methodology was applied for classification and analysis of the best practices.

2.1 Methodology steps

Fig. 1 presents a process model followed by the team, during the collection and analysis of the information. In Step 1 the team collected qualitative information about EU best practices in teaching engineering disciplines using the frameworks previously defined. Step 2 is related to the analysis of best practices collected using a form (according the framework) and content analysis. The form allowed to collect qualitative data based on experts' opinion. This data was then analysed using content analysis strategies. For data analysis, a content analysis was carried out to identify recurring topics as well as contrasting patterns amongst teacher development approaches and teaching methods [3]. Step 3 included identification of the gaps between the EU Universities best practices and Russian and Tajikistan realities in training engineers and development of recommendations for adaptation and possible dissemination of the identified European approaches. This step used a maturity grid as an assessment tool.

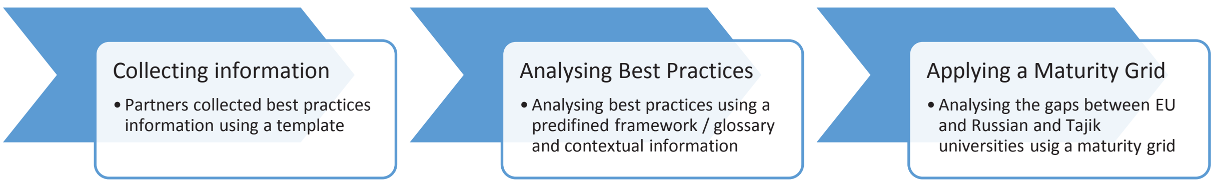

Fig. 1. Execution, analysis and development phases

2.2 Glossary

For the aims of this work, "a best practice" is defined as an Active Learning relevant teaching and/or learning tool/method/approach/structure implemented in a real life setting in education of bachelor, master or PhD degree students majoring in engineering at one or several EU universities and which has been favourable assessed in terms of adequacy (ethics and evidence), effectiveness and efficiency related to process and outcomes. Other criteria are important for a successful transferability of the practice such as a clear definition of the context, sustainability, intersectorality and participation of stakeholders [4]. The best practices described in the chapters below meet also the follow requirements: a multidisciplinary approach, a breadth of education, leadership on the national level. Finally, identification and selection of best practices were based on expert opinion of project team members following the criteria's mentioned above, the availability of information and the available capacity for processing the information. The list of 16 best practices provided was created for further analysis.

The best practices focused on using a wide variety of active learning strategies, which were classified and defined according to a predefined glossary (*Table 1*). Active learning is an approach to learning in which teaching is prepared in order to engage students in the learning process, by creating meaningful learning contexts. These learning contexts allow students to understand the relevance of *what* they learn and *what for*. An Active learning environment includes enthusiasm, energy, engagement and action. Critical thinking about learning is also a key-issue [5];[6];[7];[8] Different methods and principles can be implemented as Active Learning strategies, as referred by [9].

Table 1 presents active learning strategies classified and defined as: Problem-Based Learning (PBL); Project-Based Learning (PBL); Gamification; Team Based Learning; Work Based Learning; Research Based Learning. This list represents some of the most common active learning approaches but some other approaches can be considered during the analysis phase.

Table 1. Glossary of Active learning strategies

CONCEPT	DESCRIPTION
Problem-Based Learning (PBL)	Is an educational approach whereby the problem is the central point of the learning process [10]. The type of problem is dependent on the specific learning environment, but are usually presented as a case, based on a real life issue or a realistic approach. The problems are selected and edited to meet educational objectives and criteria. It is crucial that the problem serves as the basis for the learning process, because this determines the direction of the learning process and places emphasis on the formulation of a question rather than on the answer. This also allows the learning content to be related to the context, which promotes student motivation and comprehension. It is essential that the directing force is consistent with the way the assessment drives the educational method.
Project-Based Learning (PBL)	Is a Problem-Based Learning approach, in which teams of students must develop a solution for a problem. Thus, this also an approach based on real life issues, where the problem is ill defined and the students must be able to define the problem before developing the project solution. Dealing with an open problem, teams of students can develop several different solutions that may not even be expected by the teachers [11];[12]; [13]). Teachers act as coaches, mentors or supervisors, depending on the phase of the project and the specific learning environment. In most situations, a Project-Based Learning approach is developed during a period of time longer (e.g. semester) than Problem-Based Learning (e.g. 4 weeks) [14].
Gamification	Gamification is the use of game design elements characteristic for games in non-game contexts, in order to o increase user experience and engagement. This is not the same as serious games because the learning activities may not include simulation nor competition [15].
Team Based Learning	Team-Based Learning is an evidence based collaborative learning teaching strategy designed around units of instruction, known as "modules," that are taught in a three-step cycle: preparation, in-class readiness assurance testing, and application-focused exercise. A class typically includes one module [16]. TBL combines small and large group learning by incorporating multiple small groups into a large-group setting [17].
Work Based Learning	Is the term being used to describe a class of university programs that bring together universities and work organizations to create new learning opportunities in workplace. Typically, this may include the following types of activities: visits to professional places, networking interaction opportunities, and project-based learning approaches in interaction with external organizations [18].
Research Based Learning	Curriculum is designed around inquiry-based activities in order to create and develop new knowledge. The focus of learning through inquiry; the teacher-student division minimized and students are engaged in research practice [19]; [20] .

2.3 Maturity grid

For the aims of analysis of maturity levels regarding the current level of using active learning strategies by Russian and Tajik universities a maturity grid developed by Ph. Crosby (Crosby, 1979) has been choosing. It provides the opportunity to identify what might be regarded as good practice (and bad practice), along with some intermediate or transitional stages [21]. The maturity grid has a strong evolutionary theme, suggesting that organizations are likely to evolve through five phases - Uncertainty, Awakening, Enlightenment, Wisdom, and Certainty – in their ascent to the excellence. This can be analysed from uncertainty, no comprehension of the necessity in using the method, to certainty, proficiency and sustainability in using and applying the method. The using of this tool allows to distinguish the gaps between the European and Russian practices and approaches in training engineers.

2.4 Data Collection Summary

The 16 cases of teaching and learning best practices analysed in this study are summarized in Table 2.

Table 2. Summary of the European best practices in using Active learning strategies analysed in this study

University / Best practices*	Problem Based Learning	Project Based Learning	Gamific. / Serious Games	Team Based Learning	Work Based Learning	Research Based Learning	Other
1. AAU/PBL	X	X					
2. CUT/MMPE			X				
3. DTU/ENG		X				X	
4. DUT/ENG							X
5. IPG/IE					X	X	
6. MU/DATA		X					
7. TU/SENG							X
8. UCL/IEP		X					
9. UMinho/ENG		X					
10.UMinho/IEM-IM41		X					
11.UMinho/IEM-IM11		X					
12.UMinho/LEAN			X				
13.UW/APPR					X		
14.UW/DES							X
15.UW/REFL							X
16.UW/SELF							X
Total	1	7	2		2	2	5

* UMinho/IEM-IM41 - University of Minho (Portugal) / Industrial Engineering and Management Integrated Master (4th Year, 1st semester). UMinho/IEM-IM11- UMinho / Industrial Engineering and Management Integrated Master (1th Year, 1st semester). UMinho/ENG - UMinho / Engineering Programs. UMinho/LEAN - UMinho / Lean management courses. CUT/MMPE - Częstochowa University of Technology (Poland) / Master in Management and Production Engineering. DUT/ENG - Delft University of Technology (Netherlands) / Faculties in engineering, applied science and design. AAU/PBL - Aalborg University (Demark) / Educational programs adopted a purely Problem-Based Learning (PBL) approach. UCL/IEP - University College of London (UK) / Integrated Engineering Program. IPG/IE – Institut Polytechnique de Grenoble (France) / Master in Industrial Engineering – Sustainable Industrial Engineering program. DTU/ENG – Technical University of Denmark (Denmark) / General Engineering programme (BSc). TU/SENG - Tampere University (Finland) / International Degree Programme in Science and Engineering, BSc. MU/DATA - Maastricht University (Netherlands) / Data Science and Knowledge Engineering. UW/APPR - University of Warwick (UK) / Engineering Degree Apprenticeship. UW/SELF - UW / Self-Assessment. UW/DES - UW / Signature Pedagogies & Design Thinking. UW/REFL - UW / Reflective Practice & Learning Logs

Finally, an integrated discussion and recommendations was developed and presented in the last section of the paper.

3 BEST PRACTICES ANALYSIS – ACTIVE LEARNING STRATEGIES

For the aims of the study, 16 best practices were selected among European universities. For 7 of them, PBL model is defined as dominating. At the same time a wide range of strategies such as work based/ research based / problem based learning are used. In order to have a better grasp the teaching and learning experiences of the European universities, some common elements were identified amongst them.

First, all PBL models described present an interdisciplinary approach, which could happen between different areas of one program, or between different programs. For instance, the project development in the context of best practices represented by University of Minho (best practices 9 and 10 in Table 2), includes incorporating the knowledge and competences inherent to all courses studied by the students in the semester, which implies a collaboration amongst the course teachers. It is worth mentioning that PBL analysed in the best practices of European contexts, is used in different years of the programs, both in early and advanced semesters. The difference is in the content of the approach. What is specific for the first semester is that it is usually based on basic sciences with a realistic problem related to the professional practice. Applying PBL in more advanced semesters implies more autonomy from the teams of students and much more responsibility of the students for the solutions resulted in the projects.

Second, most of PBL models include close collaboration with internal and external stakeholders. The coordination team usually includes teachers, tutors and educational researchers from different schools/departments maintaining a wide diversity of ideas and experiences. In some cases, e.g. case of University College of London (best practice 8 in Table 2), special universities units provide students with teaching, learning and training support within the project development. Collaboration with companies, high schools or media partners within project development allows to open the university to “outside”, providing suggestions and solutions for real problems. For that reason, collaboration is a key/element in these models, not only in terms of collaboration between team members, but also with other stakeholders.

Some cases show a great combination of active learning strategies. For instance, the experience of Aalborg University (best practice 1 in Table 2) is focused on Problem Based Learning with project work based on authentic problems. It offers complex environment, engaging students in real contexts and provides them the opportunity to participate in interdisciplinary activities and develop their professional skills in the real-word.

Serious games and Gamification are approaches implemented at University of Minho and Częstochowa University of Technology (best practices 2 and 12 in Table 2) implies to use different type of equipment, tools and materials and has a strong hands-on simulation nature. In this context, students can visualize, touch and reflect about the content through the experience of learning by doing. Thus, students plunge into real practice through the hands-on approach.

Best Practices presented by Institute Polytechnique de Grenoble and University of Warwick (best practices 5 and 13) focus on work-based learning which is quite related to the practicum. In this case, external stakeholders are also actively involved in tutoring and mentoring of student’s projects. Students are encouraged to go inside of an industrial company or a research institute, during one semester to focus on a research problem or develop an innovative idea.

The case of Tampere University (best practice 7 in Table) presents an Active Learning approach, in which students are challenged to work in both ways - independently focusing on their own needs, motivations and expectations and taking responsibility for their studies in close collaboration with their fellow students communicating and working as part of a group. There is a wide range of activities that can be selected: workshops, events, conferences, social projects, etc. Finally, best practices 14, 15 and 16 in the Table 2 provided by University of Warwick are focused on developing student's imagination and creativity, empowerment and engagement.

4 DISCUSSION AND RECOMMENDATIONS

The results of analysis of 16 European universities best practices in using active learning strategies show their diversity and potential for dissemination, regarding the identified approaches, into the Russian and Tajik Higher Education Institutions. The study was also aimed at identifying the gaps between the EU universities best practices and Russian and Tajik realities in training engineers. It is necessary to highlight the importance for implementation of active learning strategies in the Russian and Tajik universities based on the current requirements for the competences of engineers. Applying the active learning strategies at the advanced level requires well-developed institutional environment [22]. In terms of active learning strategies, all types of methods and tools presented in EU universities cases are used by Russian and Tajik universities but the levels of maturity in applying them are much different (Table 3).

Ranking active learning strategies reveals that most of methods are not new for Russian and Tajik universities and tend to the levels of Awakening and Enlightenment. With this in mind, a set of recommendations are proposed.

First of all, it is necessary to develop active learning strategies such as Problem-Based Learning, Project-Based Learning, Gamification, Team Based Learning, Work Based Learning and Research Based Learning in Russian and Tajik universities in a more effective way. One of the main results of this study shows a strong focus of the European engineering programs on Project-Based Learning (7 out 16 examples). At the same time a wide range of strategies such as Work Based/ Research Based/ Problem Based Learning are used. PBL models described present an interdisciplinary approach. Most of them include close collaboration with internal and external stakeholders. The coordination team usually includes teachers, tutors and educational researchers from different schools/departments maintaining a wide diversity of ideas and experiences.

The active learning strategies Maturity Grid with regard to Russian and Tajik universities practices shows the gap in using these methods. Most of them are at the low or medium levels due to barriers of institutional nature. Regarding to Tajik universities reality the main obstacle is weak human resource i.e. low qualified teachers and insufficient technical capacity. Moreover, it should be noted that there is no clear system for organizing advanced training and retraining of teaching staff in engineering subjects in Tajik universities. It is needed to enhance entrepreneurship and management as additional competences among students in engineering fields. In this context, Problem and Project Based Learning and Gamification are effective learning methods to develop the competences of engineering students.

Secondly, it is important to implement active learning strategies with strong University Enterprise collaboration to get closer to the needs of realities and future challenges in industry. One of the emerging trends recognized in the conceptual background is the need to create explicit curricular links with external agents, namely with industrial companies. The European Union initiative, University-Business Cooperation (UBC) [23] describes the need to develop graduates' competences aligned with the needs of the labour market. The interaction between engineering educational programs and external agents incl. industrial companies can be developed by visiting industries, invite professionals or key agents of the society to deliver seminars, integrate internships and work-based learning in the curricula, or developing projects to deal with real industrial or society problems [24]. Some of the best practices show interactions with industrial companies or other external stakeholders. Therefore, strategic partnership will shift to more mature levels of using active learning strategies. Thirdly, Higher Education Institutions should support and promote continuous professional development of teachers, for sustaining the change of teaching and learning methods in direction of more effective approaches. It is important to highlight the necessity to develop institutional environment and provide sustaining continuous evolution of active learning methods in engineering education. The EXTEND centres set up within the EXTEND ERASMUS+ project will contribute to strengthening mastery of active learning strategies and best pedagogical practices in engineering education. Thus, the main recommendations for Russian and Tajik universities are to develop active learning strategies, especially Project Based Learning approach in interaction with industry, and additionally for Tajik Universities to develop entrepreneurial and management competences of engineering students.

Table 3. Active Learning Strategies Maturity Grid with regard to Russian and Tajik Universities practices

METHOD		AWAKENING	ENLIGHTENMENT	WISDOM	
Problem-Based Learning (PBL)	UNCERTAINTY		While going through teaching and training, learn more about the method benefits. (RUS, TJK)		CERTAINTY
Project-Based Learning (PBL)		Recognizing that the method may be of value but insufficient competence of the teachers is an obstacle for making advances (TJK)	While going through teaching and training learn more about the method benefits. (RUS)		
Gamification		Recognizing that the method may be of value but not willing to use it (RUS)	While going through teaching and training learn more about the method benefits. (TJK)		
Team Based Learning		Recognizing that the method may be of value but not willing to use it (RUS, TJK)			
Work Based Learning			While going through teaching and training learn more about the method benefits. (RUS, TJK)		
Research Based Learning		Recognizing that the method may be of value but the technical capacity is limited to use it (TJK)		Implementing and deployment the method at all levels of the educational programs (RUS)	
Various approaches (combination of previous methods)		Recognize that the methods are of value but limited technical base and low competences to use them (TLK)	While going through teaching and training learn more about the method benefits (RUS)		

* RUS- Russian universities, TJK - Tajik universities

5 ACKNOWLEDGMENTS

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From Customer Projects to ECTS

M. Mielikäinen [1]
Lapland University of Applied Sciences
Rovaniemi, Finland

J. Angelva
Lapland University of Applied Sciences
Rovaniemi, Finland

T. Tepsa
Lapland University of Applied Sciences
Rovaniemi, Finland

Conference Key Areas: Integrated learning environments for the digital native learners, 4th Industrial Revolution

Keywords: Project-based Learning, IoT, PBL, Internet of Things

ABSTRACT

Lapland UAS has a long tradition in Project-Based Learning (PBL). In the ICT department, PBL is implemented into the semester projects. Course integration offers an opportunity to develop the skills of both students and teachers by using new technologies and developing innovations. The integration of study courses provides additional resources for EU funded R&D projects of ICT department.

The R&D project named RURAL-IoT started in Autumn 2018. The R&D personnel contacted the department suggesting a collaboration. The 6th-semester project was selected to develop new ideas. The RURAL-IoT project's target was to create new innovations using low cost, low power and mobile IoT technologies usable in Lapland's rural areas. The lack of an electricity distribution infrastructure and poor mobile telecommunication connections are challenging. Student projects were run by the Agile SCRUM way.

During the project, two questionnaires were prepared to 3rd year students. The first was a self-assessment survey to study the level of students' innovation competence at the beginning of the project. The second survey was conducted to find how innovation competencies were developed during the project. The R&D and teaching team were interviewed to find out their ideas about integrated learning project as well as how useful they thought this kind of integrated learning case was.

[1] Corresponding Author
M. Mielikäinen
maisa.mielikainen@lapinamk.fi

This document describes the background of integrated learning and R&D-project. The results of students' innovation competence development, as well as experiences of the project staff and teachers, are also described.

1. INTRODUCTION

1.1. Innovative technologies

Internet of Things is one of the megatrends that make digitalization possible. Megatrends like robotics, IoT, artificial intelligence, and big data go hand in hand. These megatrends act as drivers for the development of sensor and network technologies and data analytics. With the advancement, the sensors become cheaper and their size decreases while data transmission speeds up and data can be processed in large quantities in real time without investing in heavy IT infrastructure. Even small software vendors can make globally scalable solutions with existing technologies.

Arctic, harsh, and rural conditions require a long battery life from the IoT device. Data must be capable of being transmitted over long distances. Devices should also withstand low temperatures during the winter and direct sunshine in the summer time.

1.2. Semester project – Case Rural IoT

The Spring 2019 Learning project task for the 6th semester was a part of “RURAL IoT (IoT innovations for Sensing and Positioning in Rural Areas)” -R&D project funded by Regional Council of Lapland. The main idea of the “RURAL IoT-project” was to develop new innovations to Lapland that can utilize cheap, low power consumption and mobile IoT-technologies. The RURAL-IoT project aimed to integrate the interests of both the R&D-project and the teaching.

During the project, two pilot projects were finished. In the first pilot project, new technologies were tested in the oldest and still vital source of livelihoods in the North, reindeer herding. One of the biggest challenges in reindeer herding is that there have always been carnivores in the reindeer husbandry area. Wolverines, bears, wolves and golden eagles have taken their share of the reindeer [1] In the pilot project a real-time solution to follow the location and the body temperature of the reindeer was developed.

For the second pilot project students developed new ideas to utilize IoT-solutions and finally designed and made a prototype. Student teams had to take into account cold climate, power consumption, and radio network coverage in the Northern periphery. In the given task students were to brainstorm a device that can monitor surroundings, is low-power and cheap and uses Low-Power Wide-Area Networks (*LPWA networks*) [2]. Other requirements for the prototype were to develop a mobile application including a real-time clock, GPS, temperature and humidification, ie. sensors, the basic architecture is shown in Fig. 1.

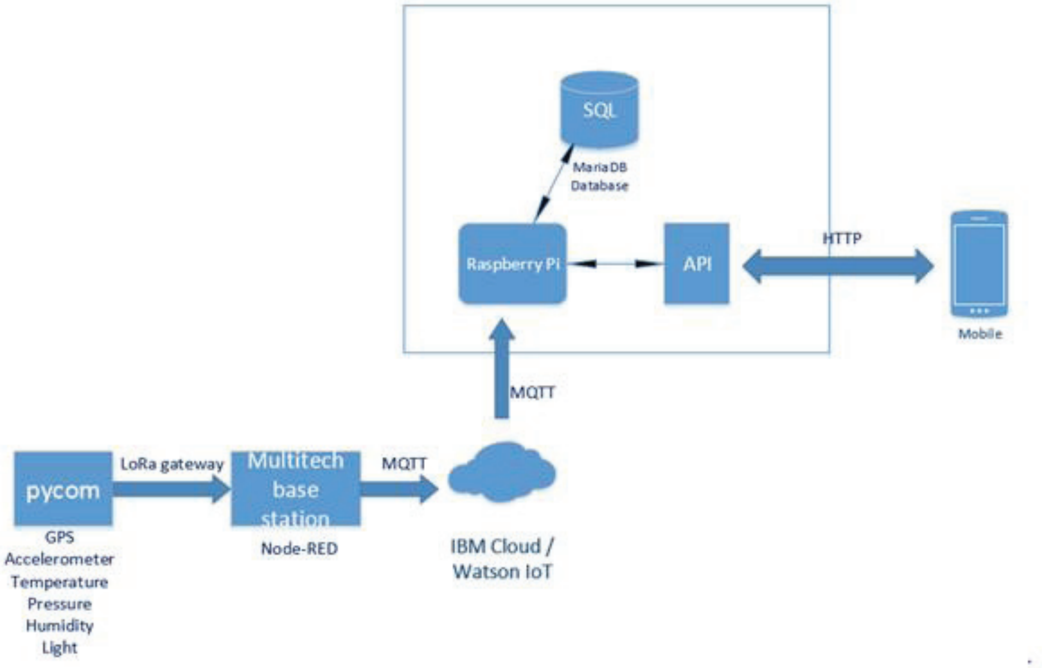

Figure 1. The Architecture of RURAL IoT

1.3. Integrated courses

The ICT Curriculum is based on semester projects due to results of piloting other options as well [3]. The learning project is supported by semester courses that are integrated into the project to meet learning outcomes.

Project-based learning (PBL) is used to integrate theoretical and practical content in a real-world context. It increases students' motivation and participation [4, 5]. The integrated learning project called "RURAL IoT" as shown in Fig. 2 consisted of five PBL courses, each 5 ECTS:

1. Professional Project Management
2. Communication skills
3. Advanced Mobile Technologies
4. System Laboratories
5. Management and Leadership

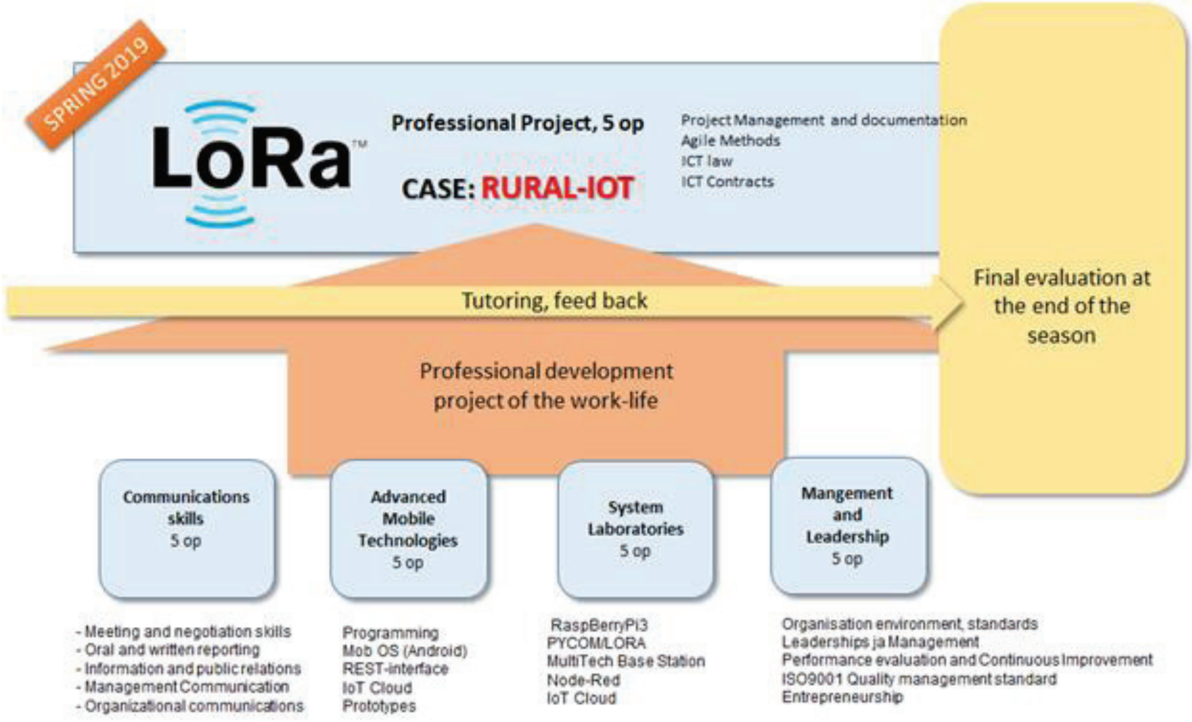

Fig. 2. The Integrated learning project.

At the end of the semester, students arranged a public exhibition called “SMART ICT EXHIBITION 2019” to show prototypes they developed.

1.4. Research questions

The study aimed to seek answers to questions about whether students can sufficiently innovate, even if the technology has already been defined in advance. Has there been any change in results between the start and end questionnaire of the project? The research will also address their experience in teamwork and problem-solving skills. Instructors were asked about students’ attitude and initiative.

2. MEASURING INNOVATION SKILLS

2.1. Data collection

In this research, the target group was the same as in the previous study about the innovation skills [7]. To be comparable the survey was based on the same questions developed in the ESF (*European Social Fund*) project [8] as it was in the previous study. The questions measure the development of students' innovation competencies as self-assessment. There were 22 questions about the following topics: Ability to creative problem-solving, comprehensiveness, goal orientation, cooperation skills, and networking skills.

The same five questions related to teamwork and innovation were chosen again for students:

- Q1: I present ideas on how the task could be carried out for the approval of others
- Q2: I present new, practical solutions for meeting the goal

- Q3: I show interest in the subject
- Q4: I act persistently for meeting the goal(s)
- Q5: I take my group members ideas into account

In addition to previous questions to students, questions Q3 and Q4 were also asked from instructors to find out their opinion about student's attitude and initiative. Questions were sent by email to eight teachers and/or instructors. Replies returned (N=6) by the deadline were taken into account in this study

2.2. Results

Results of the year 2018 (4th semester) survey are used as a baseline and reference results. The initial survey of the 6th semester was carried out at the start of the RURAL-IoT project in January 2019 and the final survey was done at the end of the project in April 2019. All surveys were conducted to the same student group. Total 18 students completed the start questionnaire and 19 students answered to the final questionnaire. The survey was carried out using the Webropol online survey tool.

Table 1. Results of the questionnaire. The data are presented as frequencies and percentages of the total amount.

	Not at all	**Poor**	**Moderate**	**Good**	**Excellent**
Q1: I present ideas on how the task could be carried out for the approval of others					
Baseline (N=24)	0	0	4 (17%)	14 (58%)	6 (25%)
Beginning of the project (N=18)	0	0	5 (28%)	11 (61%)	2 (11%)
After the project completion (N=19)	0	0	3 (16%)	11 (58%)	5 (26%)
Q2: I present new, practical solutions for meeting the goal					
Baseline (N=24)	0	1 (4%)	2 (8%)	12 (50%)	9 (38%)
Beginning of the project (N=18)	1 (5%)	0	4 (22%)	10 (56%)	3 (17%)
After the project completion (N=19)	0	0	6 (31%)	3 (16%)	10 (53%)
Q3: I show interest in the subject					
Baseline (N=24)	0	0	6 (25%)	13 (54%)	5 (21%)
Beginning of the project (N=18)	0	1 (5%)	7 (39%)	7 (39%)	3 (17%)
After the project completion (N=19)	1 (5%)	0	6 (43%)	5 (26%)	7 (37%)
Q4: I act persistently for meeting the goal(s)					
Baseline (N=24)	0	0	4 (17%)	10 (42%)	10 (42%)
Beginning of the project	0	2 (11%)	3 (17%)	8 (44%)	5 (28%)
After the project completion (N=19)	0	0	3 (16%)	8 (42%)	8 (42%)
Q5: I take my group members ideas into account					

Baseline (N=24)	0	0	4 (17%)	9 (38%)	11 (46%)
Beginning of the project (N=18)	1 (6%)	0	2 (11%)	7 (39%)	8 (44%)
After the project completion (N=19)	0	0	2 (10%	7 (37%)	10 (53%)

Two of the questions in figure 3 were taken into a closer look. Students' own opinions about both initiative skills and perseverance in problem-solving skills decreased at the beginning of the project compared to the baseline in the previous year. However, they were recovered at the end of the project.

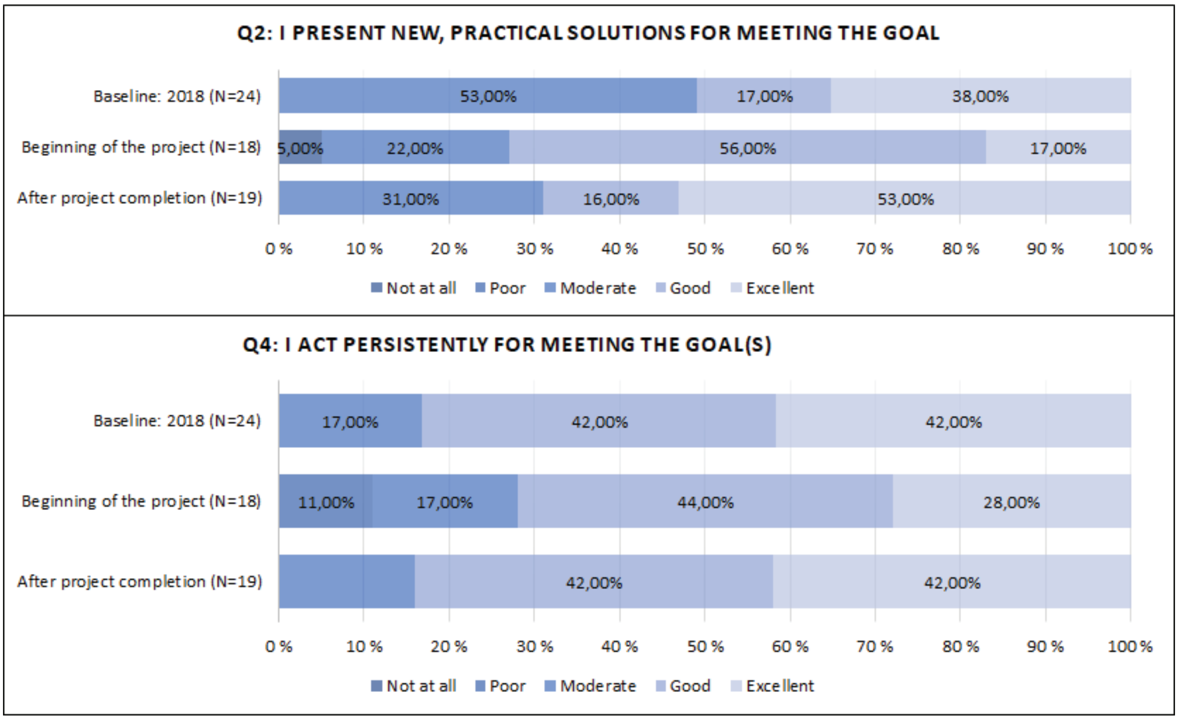

Fig 3. Development of students' initiative skills and perseverance in problem-solving.

3. SUMMARY AND ACKNOWLEDGMENTS

The conclusions of the surveys are contradictory. It seems that the confidence of students to their own substance knowledge would have deteriorated compared to the previous questionnaire. According to the survey results, one might assume that the rise in the level of requirements of the project would be a reason for the students to feel uncertain about their skills. According to questionnaires to instructors, students did not "want" to use instructors' expertise in problem-solving at the beginning. This problem was identified at an early stage when project teams were offered lessons and tutorials related to the assignment. After that, the instructors felt that the threshold to ask for guidance decreased significantly. Social interaction was likely to become easier when the instructors became more familiar.

The development of students' skills and motivation was also evaluated on the basis of the final survey, which was conducted among teachers and instructors of the project. The queries concerned student questions Q3 and Q4.

Based on the results, it seems that the assessment of the students' motivation by the instructors was positive (Q3). However, in their opinion, motivation was more visible at the group level. Personal motivation within groups varied greatly.

Question Q4 focused on students' perseverance to pursue goals. All the respondents felt that groups were persistent and aiming for goals. One of the respondents notes that some technical options were abandoned if the schedule for its implementation was not realistic to them

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Student activation in curriculum „Physics for engineers“

A. Mittelstädt[1]
Technische Universität Berlin
Berlin, Germany

A. Schliwa
Technische Universität Berlin
Berlin, Germany

Conference Key Areas: Fundaments of Engineering Education: Mathematics and Physics

Keywords: course reform, physics, conceptual understanding, concept tests

ABSTRACT

Student activation is a major concern in any university lecture. Here, we report on our approach to shift the focus to understanding physics concepts in introductory physics courses for engineers at the Technische Universität Berlin. This course is divided into two independent parts: 'classical physics' and 'modern physics', being visited by 300 and 600 students, respectively, and are offered in a one-year term. Our new setup includes an interactive lecture, which is grouped into a traditional lecture, where the 'first exposure' occurs, the demonstration of most important experiments by the lecturer and sessions with concept tests related to the topic, i.e. Mazur's peer instruction, realized with an audience response system. A second major innovation are the flipped classroom practical sessions for which a complete new set of exercises was developed. These include concept tests and conceptual tasks connecting historic experiments, also shown in the lecture or tutorial classes, with theory, real-world phenomena and applications. The weekly exercises are provided online via the university's Moodle and include introductory texts and storytelling to connect topics and illustrate the relevance. During the flipped sessions, students form small groups, discussing and solving complex problems and conceptional questions, while instructors circulate from group to group to help, promote discussions and provide feedback. Understanding concepts of physics is solidified by discussions about the new concept tests and exercises and via conducting experiments in weekly tutorials with groups of 5 to 30 participants.

[1] Corresponding Author
A. Mittelstädt
mittelstaedt@tu-berlin.de
ORCID: 0000-0002-7587-9385

1 BACKGROUND AND STARTING POINT

At the Technische Universität Berlin, Germany, we are working to reform two introductory physics courses for engineering majors. Starting in summer 2017, we established several research-based approaches to shift the focus of the courses to understanding physical concepts, including

- interactive engagement techniques, which can activate students and lead to higher learning outcomes [1] and
- addressing conceptual misunderstandings of natural phenomena [2].

The introductory physics course for engineering students is divided into two individual parts: 'classical physics' and 'modern physics', for which up to 300 and 600 students register, respectively. Each course is offered in a one-year term and is part of the curricula of at least twelve bachelor degree engineering majors, partly as a compulsory, partly as an elective compulsory subject or as extracurricular studies, see *Fig. 1.* Students in the first and second semesters make up the majority of participants. The courses consist of a lecture, small tutorial classes and flipped classroom sessions, each of which 90 minutes long, being offered weekly, and each course takes one semester, i.e. 14 weeks. The common learning objective of the courses is to study the fundamentals of physics in the following branches: classical mechanics, electromagnetism, classical optics and thermodynamics within the classical physics course, and atomic physics, an introduction to quantum mechanics, nuclear physics and solid-state physics within the modern physics course. The goal is that the students get to know the basic experiments, understand the corresponding theory and concepts and are able to apply them to problems. Previously, teaching of theory and concepts has been mainly the task of the lecture (passive learning), supported by the demonstration of

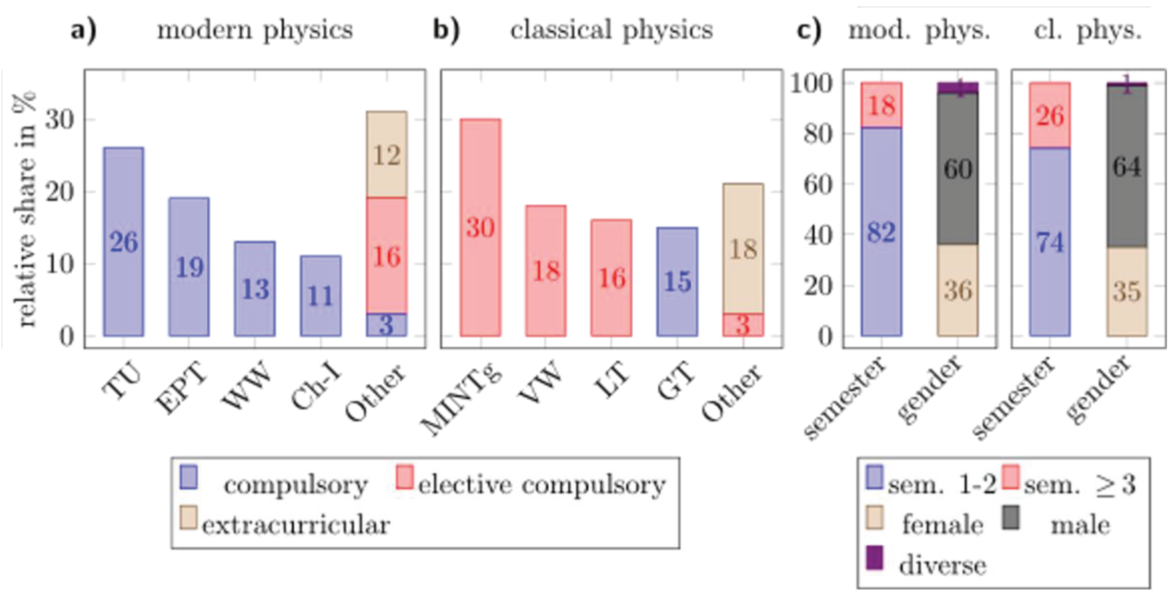

Fig. 1. (a) and (b) show the relative number of participants for the four programs that make up the largest groups within the modern and classical physics course, respectively. (c) shows the proportions of students divided according to their semester and their gender. The statistics are based on surveys carried out in 2018/19.

key experiments and interactive simulations. The content was practiced solely using exercise sheets in large tutorial classes, using algebra-based textbook questions where theory is applied to determine a quantitative value of a parameter. The course was concluded with a written exam, which mainly contained variants of those textbook questions, resulting in learning outcomes which have been observed by many lecturers [3, 4]: Most students memorize formulas useful to solve a particular type of problem, combine them and plug it into their calculator. They are often unable to explain the conceptional basis behind their own solutions to problems and cannot transfer their understanding to problems that deviate from standard textbook questions.

2 INTERACTIVE ENGAGEMENT TECHNIQUES

To shift the emphasis of both courses to conceptional understanding, we reformed several key components of the courses and implemented a combination of new types of exercises and methods. Another major concern is the incorporation of active learning to avert student passivity. It is still a challenge to encourage students to participate and learn continuously, as there is no attendance requirement for the lecture or the tutorial classes. Students register solely for the final exam. We evaluate the courses and in particular the new elements biannually in order to adapt and improve them.

In doing so, we focused on the advancement of the lecture and the development of flipped classroom sessions, since we have no possibility to change the structure of the courses as such and no additional teaching staff is needed. In contrast to usual flipped classroom approaches, we therefore have two complementary types of teaching methods, where the flipped classroom sessions deepen and practice the contents of the lecture. The small tutorials with 5 to 30 participants are led and prepared by undergraduate teaching assistants and remain as they were. About 20 of these tutorials are run on a weekly basis and have a flexible structure. Their topics are based on the current lecture and the students demands. In addition, a mandatory set of key experiments is carried out and discussed. The tutorials benefit also from the new concept tests in lecture and the new weekly exercises, as explained below.

2.1 The lecture

Our new setup incorporates interactive learning sessions as well as elements of a traditional physics lecture: Short introductions to a topic by the lecturer alternate with demonstrations of the most important experiments, being either shown live by the lecturer or as a simulation, and sessions with conceptual questions related to the topic. The latter is inspired by Mazur's peer instruction [5], realized with the open-source audience response system PINGO developed by the Universität Paderborn, Germany [6]. For example, concept tests are conducted at the beginning or end of a topic in order to clarify its relevance and stimulate discussion. Others are coupled to typical experiments linked to central physical phenomena.

For both courses, we created a repository of concept tests based on existing conceptual tests, syllabi and observations of students in problem-solving sessions. This allows the lecturer of ‘classical physics’ course to do several multiple choice questions per lecture, however, creating suitable questions for modern physics course is more difficult. All the materials used during the lecture, simulations and concept tests are provided online via the university's Moodle platform (https://moodle.org/).

2.2 The flipped classroom sessions

Another major approach in promoting conceptional understanding and reasoning are the flipped classroom practical sessions. Here we have moved away from a large tutorial classes in which algebra-based textbook tasks were solved and partly worked out by the teaching staff to a flipped classroom model. To do this, we have developed a completely new exercise that is provided to the students via the university's Moodle on a weekly basis. The students are encouraged to deal with the contents at home and to also attend the sessions not only by advertising their value but by making the exercises sufficiently difficult to solve for most students. During this weekly session, students form small groups discussing and solving complex problems as well as conceptional tasks. In addition, problem-solving strategies and supplementary material based on the students' feedback are provided online, which is particularly helpful for students who cannot attend the flipped classroom sessions. The sessions are staffed by about eight undergraduate teaching assistants and two graduate teaching assistants, circulating from group to group, helping to figure out complex problems, drive discussions, recognize misconceptions and provide feedback.

2.3 The exercises

For the courses, we developed a completely new set of exercises connecting the most important historical experiments, also shown in lecture or tutorial, with theory, real-world phenomena and relevant applications. We incorporated at least one application or phenomenon for each major concept. In addition, we provide introductions and cross-references to new and related topics, respectively, which motivates students to self-study and deepen their knowledge.

The understanding of the theory and the corresponding concepts is not only promoted by tasks and experiments, they are also partly linked by storytelling. Storytelling can humanize the teaching and learning of physics, helping students to memorize and understand the problem situation from which physical concepts first arose [7, 8]. This is particularly useful in modern physics, where the student can easily be guided from topic to topic, starting with the radical developments in physics starting in the early 20th century. In classical physics, understanding can be improved very effectively via typical concept tests and conceptional questions addressing common misconceptions. We also introduced weekly self-tests based on typical exam questions, which helps the students to test their knowledge by themselves.

We switched from algebra-based to more calculus-based exercises. Simple problems are mixed with complex ones depending on the topic, since no correlations should be unnecessarily simplified. For complex numeric exercises strategies are explained which help the students to solve the problem step by step, improving the problem-solving performance. This includes also small digressions into topics such as special relativity, quantum mechanics, particle physics, which link the knowledge of the students with other branches of physics and more recent discoveries and applications.

2.4 The exam

Students register themselves to the written exam (120 minutes) at the end of a semester. We developed a new setup of the exam for both courses in 2017 which comprises a mixture of algebra-based problems, concept tests and conceptional tasks, where students write a short text, drawing a sketch or a graph. The written exam is practiced during the semester by means of two exemplary tests during the flipped classroom sessions.

3 EVALUATION AND EXAM PERFORMANCE

In order to obtain feedback regarding the course from the students, data was collected via a survey with 28 questions conducted biannually taking 10 - 15 minutes to complete. *Fig. 2* shows an analysis of five questions that were asked within the last two semesters. Questions V1 and V2 refer to the concept tests that were presented in the lecture, we asked: "The concept tests are helpful to master the content." (V1) and "The discussion after the concept questions within the lecture promotes understanding" (V2). 82% and 71% of the students agreed to V1 for the modern and classical physics course, respectively, indicating that the concept tests are helpful to the students. Only 68% and 64%, respectively, agreed to question V2, which shows that the discussion part within the presentation can be improved.

Questions U1, U2 and U3 refer to the flipped classroom sessions, here we asked: "The explanations of the instructors are helpful to understand the content." (U1). 73% and 84% have agreed to this statement for modern and classical physics. Other questions were: "How much time in hours do you need to complete the weekly exercises?" (U2)

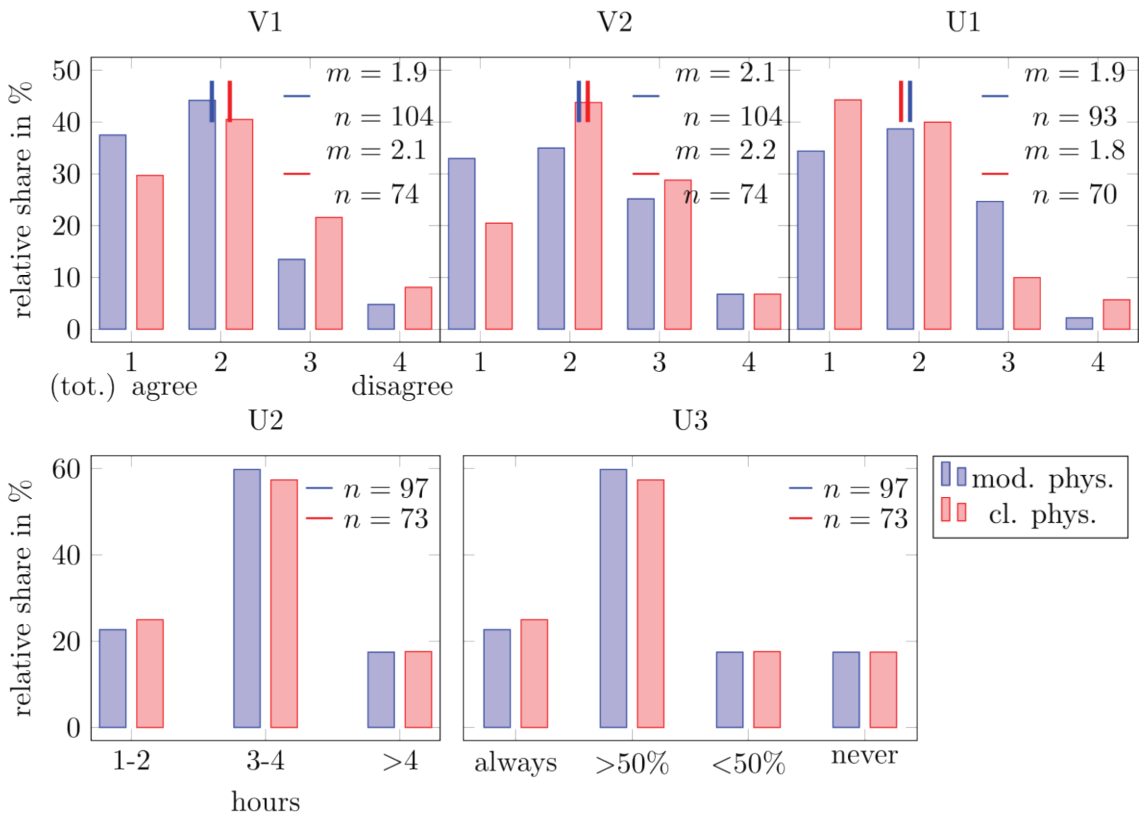

Fig. 2. The results for five exemplary questions asked during the last modern physics (blue) and classical physics (red) courses in 2018/19. The rating scale is 1 - 4, where 1 means "strongly agree" and 4 "strongly disagree." The mean value is indicated by m and n denotes the sample size.

and "How often did you attend the flipped classroom sessions during the semester?" (U3), where the majority needs on average four hours to complete the exercises. The results are very similar for the two courses, which shows a good agreement in the difficulty of the exercises, although the topics and the types of tasks vary greatly. Question U3 also shows almost identical results for the two courses, at least 82% of students attend the flipped classroom sessions more than seven times per semester. The surveys were carried out in the last third of each semester, which explains the low response rate.

We now turn to an analysis of the results of the exams carried out between the years 2016 and 2019. *Fig. 3* a shows a plot of the mean of the score for the exams in a particular year m_i subtracted by the average score for the last years M

$$m_i - M = m_i - \frac{\sum_i m_i N^i}{\sum_i N^i}, \tag{1}$$

where i denotes the year and N^i the corresponding number of participants. Only those students who passed the exam are considered, the students who failed are accounted for by the failure rate. Since the reforms did not begin until 2017, the results of 2016 are the last we have been able to obtain and are serving as a reference. For the modern and classical physics courses we observe an increase in performance of 12% and 9% from '16 to '17, respectively. The failure rate has fallen particularly for the modern physics course, i.e. the difference is 24% between the years '16 and '19. For the classical physics course, the failure rates have fallen by 7% between the years '16 and '18. We note that the informative value of these statistics in relation to the 2016 data is low, as we have reformed not only the course but also the structure of the exams from 2017 onwards. Nevertheless, the performance, at least for the modern physics course, has increased considerably in the years '17 to '19 by 15%, whereas the performance for the classical physics course is around the average score M. This could

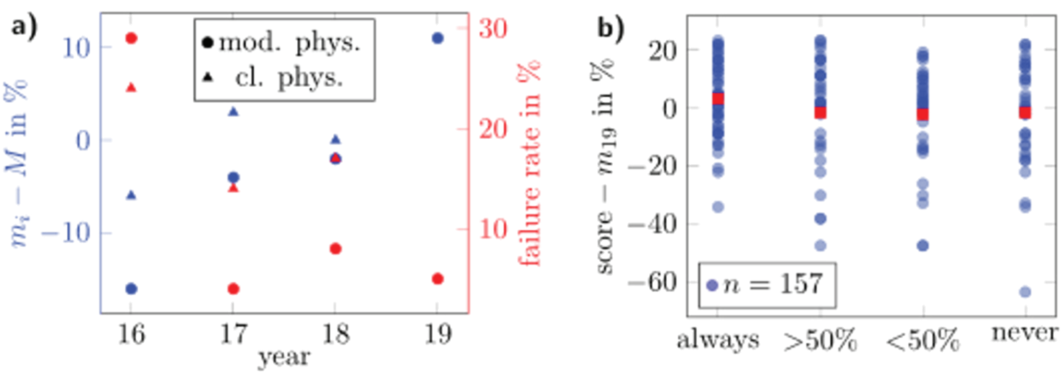

Fig. 3. (a) shows data of the exam performance for the modern physics exam (circles) and the classical physics exam (triangles) for the years '16 to '19. The value $m_i - M$ (blue axis) is the mean of the exam score m_i for a particular year i subtracted by the average score for the last years M. (b) depicts the individual exam performance subtracted by the mean m_{19} (blue circles) with regard to the attendance in the flipped classroom sessions for the 2019 exam. Red squares indicate the average values for each answer and n denotes the sample size.

also be related to the fact that classical physics, in contrast to modern physics, is a compulsory elective subject for most bachelor degree programs, see *Fig. 1* a and b.

Fig. 3 b shows the individual exam performance in relation to the participation in the flipped classroom sessions. Here we asked a part of the students again the question U3. Here no clear Trent is discernible as the results are close to the mean, but on average those students who stated that they were always present completed about 4.5% more tasks correctly than those who were never present. This could be due to the fact that we make all of our content available on Moodle and also provide help to accomplish the tasks, so that many students work independently. In addition, many students attend the small tutorials where the content and the new exercises are discussed also.

4 SUMMARY AND ACKNOWLEDGMENTS

We have reformed two major introductory physical courses for engineering students by integrating concept tests into the lecture and new exercises that are solved by the students in collaborative group work in flipped classroom sessions or by self-studying with emphasis on conceptual understanding, argumentation development and real-world phenomena. Our reforms include novel exams, exam training, self-tests and online material made available to students and teachers. Our initial assessments show that the innovations are well received and helpful and the exam performance was increased. We are now working on concept tests for modern physics and creating a library of exercises and concept tests that is constantly being improved and expanded. As a next step, we are solidifying and supporting the reforms, especially as the teaching staff and lecturers change with the semesters.

We would like to thank Axel Hoffmann, Holger T. Grahn, Sabine Morgner, the undergraduate teaching assistants and the graduate teaching assistants who helped with the courses and made these reforms possible by their commitment.

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From Drawings to Digital Devices - Additives to the History of Content and Methodological Development of Engineer Training in Hungary

György Molnár
associate professor
Budapest, Hungary

Beáta Orosz
PhD student
Budapest, Hungary

Zoltán Szűts
associate professor
Budapest, Hungary

Conference Key Areas: Diversity in Engineering Education, Diversity in Engineering Education?

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ABSTRACT

In the past, teachers have been drawing on the blackboard, but today they are using digital devices that allow for the precision needed in the engineering industry. On the one hand, this significant change is generated by the rapidly changing technology; on the other hand, there is an increasing expectation from our society. The history of engineering training is also influenced by the aforementioned trends and their impact. In this development, the role of the so-called STEM is important, the application of science, information technologies, engineering knowledge, skills in the world of work. There is a growing need for businesses to adjust, and training systems, such as engineering training, should be prepared according to market orientated expectations. Progress can only be achieved if teachers, in addition to the students, keep pace with the rapid changes and effectively adapt the possibilities of digitalization to the teaching process. One of the lines of the new labour market competences is the demands of companies on robotics and the existence of programming skills, which are specially developed in mentor programs that require interdisciplinary collaboration. These methods provide a new approach and ready-made solutions to the entrepreneurial sphere.

At Budapest University of Technology and Education the implementing of WEDO 2.0, LEGO Mindstorm EV3 Education program, myDAQ or the World Robot Olympiad tournaments, we are able to provide the new kind of support that the world of work today requires of new graduates.

PREFACE

Digital competencies in today's world of digitalization are becoming more and more appreciated. This can be accompanied by a closer and more progressive attachment to the processing of some specific subject content. Such is e.g. teaching the fundamentals of programming and information technology in higher education, as acquiring this knowledge is important for all engineering disciplines. In our presentation, we discuss these issues, which we wish to support with our experience in higher education.

The purpose of our presentation is to explore the ways subject matter and curricular developments coupled with innovative methodological solutions in the 21st century contributed to the evolution of engineer training as it is today. The connection between modern education and industry and the engineer with convertible skills are essential to industry. It has been proven that industrial success is based on the development of engineering training as well.

While our goal is not to provide a detailed history of our university, we would like to point to a few landmarks. The establishment of this institution balancing contemporary external and internal demands coincided with the accelerating industrial development made possible at first by the Reform Age and later by the Compromise of 1867. As a result of the establishment of various factories capable of producing at European or international standards cooperation began between universities and manufacturers, giving rise to an early form of dual training schemes. József Stoczek, the first rector of the university invited the leading industrial developers and scientists including Donát Bánki, Károly Zipernovszky, and Vince Wartha to teach here. All of the abovementioned developments resulted in Hungary achieving a level of industrial growth and production rivalling that of Sweden after the Compromise, and during the long 19th century education became an answer to questions related to problems arising in the international economic and political sphere.

One effective response to these challenges was provided by training at the contemporary University of Technology. We often recommend our students to read the gazettes of the Association of Engineers and Architects published at the end of the 19th century to see that these outstanding men were not only excellent industrialists, but internationally acclaimed creative individuals.

At the same time, we are equally proud of the scholarly and technological achievements realized in the interwar area. but since then the world has changed tremendously and educational institutions and education itself are faced with the task of providing answers to the challenges of the 21st century.

We used these examples to show how the internationally acclaimed achievements of engineering training at the University of Technology in the 19th century live on today.

Furthermore, let us offer some personal examples showing the connection between the industrial or business sphere and that of academia. Although trained as an electrical engineer, I became an engineer-instructor and my colleague after a career as an economist joined the university as an instructor of economics.

Our essay explores related examples substantiated by professional experiences and that of full time students enrolled in engineering programs.

1 THE EDUCATION SYSTEM

1.1 Education long ago and nowadays

In the past, teachers have been drawing on the blackboard. The students nowadays don’t prefer this method, because in this situation the teacher stands back to the audience while writing onto the board, students cannot hear the explanation, and cannot see and read the epigraph and illustrations from the back of the classroom.

Due to technical development in the education it is possible to use more modern, spectacular and visualized methods. The ICT tools and the rapidly developing technology increasingly change the everyday way of life and lifestyle, and increase the need for the digitalization of different parts of life [15]. One of these parts is the education itself, because of the stronger presence of technical achievements.

In engineering education, precision, accuracy are really as important, as visualization. Because of these, non-observance of technical achievements would be not only impossible, but a huge mistake, because consistent usage of ICT tools helps teachers, and also students. In higher education tendencies of Industry 4.0, digital microtrends and models seemed firmly established, for example Flipped Classroom, BYOD and BYOC theories, gamification, electronic learning places, and different phenomena of media convergence. Due to the effect of the ICT tools, digital culture spreads and goes ahead against traditional culture, informal learning became more important, new ways of learning, new learning environments emerged and the role of social media is valued as well.

1.2 The main characteristics and deficiencies of engineer training

”As the dean of a college of technology said once he had many times presented degrees to engineers, whom he did not consider as such real professionals despite their passing the respective examinations.. When he was asked to describe a real engineer he had emphasized the cultural and social responsibility. He also pointed out that people directing either a scientific research project or a manufacturing effort had not been prepared to fulfil such responsibilities. Furthermore, he argued that many managers had not been familiar with the latest management skills, thus there was a serious need for the emphasis on the human side in the given training programs.” [5]. In *The human aspect of higher education pedagogy.* Attila Mészáros singles out several unfortunate phenomena currently impacting engineering training programs. These include the high value assigned to passivity in learning positions and that of the respective information in entrance application procedures along with the weakened judgment of the individual succumbing to the unilateral scholarly authority which was leading to the eventual omission of the human factor. The respective training programs are generating a strong conditioning impact and are characterised by unilateral professional specification. All these features tend to narrow one’s perspective and negatively impact social skills and personal qualities [4].

Engineers have to face a number of challenges in the 21st century. Engineering professionals have to fulfil several roles, communicate in a variety of ways either with fellow engineers or non-professionals, while considering and reconciling a wide variety of interests. Although the education system should be able to prepare students for handling such situations, the development of social, communicational, and cooperation skills demand a higher number of subjects related to social functioning and pedagogy. The emphasis on subjects focusing on economics resulted in a lower priority on the humanities and social sciences whose integrated perspective is required for becoming familiar with the organisational know-how. The globalization of environmental problems including the worsening air pollution and the loss of green areas increases the importance of sustainable development-oriented training. Fortunately, several positive developments have taken place in the given institutions [2, 4, 16].

Life practice-oriented training providing information not determined by the trainers’ perspective and qualification should be included in engineering education. In addition to digitalization cooperation with business can offer a solution for these problems and deficiencies. [4]

1.3 Developing possibilities in engineers' education based on a session of CAETS and the sustainable developmental goals of UN

The main focus of engineers' education is adequacy for present-day needs. In 2013 there was a session of CAETS in Budapest. [6] This event was really significant, because of the participation of the 26 member countries all engineering academies. They all together accepted that recommendations, which are still valid nowadays. The expectation was to train engineers, who are able to initiate technical advancements, and contribute to general social wealth.

It can be efficient only if we as teachers incite engineering students for problem solving and teamwork, and if we incorporate the results of the latest researches and innovations into the training, and take advantage of technological possibilities. In case of cooperation of engineers from academic and industrial sphere, it is easier to realize integrated thinking, science and technology developing. Engineers' education has to adapt to present-days social challenges. One element of this is the existence of rapidly changing social and labour market needs. That is why training processes have to contain substances which prepare students not only for knowledge and specifications, but flexibility and adaptability for new needs and challenges, too.

All of these changes innervate lifelong learning, and the education of scientific and technological topics. In today's society, the other buzzword is sustainability, which includes individuals and communities' reformation, accommodation for economic, social and cultural environment and these continuous changes and transformation. Sustainability has serious educational implications and nexus, in connection with sustainable development goals of UN. [1, 6, 7, 8, 10, 11, 13]

Some part of it connects to engineers educations, these are the following [1]:

- "Equal access to affordable and high quality technical, professional and higher education (for example university) trainings for every man and woman to 2030.
- Increasing numbers of young and adults, who have the adequate technical and professional competencies for labour market needs, decent work and business entrepreneurial needs to 2030.
- Gender equality in education, and equal access for every level of education and training for everybody, included disadvantaged groups (handicapped, autochthon, vulnerable people) to 2030.
- Increasing number of available scholarships globally, which are aimed to help students from third world countries, developing islands and African countries. With these scholarships it is possible to study professions, ICT, technological, engineering and scientific subjects.
- Increasing numbers of highly qualified teachers and trainers, also in the developing countries, with teacher training cooperation to 2030.

- Green universities: new vocational subjects in connection with renewable energy."

According to a survey of István Lükő [3], there is a reason for the lack of the environmental, sustainability perspective and curricula in the training programs of engineers. The explanation is that there always will be environmental engineers, who solve the problems and eliminate environmental damages, which was caused by non-environmental professionals. Fortunately, this approach started to disappear, nowadays more and more technological and economic faculty contains curricula in connection with sustainability.

In 2009 István Lükő made a comparative survey in this topic. Data are from Internet and his own syllabus research [3]. He aimed to examine the currently existing and newly created subjects, and these appellation, contents and weighting in curricula. The research concerned the following countries: Great-Britain 3, Austria 3, Turkey 1, Romania 2, China 2, Taiwan 2, Canada 2, Germany 3. The numbers show the observed universities in each country. Lükő examined 35 faculties, and evinced, that besides traditional academic and technological faculties, more universities are open to modern specializations, as an answer to the challenges of the XXI. century. As mentioned, engineers' education has to contain more social subjects, to prepate students for the difficulties of the labour market.

Which were the most frequent subject titles?

- Innovation management, Environmental management, Law (general, environment–related, engineering-related) Sustainability and environmental management,
- Classic social science subjects: Sociology Environmental Sociology, Psychology, Group management, Economics, Engineering Ethics, New disciplines and related special subjects and modules: Social anthropology, Social problems and social policies, Urban sociology, Stress analysis, Individual design and research effort, Human ecology, Globalization and development, Environmental entrepreneurship, Due to the widespread presence of computerization engineers have to cope with several social consequences. Consequently, the Information Society and Digital Culture program of the University of Kent focuses on the connection between the student, the information society, and digital culture.
- The most complex and possibly most comprehensive courses are offered by the Chaoyang University of Technology. The course offerings include
- Planning and Design of Civil Works in Urban Area, Field Safety and Environmental Protection, Government Procurement Law and Act for Promotion of Infrastructure Project, Human Resources Management. Completion of these subjects is worth 3 credits [3].

These subjects have been complemented with new type disciplines responding to options and challenges raised by digital pedagogy, information technology, and digital culture These concerns are expressed by the objectives of the Sustainable Development Framework System accepted by the UN in 2015. While the Framework System is based on balanced social development, long term economic growth and environmental protection, the fourth pillar includes improving the quality of education. Hungary has played an important role in the elaboration and shaping of the Framework System from its inception. The chart below shows the 17 objectives of the Framework System.

Fig 1. Sustainable Development Goals [14]

2. ENGINEER TRAINING WITH SPECIAL EMPHASIS ON STEM PROGRAMS

The latest Vocational Training 4.0 strategy reiterates that the Hungarian economic sphere needs engineers, and experts with informatics and natural science background. Graduates with MTMI skills can be prepared to achieve success in the labour market via STEM oriented skill development programs delivered by enterprises. Such training programs and the latest vocational training-related initiatives aim to achieve a 40% rate in the enrolment in such programs among students applying to higher education. In recent years significant developments took place as while in 2012 only 22% applied to such programs, said figure reached 29% in 2018. The given enrolment rate can be increased by short-term, job-related competence development programs focusing on mathematics, informatics, and natural science-related skills.

Current examples include the professional and business-related training programs developed by the National Instruments Hungary Ltd coupled with vocational competitions. The training programs focus on students enrolled in electric engineering and engineer informatics training and provide specialized training with a specialized methodology for those at career entry positions or engineering candidates. The regular competition opportunities include the LEGO Robot contests and the LEGO Robot programming camps in the summer. Furthermore, the company offers an NI Mentor program aiming at popularizing natural sciences and promoting the algorithmic perspective required for the engineering profession at an early age. Accordingly, specially designed devices and the tools of LEGO Education provide a sense of accomplishment. Students using these devices developed for educational purposes and graphic programming options not only prepare for a career in engineering, but by solving tasks appropriate for their age they actually perform real engineering tasks while still at school. The program utilizes a state of the art and attractive set of devices as students in the lower segment of elementary school can work with the LEGO WeDo 2.0 in solving exciting tasks and students in the higher section of elementary school can become familiar with simple and more complex movements via the LEGO Mindstorms EV3. They can achieve a sense of success via solving automation-related exercises. Secondary school students can work with more complex problems by the help of the LabVIEW, and their knowledge of physics and electronics can help in solving problems via the myDAQ. The main levels of the mentor program and its grade-based distribution is described by the figure below.

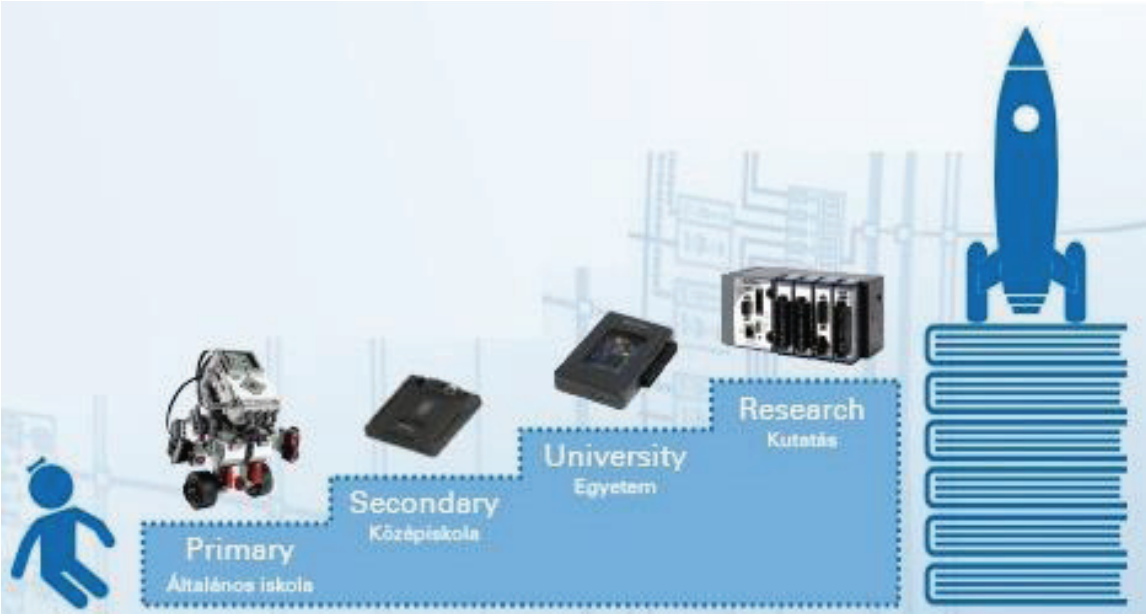

Fig 2. Vocational Training 4.0 strategy

3. EMPIRICAL RESEARCH PERFORMED AMONG ENGINEERING STUDENTS

Empirical research focuses on the digital competence skill level and device use of young engineering candidate students along with the impact of applied ICT methods. Said survey was performed in autumn 2017 via a quantitative questionnaire with a layered sample of 100. The sample population included full time engineering students enrolled in a special career preparatory course titled ”I will be an engineer!” The sample that eventually served as a basis for the research included 94 respondents. The explorations were performed by an interactive, experience-based kahoot type measuring device. Our survey took advantage of the Bring Your Own Device method and used close ended questions in order to obtain data to be processed via a descriptive statistical approach. The respective results were displayed in diagrams and we deployed a multivariable statistical method, the Kruskal-Wallis analysis. Keeping spatial restrictions in mind, we have compiled a brief summary of the most significant and characteristic results by descriptive statistical methods.

The next figure shows that 91% of the engineering students participating in the survey graduated from high school but did not obtain a vocational qualification. Only 6% of the respondents graduated from a vocational secondary school with a maturation certificate or a high school diploma and a vocational qualification as well. Another 3% came from a special vocational high school after earning a vocational qualification.

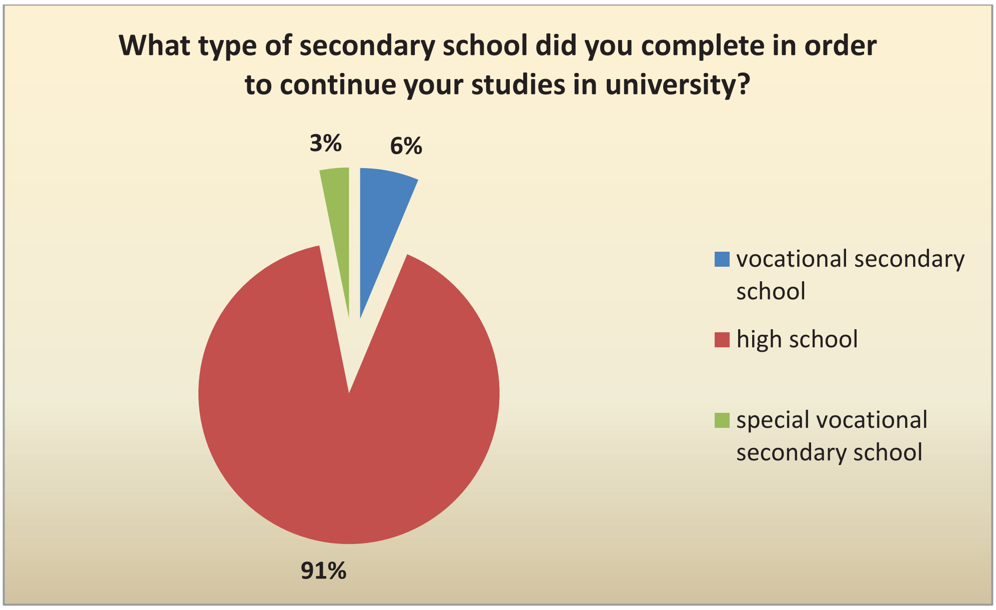

Fig 3. Distribution of the educational qualification of the respondents Source: author's own chart

The next figure reveals the level of the respondents' openness to the modern and new open teaching and learning methods. It can be concluded that 50% of the respondents are fully open to new educational methods (4), 28%, that is over a quarter, are significantly open (3) and 12% (2) and 10% (1) indicated that they were reluctant toward new generation learning methods respectively.

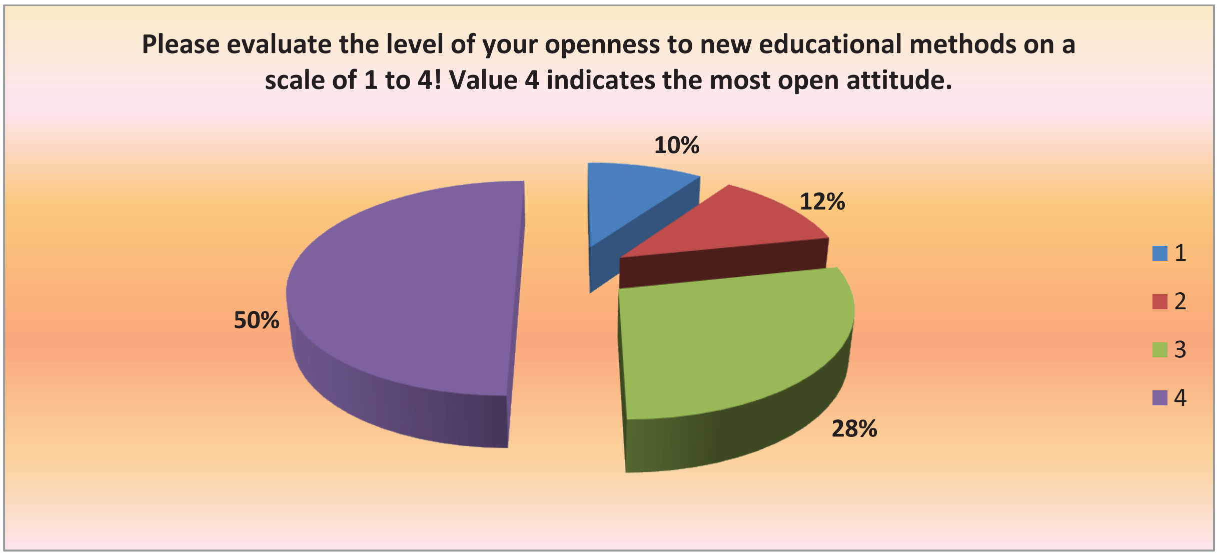

Fig 4. Distribution of the levels of students' openness toward modern, new generation learning methods, source author's own chart

4. SUMMARY

Current learning theory models emphasize the need for the inclusion of on-line digital devices and educational material content in order to provide a background for modern and effective teaching. Educational materials have been expanded to include new media elements, videos, animations, and e-books. Such developments and trends can be beneficial for assuring the quality of engineering training as well. The digital world and its devices increasingly support the improvement of STEM-related skills. Most of the abovementioned developments focus on meeting the demands of the labour market while shaping the respective competences of engineering students in an informal way. It was also proven that today's engineering students are open toward new methodological cultures and the application of pedagogical approaches promoting a shared, cooperative competitive perspective. Such tendencies coincide with the aspirations of the current Industry 4.0 and the Vocational training 4.0 strategies as well. Digital technology and digital culture are expected to be represented by separate subjects as shown by the draft version of the National Curriculum issued in 2018. The high priority assigned to these areas can facilitate the formation and development of the digital competence section of engineer training in higher education institutions. Consequently, engineering students can obtain knowledge, experiences, and skills required for the completion of such programs.

5. ACKNOWLEDGMENTS

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Critical media literacy in the Education of Engineers

How can we tackle the social risks posed by algorithms?

K. Nagy
Budapest University of Technology and Economics
Faculty of Economic and Social Scinces
Budapest, Hungary

Conference Key Areas: Strong demand for democratic involvement in educational processes, Sustainability reflecting the complexity of modern society
Keywords: fake news, online platforms, algorithms, learning by doing

ABSTRACT

Digital technology has profoundly changed the information ecosystem and the way people access information. It is a new phenomenon of the online environment that the operation of online platforms contributes to putting online disinformation and fake news into a new dimension. The paper presents a higher education course which aims to structure the social, social psychological, economical and regulatory aspects and dimensions of the online disinformation phenomenon. The complexity of the information environment in the modern society is presented in this framework. The course focuses on the big internet intermediaries' operation and the impact of their operation. The objective of the course is to ensure that the training of engineers and software developers includes the relevant market, sociological, political scientific, social psychological, and legal/regulatory knowledge that will help foster a responsible attitude in the persons who are behind the creation of the relevant algorithms. The core message of the course is that developing an algorithm to organize the information flow is a kind of regulation, which influences the condition of the public debate and the freedom of expression.

A special pedagogical, methodological approach, based on cooperative learning and learning by doing techniques is presented in the paper. This approach prepares students for creating a policy paper against online disinformation at the end of the course. Besides this, the main element of the methodological approach is that the students' skills to tackle disinformation and propaganda are improved as well. The course adds an interdisciplinary approach to the engineering education, making students understand all aspects which influence the impact that online platforms and algorithms have on the increase of online disinformation in the information environment.

1. INTRODUCTION

How do algorithms that perform internet traffic management shape people's media usage and news consumption patterns? What is the impact of the mass of fake news in the online space on the operation of public discourse? What role might algorithms play in managing the risk stemming from the fake news phenomenon? What ethical norms and social values are reflected in the way these algorithms work? What role and importance could an overview of the social, economic and regulatory dimensions of the information technology ecosystem play in training engineers? These are some of the issues that our course entitled *The regulatory issues of online platforms*[1] *in the context of the fake news phenomenon* seeks to explore.

In the early stages of the internet, it appeared as if the world wide web would help advance democratic culture and democratize public discourse by opening up the public space to every individual, allowing them to speak directly to everyone else and by expanding the possibility to access information to a hitherto unprecedented and previously inconceivable degree.[2] However, these days it has become apparent that the new communication environment generated by the internet is not all positive, that is its impact is not limited to fostering a more democratic culture of communication. It is at the same time also a source of a variety of new and previously unanticipated social risks. The rapid mass proliferation of fake news in online communication is a preeminent example of the variety of risks that plague democratic discourse in the age of online communication.

The underlying cause of this phenomenon appears to be that the information flow bottlenecks have been transformed by the internet, undermining in the process the power of media players that previously operated as gatekeepers, so to speak, in the dissemination of information[3]. Editorial work based on the professional and ethical standards of journalism worked as a filter of sorts sifting through and removing vast quantities of misleading information and fake news that might otherwise have been published. The dissolution of the gatekeeper structure simultaneously resulted in the loss of the filter mechanisms against such harmful and damaging contents and the risks they pose for society. At the same time, we are witnessing the emergence of new types of controlling mechanisms in the form of online services, such as the algorithmbased search engines and algorithm-based editorial control over social media platforms[4] . Since these services have substantial influence on how we access information, and thus on the totality of the information that is published in public discourse, we can regard these as the new gatekeepers of information flows. The strength and value of these services is based on the information flows that are individually customised by the algorithms. The algorithms select between incoming information – reducing the array of information that is potentially available to the given individual – and convey pre-selected information to any given individual based on the personality profile they have compiled about that person by tracking their digital footprint. Managing the flow of information by way of algorithms has become so dominant over the past years that it has given rise to the concept of an algorithmic society, which may be more useful in capturing present-day society than the previously used categories of network and platform society. According to Balkin's definition, an algorithmic society is a "society organized around social and economic decisionmaking by algorithms, robots, and AI agents, who not only make the decisions but also, in some cases, carry them out"[5]. An algorithmic society is characterised by the grand social media platforms that connect nations and average persons, and by their reliance on algorithms and artificial intelligence to control the masses[6], where "algorithms mediate almost all interaction and content that we do not experience directly, face-toface and in person"[7].

Balkin also includes the wide-ranging collection of individual data that helps monitor and keep track of individuals among the key features of an algorithmic society, and he also mentions the appearance of new forms of discrimination and manipulation. The new gatekeepers of the underlying information flows are the multinational corporations which dispose over the infrastructure that serves as the conduit of online communication. It is the decisions taken by these corporations and the workings of the algorithms designed by them that "govern the digital spaces in which people communicate with each other" and "our practical ability to speak is subject to the decisions of [these] private infrastructure owners"[8].

The transformation of the infocommunications environment described above gives an entirely new dimension to the phenomenon of fake news and false information. A striking change is the rapid mass proliferation of fake news in online communication; the underlying cause is found in the mechanisms and key phenomena that govern the operations of the information ecosystem. The inclusion of users in content production and – through the social media platforms – in content dissemination has served to supplant the previously dominant method for filtering information, which rested on editorial practices and standards. Vast amounts of information appear in public that circumvent the traditional methods of information filtering, and the ability of traditional mass media to act as information gatekeepers is seriously diminished. A technological/infrastructural reason for the shift to the new dimension is that the present info-communications environment holds out the possibility of spreading information extremely rapidly – and that is true for fake news, too. The information flows, which have become personalised with the help of algorithms, have engendered an architecture that helps access information that meshes with the individuals' prejudices and preconceptions of the world, thus reinforcing their prior worldviews. The phenomenon of the information filter bubble is one consequence of the individually customised flow of information[9]. Its result is that the information stream that we personally encounter has been pre-filtered based on our previous preferences. This individually customised information stream will not even remotely present all the relevant information on a subject matter, it will only show a narrow segment of the information out there. The segment of information that we do actually encounter will orient itself along the line delineated by our previous online activities based on our personal profile, which was created by algorithms.

Thus, the algorithm-based steering of information by online platforms reinforces the previously observed attitude that governs people's acceptance of information, which suggests that they have a predilection for views and information that meshes with or matches their own, while they tend to disregard information that does not fit into their own view of the world. Such a consumer attitude also favours the spread of fake news. It is worth emphasising that "social media are particularly effective at directly reaching large numbers of people, while simultaneously micro-targeting individuals with personalized messages.[10] Social media have gone from being the natural infrastructure for sharing collective grievances and coordinating civic engagement, to being a computational tool for social control, manipulated by canny political consultants, and available to politicians in democracies and dictatorships alike"[11].

In addition to the problems stemming from the way the broader infrastructure operates, the business model of online platforms and the way they operate in the market also contributes to the mass proliferation of fake news by virtue of the fact that information traffic management is click-sensitive and fosters the rapid dissemination of sensationalistic, click, like and share-bait contents, and correspondingly it also offers a profitable business model for fake news factories.[12]

Needless to say, the online platforms and algorithms that organise the communication on these platforms are not alone in bearing the responsibility for the mass spread of fake news – nevertheless, the way these services operate and their features play a major role in boosting the phenomenon of fake news to an entirely new level, and correspondingly they could also potentially play a major role in combatting fake news.

2. WHY IS IT IMPORTANT FOR THE TRAINING OF ENGINEERS TO INCLUDE A DISCUSSION OF THE SOCIO-ECONOMIC CONTEXT OF THE FAKE NEWS PHENOMENON?

The rapid and mass proliferation of fake news is a complex phenomenon, depending on the perspective one brings to the issue it could be captured as a contemporary problem of either politics and/or media. Technology reinforces the impact of these unresolved problems, and information traffic management systems that are not designed with sufficient care and circumspection could result in massive social risks and harmful side effects. At the same time, it is also true that technological instruments can be used in combatting online disinformation. Today, artificial intelligence can be used to filter out fake profiles on social media platforms that are engaged in coordinated disinformation, while algorithm-based information traffic management allows us to reduce the visibility of fake news. It is thus of the utmost importance whether the companies or engineers that develop the algorithms are cognisant of the social consequences of information traffic management. Similarly, the ethical principles and norms that influence the work of the developers in designing algorithm-based editorial control are also vital. The social responsibility associated with this new type of control is predicated on a knowledge and understanding of how public discourse and the socio-economic context of the media environment operate. This also means that the training of engineers may increasingly call for an approach that takes into consideration the anticipated social impact of technological development, with the corollary awareness of the economic and sociological skills that are needed to understand the relevant social phenomena. This approach is also reinforced by an expert document released by the Council of Europe,[13] which posits that an indirect factor in the design of algorithms ought to be the goal of ensuring that those who produce these algorithms "are aware of the legal challenges, ethical dilemmas and human rights concerns that arise from automated data-processing and decisionmaking techniques. An instrument to achieve such goals could consist of standardised professional ethics or forms of licensing systems for data engineers and algorithm designers, similar to those that exist for professions like doctors, lawyers or architects".

3.THE COURSE ENTITLED *REGULATORY ISSUES CONCERNING ONLINE PLATFORMS IN THE CONTEXT OF THE FAKE NEWS PHENOMENON*

The Department of Business Law at the Faculty of Economic and Social Sciences (abbreviated as GTK in Hungarian) of the Budapest University of Technology and Economics (BME) launched the course entitled *Regulatory issues concerning online platforms in the context of the fake news phenomenon* in the academic year 2018/2019. The course was intended as a pilot project for GTK students. Among other things, the goal was to turn this pilot project into a standard part of the engineering curriculum at the university. It is a one-semester course with two weekly class hours. In terms of its thematic structure and methodological approach, this course qualifies as an innovative element in the educational programme offered by the faculty. It seeks to furnish students with knowledge about a contemporary problem, to wit the mass proliferation of fake news in the online environment, using an interdisciplinary approach to present the risks for society that they give rise to. The basic objective of the course is to review the economic and social aspects of the fake news phenomenon, which has recently become exacerbated to such an extent that is has risen to an entirely new quality and level. In this context, the focus is especially on identifying the roles of online platforms and the algorithms that serve as their information traffic management system, as well as raising awareness about the social responsibility of platform providers and discussing the relevant dilemmas of professional ethics.

3.1. The structure of the course and the outline of the topics

The course is based on three major pillars. The first pillar organises and structures those technology, economics, market, politics and media-related issues and phenomena that had an impact on shifting fake news into their new current dimension. At the same time it also explores the social risks and threats stemming from the rapid mass proliferation of fake news. It reviews the regulatory framework that applies to fake news contents, that is it explores the limits that the existing legal regulations impose on the public dissemination of misleading and false information. As part of the discussion of the relevant regulations, the review of the pertinent rules concerning the regulations of online platforms with respect to their handling of fake news will receive special attention. The discussion will also highlight those social values and objectives that can only be realised with the active involvement and cooperation of platform providers and technology developers, such as for example the transparency of their algorithms or, closely related to the latter, the issue of the research community's access to data that is pertinent to our understanding of the fake news phenomena"
The second pillar is the issue of internet governance. The objective of the course is to review the regulatory processes that pertain to the operation of the internet and to discuss the questions of professional ethics concerning technological development in their broader regulatory context. The course will also present the efforts at tackling the issue at the level of the European Union. It will discuss the expert consultation

procedures that have been ongoing in the EU over the past years to shine a light on the details of the efforts to identify solutions at the European level.[14] The focus on the applied aspects of the regulatory process will provide the students with an idea of the potential methods and workings of internet governance. The regulatory process that is implemented in the framework of governance is based on the mutual cooperation of stakeholders (e.g. market players, the state and academia), and the eventual regulatory solutions in such an approach are designed in the complex network of cooperation between state, economic and social players.[15] The course models the underlying regulatory process, and the final output of this effort is a policy paper jointly drawn up by the students, which will include a package of strategic solutions against online disinformation.

The third pillar is the development of critical media literacy. The relevant skills are all part of the 4C framework: critical thinking, communication, collaboration and creativity.[16] Among the various competencies that make up the broader concept of media literacy, critical media literacy stresses the importance of bringing a critical perspective to media use and information consumption. The key features of today's information environment, i.e. the confluence of the sheer mass of information, the relative ease of manipulating digital contents, and the disintegration of the previous system of information gatekeepers, necessitate a higher level of critical skills than previously. If someone is unable to properly sift through the mass of information they receive, and to effectively analyse, evaluate and synthesise the information thus collected, or if they are unable to properly communicate their messages to others, they could easily become vulnerable and readily manipulated in the realm of digital communication. Critical thinking also includes the ability to avail oneself of the skills one has acquired to solve problems and to properly use data and facts in the process, which is why critical thinking and problem-solving skills are frequently interrelated.[17] The course uses exercises to improve the students' critical thinking.

Communication is developed through collaboration in this course. "Collaboration is a process through which a group of people productively explore their ideas to search for a solution that extends into the exploration and generation of new concepts".[18] In our presentation of the course methodology, we will also provide a more detailed discussion of how communication and collaboration skills will be improved; for the time being, we only wish to stress here that we will typically use small group cooperative learning techniques to work through the curriculum and convey the relevant skills.

Creativity can also be described as thinking differently or, to put it metaphorically, as "thinking outside the box". Creativity means imagination, the formulation of new thoughts, solutions and unique ideas. In the course, the development of creativity will play an especially important role in drafting the joint policy paper, where the students will apply the knowledge and skills they acquired during the classes to come up with a package of solutions to tackle the mass proliferation of fake news.

To review the thematic structure of the course, we have chosen the method of presenting the details of individual topics by laying out the questions that we will discuss during the respective sessions.

1.Introduction: the phenomenon of fake news in the algorithmic society What is fake news? What definition could be used to accurately capture the concept of false and misleading information that poses a risk to society, and on what type of fake news contents should one focus on in the process of coming up with solutions? (Typology of fake news and online disinformation) Fake news has always existed. What factors have elevated the problem to a whole new level?

2. The technological context of the fake news phenomenon: network science, artificial intelligence, algorithms What technological tools help spread the mass dissemination of fake news, and what tools might technology provide to combat fake news? (recommender systems, semantic technology, fake news-spreading bots, algorithmic news analysis)
3. The social and news market context of the fake news phenomenon and its impact on public discourse What are the media-related causes and background of the fake news phenomenon? (changes in news consumption and information patterns, the transformation of the news market) Why do fake news spread? (psychological and social psychology background) What impact does the mass proliferation of fake news have on the functioning of public discourse and on the quality of democracy? (fragmented public discourse, emotion-governed public debates, a general loss of trust in the media)
4. The economic and market context of the fake news phenomenon What economic and business reasons might explain the mass proliferation of fake news? (the mechanisms that govern online advertising: personalised advertising and the possibility of monetising fake news contents in the online space)
5. Fake news and content management regulation Does the law prohibit the public dissemination of lies? Are we living in the post-truth era? What tools does the law provide us with to stem the spread of fake news? (freedom of expression, lies concerning specific persons – defamation, media law instruments)
6. The regulatory framework of online platforms – regulatory provisions that are relevant with respect to the fake news phenomenon, with a special focus on the regulatory universe of Facebook What is the responsibility of online platforms for contents published by their users? Can online platforms regulate autonomously? Are Facebook's activities involving the removal of contents and blocking of users lawful?

7.Self-regulation mechanisms: The answers and initiatives of online platforms What measures and service functions do online platforms deploy to reduce the level of fake news contents published on their platforms? (action to combat coordinated misleading communication, ranking policy, solutions to demonetise fake news contents)
8. EU policies with an impact on the operation of online platforms: regulatory approaches, pending initiatives, proposed solutions
What were the key stages over the past two years of the European Commission's policies aimed at combatting online disinformation? (internet governance, official EU documents, the self-regulation documents of online platforms)
9. Overview of problems: defining the issues that a set of solutions to tackle online disinformation must address Assigning the issues to small groups that address them individually.
10. Developing critical media literacy: The possibilities and practice of strengthening the consumer side. (Reviewing the credibility and reliability of information, the practice of critical questions, analysis of sources and fact-checking practices)
11. Presenting policy materials concerning individual policy areas – results of the small group problem-solving exercise
12. Using teamwork to develop a package of solutions against online disinformation (joint policy paper)

3.2. The methodology of the course

Diversity

The course will realise the envisioned multi-layered development of student skills with the combined deployment of diverse methodological elements, which will include regular teacher presentations, small-group in-class exercises, small group research outside class, individual desk research, drafting and giving presentations; as well as a large-group structured exercise.

Personal media experience and individual information consumption patterns

The starting point of the underlying pedagogical approach that we have adopted for the course is to draw on personal experience and individual information consumption patterns – as well as the relevant personal experience – and integrate these into the teaching/learning process. The students' recalling of their own experiences will help the instructors convey the relevant knowledge about the given topic and to share the relevant experiences within the group. At the same time, no substantial progress can be attained in developing media literacy without bringing the students' own experiences out in the open: a reflection on one's own information consumption and media experience helps the emergence of a more deliberate and reflective media consumption.

Topicality, current developments

The course will also present the various regulatory approaches towards internet governance and it will track the current developments that try to get a handle on the fake news phenomenon. To enhance the success of this effort, the course will also look at the rapidly changing technological and business environment, and in the process of discussing these we will also refer to current events, news, and new features developed by the various platforms as part of their effort to combat fake news, as well as the evaluation of the aforementioned. We will discuss current and topical research, such as for example surveys of consumption patterns and media markets, statistics, and the continuously changing service functions of online platforms and recent changes in their terms of agreement with their users. If Facebook adds a new feature aimed at reducing the visibility of fake news, that will also be a part of our discussions, and the same holds for the assessment of the most recent transparency report on the deletion and blocking activities of Facebook. In addition to reading and interpreting the texts, such classroom activities also offer excellent opportunities for games that help us work through specific problems by looking at the event from the perspective of various stakeholders. One example is the exercise in which small groups of students take the role of Facebook decision-makers who need to come up with a package of solutions in response to the adoption of detailed German regulations concerning online platforms. These solutions must allow Facebook to operate without violating the new law and to avoid becoming subject to the sanctions set out in the law.

Using multimedia materials for education

The course also relies on scenes from films that are particularly apt for demonstrating certain phenomena under discussions. In the previous semester we used scenes from two films on topical issues, the documentary *The Cleaners*[19] and the movie *Brexit*[20]. In addition to the films, we also use online teaching interfaces in the course. The website News Literacy Project[21] Checkology.org and the e-learning curriculum (alhirvadasz.hu) created by a Hungarian investigative news portal[22] are aimed at improving critical media literacy. Assessment

The assessment of the students' work and progress during the course will orient itself along the lines of the course objective. The assessment is based in equal parts on two distinct elements: a mid-term paper written about the course materials at the end of the two-thirds segment of the course as well as the evaluation of the research/presentation exercise.

4. CONCLUSIONS

The fake news problem has shifted to a whole new level due to a complex confluence of social, economic and technological developments. This new informational environment that has emerged as a consequence of the pervasive use of algorithms harbours new types of risks for the workings of our public discourse and the democratic values that govern society. Exposing and understanding these risks is a basic precondition for the ability of the companies and developers who are responsible for the operation of the algorithms to define the infrastructural framework of online communication in line with consensual social norms and ethical principles. The most fundamental objective of the course presented here is to ensure that the training of engineers and software developers include the market, sociological, political scientific, social psychological, and legal/regulatory knowledge that will help foster a responsible attitude in the persons who are behind the creation of the relevant algorithms. In addition to the academic/technical knowledge, the course will also place a substantial emphasis on developing the students' skills, since critical media literacy not only serves to increase the students' awareness when they consume information but also seeks to convey the possibilities for and potential impact of technological manipulations.

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Hands-on work in a web-based Basic Electronics course

J.K. Naukkarinen [1]
Post-doctoral researcher, LUT University
Lappeenranta, Finland

M. Kuisma
Associate professor, LUT University
Lappeenranta, Finland

H. Järvisalo
Junior researcher, LUT University
Lappeenranta, Finland

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Keywords: web-based learning, project work, outreach activity, electronics

ABSTRACT

For the past eighteen years, LUT university has offered a basic electronics course for secondary high-school students as an open and distance education. Over the years, the course has evolved in many ways. As the latest development step, a set of practical hands-on activities was added to the mainly web-based course in the quest to make the study matters more interesting and better relate the theory of electronics to the everyday life.

The latest edition of the course consisted of self-study materials, weekly assignments on a learning platform, a laboratory day on the university's premises, and an electronics-related project work, where students devised a project plan, executed, documented, and presented the project. To get acquainted with the Arduino platform the students completed three small programming exercises.

There were many different challenges in adding hands-on work to a distance teaching course. The students came from seventeen different high schools, hundreds of kilometres apart, and most of them quite far from the university. Most of the students had no prior experience in using Arduino boards, and the high-school teachers were not involved with the course, so all the supervision had to be arranged by the university.

Despite the obstacles, the addition of a hands-on element to the course was considered a success. In the course feedback, the students rated the project work high

[1] Corresponding Author
J.K. Naukkarinen
johanna.naukkarinen@lut.fi

in terms of its support for learning. In the web discussions, many of the students mentioned the project as the most interesting experience in the course.

1 INTRODUCTION

Web-based teaching offers new kinds of opportunities in many areas of engineering education, including outreach activities. In outreach activities, the benefits of online education are much the same as in degree education: flexibility in time and space makes the course accessible to those for whom it would otherwise not be possible to participate in the course. Web-based learning platforms also allow new types of teaching and learning tasks and new means of feedback and assessment [1].

Although web-based activities may enable reaching wider audiences, in order to be considered successful outreach activities, they also have to be interesting enough for people to engage in them and complete them. Student persistence in a web-based course can be enhanced in many ways, such as continuous facilitation by the teacher [2] or built-in time management help for the learners [3]. However, at least in engineering-related outreach activities, hands-on experiences have been noted to increase participants' knowledge, interest, and confidence in the field [4].

The challenge of combining web-based and hands-on activities had been tackled in the Basic Electronics course for high-school students for years by organizing a web-based course ending with a day at the laboratory. This arrangement followed the traditional "theory first" approach and was based on the idea that on the laboratory day the students could put into practice the things that they had learned before. It did not, however, ideally support experiential learning through interplay of theory and practice [5], and thus, some novel additional features had to be developed.

2 BASIC ELECTRONICS FOR HIGH-SCHOOL STUDENTS

Basic Electronics is a 5 ECTS, Bachelor-level study module, which is compulsory for students in the degree programme of Electrical Engineering. For the past eighteen years it has also been offered to the secondary high-school students as an open and distance education. The intended learning outcomes for the module state that after the module students will be able to:

- "recognize the most important passive and active components in electronics and list their applications,
- explain the main differences between analog and digital electronics,
- define concepts of amplification on filtering,
- explain the operation and simplified physical structure of an ideal semiconductor diode,
- describe the operation and main applications of a transistor,
- describe the operation principle of digital logic gate and list common logic functions,
- recognize the main phases and materials of manufacturing an electrical apparatus,
- apply Ohm's law, Kirchhoff's voltage and current laws, and definition of electrical power to a simple electrical circuit, and
- recognize the main components of an embedded system" [6].

Before the year 2018, the module consisted of a seven weeks long self-study period, where a new topic was introduced every week. Topics of the course were: Introduction to electronics and signals, Passive components and filtering, Amplification in electronics, Semiconductor materials and diodes, Transistors, Digital electronics, and Manufacturing techniques in electronics. After studying each topic, the students took a week test, and after completing all the topics, they took an exam on the learning platform.

The self-study materials were accompanied by weekly discussion forums, where students could ask questions and make comments. Active participation in the discussions could yield some extra points to be added to the week test and exam points. The course area also included forums for more general discussion about the course.

After passing the exam, the students could attend a laboratory day at the campus, where they learned soldering by building an electronic circuit from an assembly kit, such as a blinking LED array in the form of a heart. Furthermore, the students could practice their presentation skills by explaining the operating principles of their circuits to their peers.

In recent years, the number of high-school students enrolling in the module has varied between 50 and 70. The drop-out rate is quite high, which is common in web-based courses and trainings. Typically, about half of the enrolled students also finish the module and get a grade. Students come from about fifteen different high schools in a large geographical region. The students may live as far as 200 km from the university campus. Some attendees may be the only ones from their high school, whereas some schools get more than ten of their students to enroll in the course.

3 PROJECT WORK WITH THE ARDUINO ELECTRONICS PLATFORM

In spring 2018, a project work was added to the module to enhance the students' hands-on learning experience. The decision to include more practical elements in the course was based on the good student feedback regarding the laboratory day, the positive experiences of introducing the open-source electronics platform Arduino [7] in other outreach activities [8], and the development ideas collected from high-school teachers and headmasters in the region.

The concept of project work was first tested with electrical engineering B.Sc. students. The theme of the project was decided to be kept open so that the students could make a small application according to their own interest. The students were free to choose their project topic; however, it had to apply a microcontroller platform, in this case Arduino. Furthermore, the project had to have an interface to the outside world, such as a button, a sensor, or a LED display. A couple of different project examples were built and documented to illustrate the diverse options available. The students were also given a list of components at their disposal, but they were also told where they could easily purchase additional components if required.

The project work was divided into four subtasks: writing a project plan, building the gadget, making a project report, and peer evaluation of the works of the others. Three small assignments were devised to familiarize the students with Arduino boards. The timetable of the self-study and the project work is presented in *Table 1*. The projects were done mainly in groups of 2–4 students, but also an individual project was an option chosen by some.

Table 1. Timetable of the learning activities

Week	Self-study	Project work
6	Getting to know the course and the course mates	
7	Introduction to electronics and signals	
8	Passive components and filtering	Project info
9		
10	Amplification in electronics	Forming of project groups
11	Semiconductor materials and diodes,	Arduino assignment I
12	Transistors	Arduino assignment II
13		Arduino assignment III Handing in the project plan
14	Digital electronics	Working on the project
15	Manufacturing techniques in electronics	Working on the project
16		Working on the project
17	Web-exam	Working on the project
18		Handing in the project report
19		Peer review of project reports
20	Laboratory visit to LUT University	

A designated discussion forum was established for the supervision and guidance of the project work. The work was mainly guided by two teaching assistants, who for example reminded the students of the approaching deadlines or informed them about different instructions and guiding materials. Some students were very active in answering other students' questions and gave the others good tips and advice.

In addition to the topic of the project, the students could choose their mode of documentation. Again, a couple of different alternatives were offered. Most of the documentations contained images or videos or other kind of multimedia elements, which added also to the objective to make the learning more hands-on as opposed to writing plain text only. Students experimented different publication platforms and presentation programs, producing visually and informatively high-quality reports. Further, the oral presentation of the projects during the laboratory day enhanced the students' generic communication skills, team building, interpersonal skills, and the sense of responsibility—skills required of modern electrical engineers [9] as well as many other professionals.

4 EFFECTS ON LEARNING

In general, the implementation of the practical project work in the otherwise web-based course succeeded as planned. The basic figures of the year 2017 (before the project work) and year 2018 (first implementation of the project work) are collected in *Table 2* and show improvement in all the areas: the proportions of students completing the exam and the whole module, and the average grade of the students both in the exam and for the whole module are higher. It should be noted that the grading scheme for the module varied between the years, because in 2018 the Arduino assignments and project accounted for 30% of the total grade.

Table 2. Key figures of the Basic Electronics course for high-school students

	2017	2018
Enrolled students	61	70
Students completing the web exam	31	45
Students completing the whole module	30	41
Average grade in the web exam (max. 5)	3.43	3.59
Standard deviation of the exam grade	0.50	0.49
Average grade for the module (max. 5)	3.1	3.8

The web exam was exactly the same in both years; the relative distribution of the exam grades is illustrated in *Fig. 1.* Even though the number of students taking the web exam in 2018 was almost 50% higher than in 2017, the average, median, and mode of the grades were all higher in 2018.

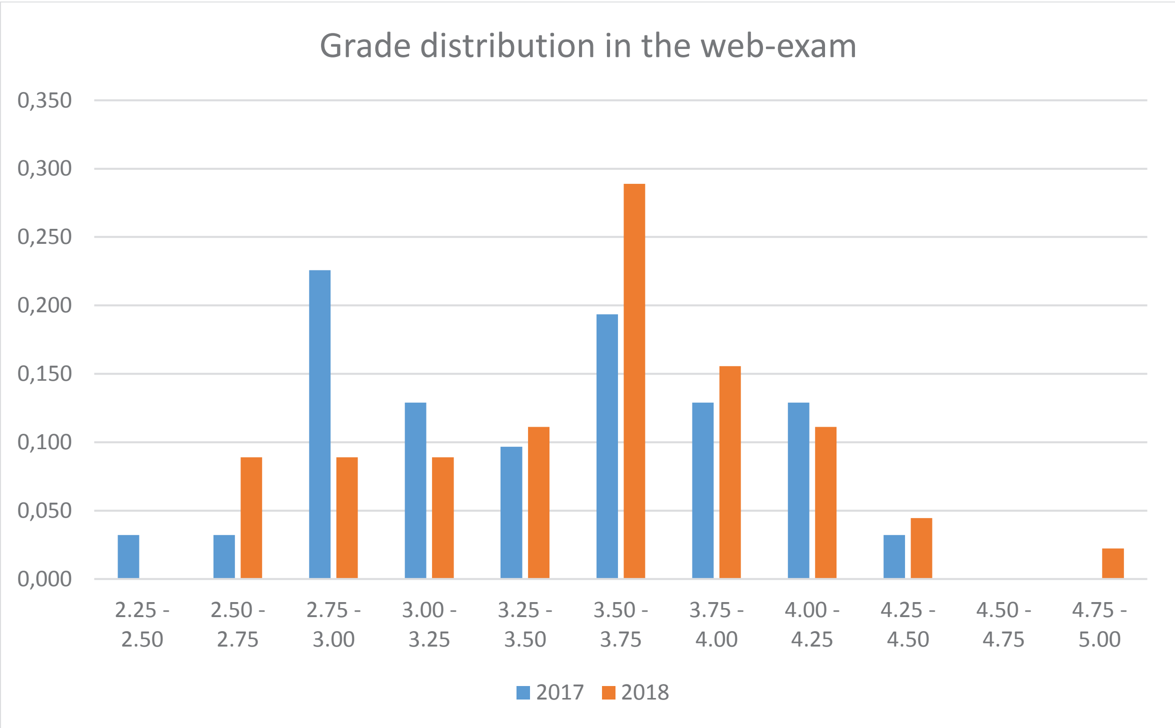

Fig. 1. Distribution of exam grades in the Basic Electronics course for high-school students

At the end of the course, the students were asked to assess their learning experience and the role of different learning activities in it. The survey shows that students perceive the hands-on activities also educative and not just entertaining. The results are collected in *Table 3.*

Table 3. Student feedback regarding the support of different activities for learning

How did the following things support your learning during the course (1=not at all, 4=very much)?	2017 (N=27)	2018 (N=40)
Written teaching material	3.5	3.3
Teaching videos	2.0	2.1
Weekly assignments/quizzes	3.3	3.1
Discussions in the discussion forum	1.7	1.9
Moodle exam	3.0	2.8
Arduino assignments		3.2
Arduino project		3.3
Laboratory work	3.4	3.4
Poster presentation in the laboratory day	2.7	

Students liking the project work also participated in a discussion thread spontaneously started by a student who wanted to know what the others thought of the course. In the thread, the project work got most of the votes as the most interesting thing:

> *"Absolutely best thing was building with Arduino"*
>
> *"In my opinion, the best part of the course was the Arduino project, which went really nicely with familiar people, once we got over the starting difficulties."*

In the same discussion thread many students acknowledged the challenges with self-study:

> *"For me independent studying has been challenging, because I haven't been able to push myself to study as much as I should have."*
>
> *"The course was more difficult for me than they usually are. This may be because of the self-study."*

Some students suspected that they would have learnt better in a more traditional classroom setting:

> *"I still think that I could have done better if the course had been organized in a more traditional way in the classroom."*

Thus, it seems that adding a hands-on group project in a web-based course in Basic Electronics has the potential to increase students' interest, support their learning, and bring about better sense of communality to the otherwise quite challenging realm of self-study.

5 CHALLENGES AND DEVELOPMENT NEEDS

Perhaps somewhat surprisingly, some of the major challenges with the implementation of the project work were related to the physical delivery of the microcontrollers and components to the students. Within the rather tight course schedule, the deliveries lost in the mail or in schools delayed the projects of some students and caused confusion and irritation. Unfortunately, some of these problems repeated also in spring 2019, and therefore, a satisfactory logistic solution is yet to be found.

Even though many of the students had never worked with the Arduino platform before, they managed well with the help of our instructions, peer support, and the Internet. Discussion forums in the learning platform seem to work sufficiently once the students find them, but more help is needed to help the students to navigate in the learning platform and the material bank. Although the high-school students are “digital natives” in many respects, they are not as used to the learning platforms and independent study as the university students and need more orientation and scaffolding for time management and navigation in the course area. In this, the constant web presence of the teacher and teaching assistants along with reminders of different obligations and deadlines is essential.

6 CONCLUSION

Complementing web-based learning with hands-on activities requires some effort but appears to be worth it. Although this kind of a tinkering project in groups adds to the workload of the students and poses some logistic and instructional challenges to the teachers, it also strengthens the connections between theory and practice, lets students use their creativity, enhances the development of generic skills, and increases the peer support and sense of community. As the project undoubtedly increases the students’ time management challenges, it is important to design and structure the activities in a way that scaffolds the student progress, but also to ensure the constant web presence of teaching staff in the course. At its best, combining modern information and communication technology in its different forms and the practical hands-on construction of artefacts in the same outreach activity clearly demonstrates to the high-school students what engineering is all about: creating technological constructs with people and for people.

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Engineer to Manager Work-Role Transition: A Single Case Narrative

S. Nittala[1]
Purdue University
West Lafayette, United States

B. Jesiek
Purdue University
West Lafayette, United States

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ABSTRACT

Promoting engineering talent to managerial and leadership roles has been an on-going challenge for many organizations. A growing body of research suggests that engineers are often ill-prepared for taking up managerial roles, leading to reduced job effectiveness and performance. Moreover, there is a lack of clear understanding of the nature of the engineer to engineering manager transition. To address this gap, this study aims to uncover the lived experiences of recently transitioned engineering managers. More specifically, this paper addresses the following primary research question guiding the study: What are the work-role transition experiences of recently transitioned engineering managers? The data for the larger study comes from interviews with 18 recently transitioned engineering managers. An interpretive qualitative analysis approach is employed to analyse the interview data. To keep the scope of the current account more manageable, this paper presents preliminary results in the form of a holistic narrative for a single participant. By providing rich accounts of one participant's experiences and transition journey, we highlight three major themes emerging from our preliminary findings: 1) psychological and cognitive changes associated with the work-role transition, 2) on-the-job learning and mentoring supports for transition, and 3) social skills as essential attributes for the transition. We conclude with some potential implications for continuing education and professional development programs aimed at engineering professionals. It is expected that this paper will help students, engineering educators, engineering leadership faculty, and industry affiliates reflect on the realities of engineering managerial practices.

[1] Corresponding Author
S. Nittala
snittala@purdue.edu

1 INTRODUCTION

Changing organizational structures and job expectations demand that many engineers and other technical professionals transition into managerial and leadership roles very early in their careers [1,2]. Yet engineers and employers alike often characterize this as a difficult transition, leading to a less productive and effective technical, managerial workforce. This, in part, could be attributed to the lack of preparedness of engineers to cope with managerial work demands. Recent studies have also confirmed that engineers are often ill-prepared to meet the responsibilities of managerial roles [2,3] such as effectively delegating work, moving away from technical work tasks, etc. Many also struggle with a lack of understanding of what managerial roles entail. Some of these challenges have additionally been evident in the lead author's experiences working as an intern at a major telecommunications company. Yet despite a small but growing body of evidence about the criticality of the engineer-to-manager transition and the associated challenges, high-quality empirical research studying various aspects of this transition remains scant.

These observed gaps and challenges serve to ground and motivate further investigation of several issues, including: a) the lack of preparedness of engineers to take up engineering managerial roles; b) the specific challenges engineers face as they move up the ladder as managers; c) the lack of clear understanding of how engineers are promoted to managerial roles; and e) the lack of clarity on training and onboarding processes for new managers. This paper reports preliminary results from a larger qualitative study involving interviews with 18 recently transitioned engineering managers. Here we present preliminary results in the form of a holistic narrative for a single participant. We conclude with some potential implications for continuing education and professional development programs aimed at engineering professionals. It is expected that this paper will help students, engineering educators, engineering leadership faculty, and industry affiliates reflect on the realities of engineering managerial practices.

2 LITERATURE REVIEW

2.1 Career Transition

Historically, career transition has been associated with role change or a change in orientation to existing roles [4]. Recent definitions broaden the scope further by defining the transition as a process of engagement and disengagement from any work role and/or work situation [5]. While authors and scholars have explored a wide range of topics under the broader career transition phenomena from a variety of perspectives, in this study we specifically explore and characterize transition as a change from a technical professional or engineer role to a managerial role.

2.2 Engineer to Manager Transition

While there have been numerous studies to date in nursing, social psychology, management, and other fields focusing on work-role transitions, research specifically focused on the transition from an engineering role to a managerial role remains scant. Furthermore, in a prior literature review conducted and presented by the authors [6], we discuss how published work on the engineer to manager transition has been mostly limited to three main considerations, namely: 1) competencies and skills required for engineers to transition into managerial roles (e.g. [7,8]); 2) challenges associated with the transition (e.g. [2,3]); and 3) strategies for effective transition (e.g. [9]). We further note that there remains a dearth of literature describing holistic experiences of recently transitioned engineering managers which in turn could uncover several aspects of the transition from the perspective of the engineers themselves [6].

2.3 Work Role Transition Theoretical Framework

For this study on the engineer to manager transition, theoretical concepts from work-role transition models are used as a guiding framework. This framework is well suited for this study, as it revolves around understanding the transition from the individuals' perspectives. The literature on work-role transition is often concerned with addressing questions such as how individuals disengage from one role and engage with a new work role. As synthesized by Anderson [10], work-role transition theories and models explore "aspects of entry into the role, the transference of role expectations, and exit from the previous role" (p. 204) related to any transition.

Work-role transition theory was first proposed by Nicholson [11], who explored aspects of the individuals' adjustment to new roles during transitions. He proposed that individuals in role transitions often go through two types of adjustment processes – role development and personal development. These processes are further accompanied by several changes in individuals' behaviours, identity, formal and informal relationships, etc. Building on Nicholson's model, further studies in the field have also examined the changes associated with the transition for individuals disengaging from old roles and engaging in new roles. In synthesizing the several aspects of changes that are critical to work-role transition, Ashforth and Saks [12] suggest that "work-role transitions often entail a reorientation of goals, attitudes, identity, behavioural routines, informal networks and many other large and small changes" (p. 157). Not surprisingly, most literature on work-role transition addresses one or more aspects of these changes related to the transition experience.

Notably, authors have been approaching the studies on transitions and associated changes from three broad perspectives: psychological, relational (social aspects), and cognitive [10]. The psychological perspective deals with understanding changes and/or adjustments in individuals' physiological constructs such as identity, persona, etc. as individuals transition into new work roles. Similarly, relational changes are often described in terms of individuals' social connections, including inter-personal relationships, informal networks, etc., that are critical for adjustment into a new role. While social and psychological changes are often central to most literature on work-role transition theories and models, Anderson [10] also advocates for exploring the cognitive or thinking changes associated with the role transition to provide a more holistic understanding of transition.

Although the work-role transition theoretical framework has been used to study nuances of a wide range of role transitions such as from expert clinician to novice academic educator (e.g., Anderson [10]), and from middle manager to senior manager (e.g., Nicholson and West [13]), it has not been used to study the transition process from individual contributor role to engineering managerial role.

3. STUDY DESIGN

The overarching purpose of the larger research project is to explore and understand the meaning making and lived experiences of engineers who have transitioned to engineering managerial roles. In order to describe the transition journeys of engineers as they move into engineering managerial roles, the following primary research question and associated sub-questions are addressed:

Research Question 1 (RQ1): How do engineers describe and make sense of their experiences of transition from individual contributor roles to engineering managerial roles?

a) How do engineers experience and describe the changes and challenges associated with the transition from individual contributor roles to managerial roles?
b) How do engineers describe their preparations for the transition?

To address the primary goal of understanding the experiences of recently transitioned engineering managers, we have employed an interpretive qualitative study design. An interpretive approach is concerned with "understand[ing] how people make sense of their lives" (p. 38 [14]), which is central to the research objective for this study. In accordance with this methodology, semi-structured interviews were conducted with 18 recently transitioned engineering managers. Each interview was approximately 60-90 minutes in duration. The data collection phase is mainly inspired by narrative [15] and critical incident [16] interviewing techniques. These methods are employed to elicit grand narratives or stories of the participants' experiences, which are used for further analysis to address the research questions presented above. The data collection was carried out under appropriate guidelines and approvals for human subjects research.

For the data analysis process, we initially analysed the data using only an inductive thematic analysis approach. However, as we began coding, we realized that the complexity of the transition process would not fully be captured only through the codes. We felt that categorizing data into smaller units did not adequately justify the incredible journeys of transition that the individuals shared with us, as they talked about their experiences moving from engineer to engineering managerial roles. We thus decided to follow a thematic narrative approach inspired by Kellam, Gerow & Walther [17] for each participant to describe their journeys of transition.

The following steps were followed to construct these third-person narratives. First, we identified critical incidents from the interview data that are relevant to the research objective – experiences of engineers as they transition to managerial roles. Second, we chronologically arrange the incidents. Third, we identify quotes from each interview transcript that validates the narrative plot. Finally, we will include our analysis as we develop the thematic analysis narratives that are interjected with our interpretations of each participant's experiences and journeys. Once the narratives are developed, we will also identify specific themes/patterns emerging from the narratives and interview transcripts as relevant to the research questions.

To keep the scope of the paper manageable, here we present a single participant narrative highlighting our analysis of the major themes running through the transcript. Two interviews, including initial and follow-up interviews conducted with a single participant, are used to construct the narrative using the steps mentioned above. The narrative begins with a brief profile of the participant and then presents a series of incidents that are thematically related to the research questions.

4. FINDINGS

After receiving a master's degree in Construction Management from a large research university in the Southwest U.S., Kris took a position as a technical analyst at Pie Corporation (all identifying information anonymized) in the Midwestern U.S. Over a period of about 6 years, Kris moved up the ranks in the company, from a technical analyst (or consultant) role to a program manager. In his current role as a program manager, Kris's responsibilities not only include managing a portfolio of projects but also managing and leading seven employees who directly report to him. In talking about his responsibilities as a program manager, Kris also emphasizes the people aspect of his role when he states: "So, my current responsibilities also include managing the people as a mentor, so I'll be, I'm not just a project, I'm also a people manager where I manage and mentor the constituents that report to me."

Transitioning from an individual contributor role to a program manager has been a "big change" for Kris. Reflecting on this journey, Kris not surprisingly characterizes the transition as big and difficult as he talks about the associated increases in stakes and responsibilities. Throughout the interview, he uses the words "challenging," "big," and "difficult" to describe the transition. For example, as Kris explains:

> So it's been a big transition from being an individual contributor to a people manager as well as now the stakes have increased. As a consultant, I could always go back to my manager to manage them. But right now, I have to manage escalations. So that was a big challenging transition that I had to make for myself.

This experience of difficulty in navigating transition aligns well with prior empirical research on the engineer to manager transition [3] as well as the work-role transition theory [6]. Primarily, as Kris began to enter his new role, he experienced several changes that he wasn't quite prepared for. These, in turn, made the transition difficult for him. One such change that Kris had to cope with was the initial perceptions he had about the managerial role. Contrary to his expectations, the managerial role demanded more work form him than he had perceived:

> Yeah. So when I was a consultant, I used to think: what is the job of a manager, what does he do? He doesn't do anything; he's always free. He just assigns activities and then- (laughter). Once I've moved into this role, I really understood the pain and the amount of responsibility of a project manager. It's not just tracking the project to the schedule or budget, it's a lot more about soft skills and how do you handle your customer escalations and also how do you make sure your resources are also, it's about selling something to the associates, not just assigning work to them. So you need to make sure we get the required interest from the customer to do the activities, not just assigning the activity to them. Now I understand how much work it is and how much struggle or pain the managers go through.

One of the other changes that Kris struggled with was the addition of the people management component in his new role. Not having any prior formal experience managing people, Kris struggled a bit initially with this new job responsibility. He realized that he was now “accountable for the whole team” and not just for himself, which was something he had to learn on the job.

While aspects of the transition were challenging, Kris adapted to some changes associated with the new role rather confidently. Positive experiences also helped him ease into the new role more quickly. For instance, although Kris had to assimilate himself into the new role as a manager, he still retained his former identity as a technical contributor:

> I identify myself as a project manager right now, but I cannot forget what I have gone through as a [technical] consultant, so I still know the reality of that role, so I don't, um, push my people because I know what they are going through. So instead, I try to understand their problem and come up with a solution, so it's easier for them to handle that too.

Despite the challenges thrown at him due to the role change, Kris eventually found ways of navigating these challenges as he spent more time in his new job role. Interestingly, Kris had a steep learning curve in his first six months of transition. In talking about his preparations and learning to assimilate into the new role, Kris states that he learned most of it “on the job.” Notably, the mentoring he received on the job from his managers as well as the initial job shadowing of his manager greatly helped him cope with the transition. Referencing the mentoring relationship he had formed in his initial years, Kris says,

> I was assigned a mentor from the senior leadership team who helped me with project management aspects. He also guided me if I went off track on something. There wasn't any formal classroom teaching, but it was mostly on-the-job learning.

After spending close to two years in his new role, Kris finally feels settled and confident to handle the job responsibilities of a manager. In this narrative, we also see a shift in Kris's perspective in dealing with the role change. Whereas initially he was mostly focused on trying to stay afloat and navigating through the challenges, now his attention has shifted toward playing on his strengths and weaknesses to excel and succeed in the role:

> So, I think I have improved in my communication skills, so soft skills, but I'm not yet, I think I'm not yet perfect in it, but I have improved a lot since I've started. Also, I'm good at now understanding the expectations of all the different people that are involved. And also learning to be a better program and people manager than just a manager.

In this quote, Kris characterizes his transition as a positive learning experience. This is quite contrary to his initial experiences of feeling the role was difficult and challenging. Now he is in a state where he is looking to learn more and grow further in his role.

5. SUMMARY, DISCUSSION, AND IMPLICATIONS

Kris's account of his transition journey provides a brief yet critical window into the world of engineering managerial work practices. While the narrative provides a holistic view of the transition as experienced by the participant, we also intend to shed light on three major themes emerging from the narrative transition including the psychological and cognitive changes, preparations for the transition including on the job learning and mentorship, and the emphasis of social skills required to successfully transition into the new role.

In terms of changes experienced, the subject alludes to changes in psychological and cognitive constructs as prescribed by the work-role transition framework [10]. For instance, psychological shifts are evident as Kris references shifts in his identity as he talks about considering himself a manager along with retaining his old self-identity as a technical professional. Similarly, in terms of cognitive shifts, Kris talks extensively about the disconnect between managerial role expectations and reality. Primarily, he was surprised by the amount and kind of work the new role entails, which was quite inconsistent with his earlier perceptions of a managerial role.

However, differing from prior research on the work-role transition framework, we observe that Kris does not mention any substantial relational changes.

In describing the preparations for the transition, not surprisingly, Kris credits on-the-job learning as his primary source for learning about and preparing for the new role. Through his narrative, it is evident that having a mentor also bolstered his learning and preparations for entering the new role. These insights into learning mechanisms suggest the importance of mentorship programs in organizations to enhance the transition process for engineers. A robust job-shadowing process could also help engineers transition more quickly and productively into managerial roles.

Through Kris's narrative, we also find that social skills are essential for successfully transitioning from technical into managerial roles. Reflecting on his new-found appreciation for communication and social skills, Kris states that he has improved a lot in this area, which helped ease his transition into the managerial role. Perhaps not surprisingly, elsewhere in the transcript Kris also advises new engineers to work on their social skills to grow in their careers if they wish to move into managerial or leadership roles. This emphasis on social skills reflects the complex socio-technical nature of engineering managerial work practices.

The next phase of this research study centers on developing similar narratives for the remaining 17 participants, which will in turn allow us to identify emerging patterns across the narratives as well to provide a more holistic view of the transition. Through the thematic narratives and findings resulting from this paper and the larger project, we hope to showcase the realities of engineering management practice. We believe the study can benefit several stakeholders. First, the findings contribute to a growing body of research on engineering practice in workplace settings. Second, the study will likely be of interest to recent graduates and early career engineers looking to advance in their careers. More specifically, the narratives on the lived experiences of recently transitioned managers might serve as a valuable guiding resource for future engineering managers. Third, the findings will benefit Human Resource (HR) staff and other industry leaders looking to understand better ways of developing engineering talent in companies. Fourth, the findings will benefit engineering educators and faculty of engineering leadership development programs by providing them insights about the nature of engineering managerial work practices which can, in turn, inform better ways of preparing future engineering managers and leaders.

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Mind Games: An Investigation into the Response of Irish Engineering Students to a Mindset Intervention

D. K. Sheridan
TU Dublin
Dublin, Ireland

Michael Carr
TU Dublin
Dublin, Ireland

Lynn Van den Broeck
KU Leuven
Leuven, Belgium

Conference Key Areas: Educational research

Keywords: Psychology, Mindset, Intervention

ABSTRACT

Stanford psychologist Carol Dweck has studied motivation and learning all her career. After 20 years of research, she concluded that a student's mindset was a key determinant of academic success. She divides learners into fixed and growth mindsets persons. The fixed mindset person believes that intelligence is a fixed quantity, and so when such a learner encounters failure, they tend to give up, believing that they have reached their natural limits. The growth mindset learner, by contrast, believes that difficulties and failures are essential elements of learning, challenges to be overcome, rather than the end of the learning road. She has written a bestselling book on this, Mindset: The new psychology of success. [1]

Not much work has been done on Mindset in Europe, and this project is to investigate if European students behave in similar ways to American students. The research was done with First-year Level 7 students of Mechanical Engineering at TU Dublin. A five-week intervention, following the methodology outlined in Professor Dweck's book was done, with a different Mindset survey given to the students each week. The final week was Professor Dweck's standard Mindset survey, but of the first four weeks, three were taken from Annie Brock's book, The Mindset Coach [2] and the fourth from the University of Illinois at Chicago's Maths Department version [3]. Brock's surveys were dichotomous, whereas all the others were Likert scales.

The results show limited success in changing students' mindsets and in correlation between Mindset score and Exam results.

1. INTRODUCTION

Over the past twenty years, educational psychologists have become aware of the importance of non-cognitive factors on the academic success of students. The excitement generated by this research stems from the fact that many of these factors are learnt, and if detrimental to learning, can be unlearnt.

The term ‘non-cognitive’ is, of course, a misnomer, as all the activity being studied is cognitive, just not traditionally academic. Duralak [4] suggests the phrase ‘social and emotional learning’, but it has proven difficult to shift the long-used term ‘non-cognitive.’

This paper looks at Mindset, developed by Carol Dweck of Stanford University, which claims that people can have either of two mindsets, fixed or growth. A short test indicates into which category a student fits, and if it is the ‘fixed’ category, Dweck has a series of tutorials designed to move them into the growth mindset and improve their learning outcomes.

2.0 BACKGROUND

Educational research is not a straightforward enterprise, mainly due to the multiplicity of factors, from both nature and nurture, which blend together in unpredictable ways, making it difficult, if not impossible to isolate direct causality in research.

The Latin word *educare* means to ‘draw out.’ The role of education is to draw out the natural ability of the child, an ability that is the melding of their genetic heritage (their genotype) and their environment (both shared and non-shared). Behavioral geneticists study this interplay and have come up with some important insights [5].

Everyone knows that some children have an aptitude and a taste for traditional academic work. Both qualities are influenced—but not determined—by genes. These pupils are the easiest for schools to handle, and they tend to do well in the current system. They are also the pupils that selective schools pick out and whose successes are then claimed by the schools to be the result of a superior education. Current policies and the “blank slate” philosophy hold up these children as models. They suggest that if we work harder then all children can be made to fit this mold. As a result, current approaches push non-academic children to become mediocre generalists regardless of their natural abilities, interests, hopes, and dreams.

Studies of reading by behavioural geneticists identifies the genetic component as being somewhere between 60 and 80%. Knowing this, the task of the educator is to use the genes to their best advantage in each case, meaning that education, from primary to tertiary, should be personalized.

2.1 MINDSET

The US psychologist, Carol Dweck [1], identifies two mindsets, fixed and growth. Fixed minds make little effort, relying on their ability. If their ability is not enough, they quit, usually blaming someone or something for their failure.

Growth mindset people know they have to work. They accept failure along the way as a challenge, a lesson, not a reason to give up.

The fixed mindset is easy. You don’t have to do any work, because you either have it or you don’t. If you don’t succeed, it’s not your fault, it’s someone else’s: your teacher, the referee, your boss.

The growth people enjoy working to succeed, enjoying the challenge of getting there.

Malcolm Gladwell [6] put a rough number on the effort hours needed for complete mastery: 10,000. He reckons that’s roughly the hours put in by diverse people, from a teenage Bill gates on his computer, to the young Beatles in Hamburg. Before their amazing success, there were years of work which moved them up a level from the rest of us.

Dweck has devised an eight-item self-answered survey, with a six-point Likert answer scale with possible responses ranging from ‘disagree a lot’ to ‘agree a lot’.

The key lesson from Dweck’s work is that Mindset is acquired, and can be changed. She has devised online workshops to help people make the change from fixed to growth mindsets, and this has resulted in improved academic scores. [1]

3.0 THE HIGHER EDUCATION SECTOR IN IRELAND

Ireland has seven traditional universities, ranging from the oldest, Trinity College, Dublin (TCD, founded in 1592) to the newest, NUI Maynooth (1997). Then there is the Technological University, Dublin which was created from a merger of the Dublin Institute of Technology, and the smaller Institutes of technology at Blanchardstown and Tallaght. TU Dublin is a member of the European Universities Association, with degree awarding powers to doctorate level. There remain ten Institutes of Technology, some of which are in the process of becoming Technological Universities. There are also small private colleges and other independent colleges.

Admission to higher education in Ireland is via a State body, the Central Admissions Office (CAO). Access to programmes is allocated on the basis of points obtained in the State Leaving Certificate examination (maximum attainable points were 600 over a range of six subjects, and are now 625 with a bonus for passing the higher level mathematics exams). Qualifications are graded according to a scheme devised by the National Qualifications Authority of Ireland (NQAI). In this scheme, Level 7 is an Ordinary bachelor degree, Level 8 is an Honours bachelor degree, Level 9 is a master’s degree and Level 10 is a doctorate.

In this group, TU Dublin has perhaps the most interesting history, having grown organically from a late 19th century group of technical colleges that dealt mainly with craft education, into a degree level institute – initially with degrees awarded by TCD. Since 1993, DIT has been a fully independent institution with degree-awarding powers, covering the full-range of higher education courses, from Level 6 certificates all the way to Level 10 doctorates. It is now Ireland’s first Technological University.

3.1 THE TU Dublin LEVEL 7 ENGINEERING STUDENT BODY

The first-year students of Mechanical Engineering in TU Dublin constitute an above average (for level-7 nationally) group of students, with Leaving Certificate entry points typically around 350 (out a maximum possible of 625). In the Academic year 2018-19, the number of students was 60, with an average of 354 points. It is also worth mentioning the overwhelming male bias of the that class, with only seven female students on the course in that year.

4.0 METHODOLOGY

In the physical sciences, theory is verified, or falsified, by laboratory experiments. Even in Psychology, which deals with the more complex and multi-faceted subject of human beings, it is possible to devise empirical experiments to test various theories. Walter Mischel’s famous Marshmallow test, first done at Stanford in the early 1960s measured children’s self-control by how long they could resist a marshmallow, given the promise of a second one if they waited. [7]

In educational research, it is rarely possible to do such tests, both on grounds of scale and expense. Instead, the researcher is reduced to devising surveys, and hoping that students will take them seriously enough to answer honestly. This paper relies on surveys using standard instruments developed by psychologists over many decades, and tested on tens of thousands of students, mainly in the United States. An important difference between Europe and the United States is that students are usually paid for completing surveys, and this does improve participation and completion rates.

Even with good quality instruments, there are still some issues:

1. Only those who attend can answer, making university surveys quite different from primary and secondary level where attendance is legally compulsory.

2. The surveys are voluntary, so only those motivated will answer.

3. The central tendency problem, where bored responders answer 3 for most 5-item Likert surveys.

4. Longitudinal surveys are particularly problematic, as the subset who respond are never the same from survey to survey. This was clear with this intervention, which was spread over five weeks, and only 11 students did all 5 surveys.

5. The questions are standard instruments developed by psychologists. The language can be confusing for young students, e.g. words such as ‘diligent’, ‘aloof’, not normally a part of a teenager’s vocabulary. This is even more true for non-native speakers of English.

6. Some questions in Carol Dweck’s Mindset survey are, in our opinion, ambiguous. For example, ‘I like my work best when I can do it really well without too much trouble’ is evidence of a healthy attitude to work/life balance, not of a closed mindset. And ‘I like my work best when I can do it perfectly without any mistakes’ is a reasonable position to hold, and not necessarily evidence of a closed mindset.

5.0 METHODS

The Mindset intervention in Semester 2 of 2018-19, consisted of two parts: a twenty-minute presentation on Mindset, followed by a short survey. The first week was introductory, mainly focusing on a TED talk given by Carol Dweck on Mindset, with a 10-question Likert survey on Fixed and Growth Mindsets. [2]

The second week had a more detailed presentation on the fixed and growth Mindsets, and the ways in which each is present in everyone. It was followed by a 10-question dichotomous survey. [2]

The third week focused on how the brain operates, its different parts, but especially the way in which new neural pathways grow when new intellectual talks are undertaken. This was followed by a 20-question Likert survey from the University of Illinois [3].

The fourth week tackled the issue of individual responsibility for learning, in what Carol Dweck terms her SMART scheme:

Specific — Write a specific description of your growth-mindset goal

Measurable — Write how you plan to track progress toward the goal

Actionable — Write specific steps you can take toward attaining your goal

Realistic — Write what resources and supports you need to achieve the goal

Timely — Write your deadline for achieving your goal.

This was followed by a shorter 8-question dichotomous survey on Fixed and Growth Mindsets, with the balance shifted 5/3 in favour of Growth questions. [2]

Week five examined the historical context of intelligence measurements, beginning with Alfred Binet's work on IQ and finishing with James Flynn's [12] discovery of the growth of IQ scores per decade, due to the transition from simple and concrete rural societies of the late 19th Century to the more complex, and abstract, urban world of the late 20th Century and early 21st Century. It was emphasised that the Flynn effect is positive evidence of the Growth hypothesis, that undertaking more complicated tasks requires the human brain.

It was followed by Carol Dweck's standard 8-question Likert survey on Fixed and Growth Mindsets [1].

6.0 RESULTS

The average score in the Dweck Mindset survey was 32.29. Dweck categorises this as G1, and describes such a person as follows: 'You are unsure about whether you can change your intelligence. You care about your performance and you also want to learn, but you don't really want to have to work too hard for it' (Mindset Works® EducatorKit - Module 1 Toolkit). This corresponds to the average Mindset score from the previous academic year, 2018-19, which was 30.66, and is also in Dweck's category G1.

As the five surveys have different numbers of questions, ranging from 8 to 20, and are both dichotomous and Likert, it was decided for each survey to calculate the total percentage fixed and growth component, based on the maximum possible score in each category. This allows for comparisons to be made between the different surveys.

Table 1: Student Scores from the Five Mindset Surveys

	W1 Fixed	W1 Growth	W2 Fixed	W2 Growth	W3 20-point Likert	W4 Fixed	W4 Growth	W5 Dweck Likert
n	27	27	24	24	23	19	19	24
Mean	14.81	20.11	1.16	4.16	41.82	0.63	4.89	32.29
SD	4.61	2.69	1.09	0.76	6.99	0.76	0.32	5.88
Adjusted Mean %	59.25	80.44	23.33	83.33	69.71	21.05	97.89	67.27

7.0 ANALYSIS

In week 1, on average 59% selected the fixed statement as true. By week 2, this had dropped to 23%, and to 21% by week 4.

Conversely, the percentage of students who selected the growth statement as true was 80%, 83% in week 2, and 98% in week 4.

The Likert surveys in weeks 1 and 5 were compared for the 11 students who did all 5 surveys. As week 1 had a 1 to 5 option, and week 5 had a 1 to 6 option, the data in week 1 was adjusted using the following linear transformation [9]:

$$Y = \frac{(B-A)\ (x-a)}{(b-a)+A} \tag{1}$$

Where a is the original minimum (1) and b the original maximum (5), A is the new minimum (1) and B the new maximum (6).

The week one data was also scaled up by 2.67 to match the higher number of questions in week 5 (8 versus 5). The two means were then compared using a two-tailed Mann-Whitney U Test for non-parametric data.

The result was p = 0.2627, with a z-Value of -1.116.

There is therefore no difference in the Likert scores in week 1 and 5.

Two things seem clear from the data: firstly, the Likert scores show no effect from the intervention, and indeed are little different from the previous year's class, who had no intervention.

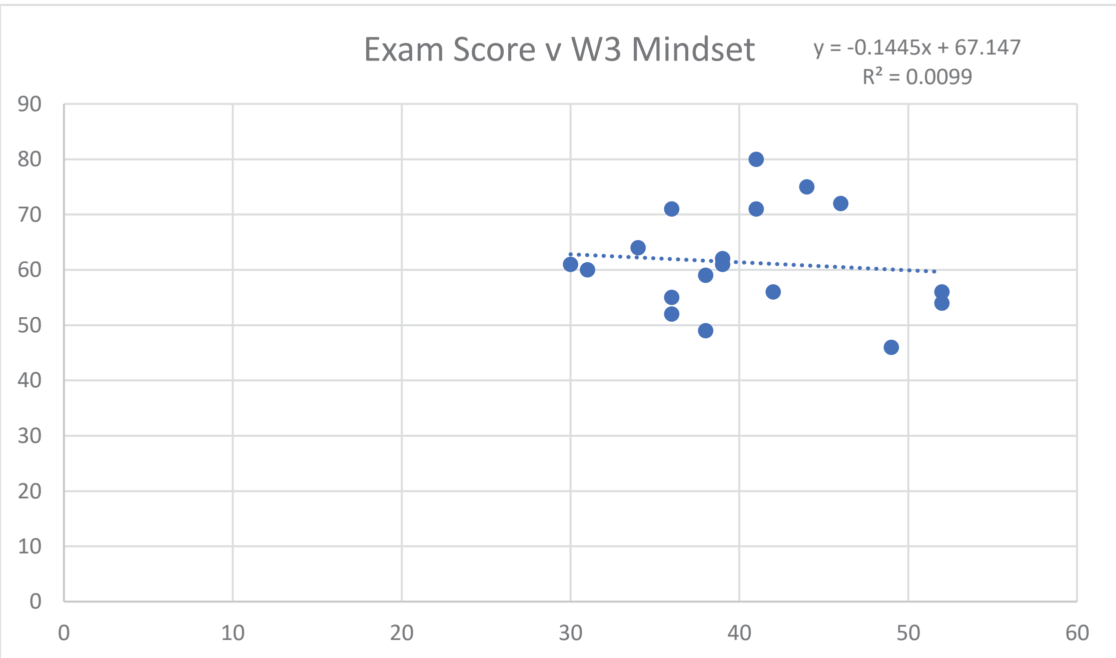
Secondly, the dichotomous scores do show a consistent trend of improvement over the course of the intervention.

Perhaps because of the central tendency inherent in Likert scales, the presence of a neutral option makes it difficult to see how the Likert survey can be used to track the efficacy of the intervention.

At the end of the year, the students average mark across all modules was plotted against their Mindset score from Week 3.

The R-squared value was 0.0099, indicating almost no correlation.

Figure 1: Plot of Exam Scores at Year End 2019 v Mindset Scores from W3



This might seem as if the intervention did not achieve anything, but it is well to remember that the fruits of education may take a long time to appear. The Mindset intervention does give students some ideas about how learning works, and so might benefit them in their life-long learning experience.

8.0 CONCLUSION

This is very much a preliminary work, and as they (probably) say in France, *une hirondelle ne fait pas le printemps*!

However, it is interesting, even with a small amount of data, that the effect of an intervention can result in clear changes in Mindset scores, as shown in dichotomous surveys, but not in the Likert surveys.

Carol Dweck claims great things for Mindset intervention, for example in her 2013 paper [10], she said a single class Mindset intervention, delivered over the web, improved the failure rate by 7% compared to a control group who had no intervention. It should be borne in mind, however, that Dweck has a commercial interest in Mindset interventions, as she sells her Brainology software to thousands of secondary schools

Others are not so sure. Brooke Macnamara, Assistant Professor of Psychology at Case Western Reserve University, finds little evidence to support her claims: *'School officials, policymakers and other stakeholders may want to think twice before they buy a growth mindset intervention product or dedicate part of their curriculum to teaching growth mindsets thinking it's going to make a difference in children's academic performance. Our research suggests there is a good chance it won't.'* [11]

It is over one hundred years since Alfred Binet produced the first standardised IQ test. Binet was motivated to create the test to identify weak students, so that they could be given extra teaching, to bring them up to the standard.

Binet's insight that intelligence is malleable has been shown in recent years by the American psychologist, James R. Flynn. In his 2009 book [12], *What is intelligence*, he discusses what is now known as the Flynn Effect, the massive rise in average IQ scores over the 20th Century. As Asbury and Plomin discovered as geneticists, genes determine that which is constant, environment that which is variable. Education will have succeeded when the only variation between students is genetic, not environmental. The challenge for educators is to so personalize students' education so that that goal can be achieved. A short Mindset intervention could be a simple, but effective, part of that process.

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Reframing Engineering Creativity through Meaningful Interdisciplinary Writing

D. S. Ozkan[1]
Virginia Tech
Blacksburg, VA, USA

D. Bairaktarova
Virginia Tech
Blacksburg, VA, USA

M. Eodice
University of Oklahoma
Norman, OK, USA

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ABSTRACT

In engineering education, creativity is riddled with ambiguity, so much so that we wonder how to teach it but stray away from open-ended questions that give it room to breathe. In the current of free-market principles, creativity becomes a valuable skill as it can pave the path to profitable technological innovation. Under the influence of psychologists, engineering educators have identified creativity as a necessary skillset for engineering graduates [1]. In this concept paper, we reframe creativity cultivation as a process of reframing knowledge. We focus on writing as a form of manipulating language that undoubtedly reframes knowledge. In its application to engineering problems, writing can serve as a tool of reframing that leads to creative problem solving.

[1] D. S. Ozkan
desenoz@vt.edu

1 INTRODUCTION

Ever since J. P. Guilford's 1950 presidential address to the American Psychological Association on creativity, researchers from a variety of disciplines have taken it upon themselves to distil this amorphous ability into a measurable skill. Creativity as an educational quality is coveted across disciplines as it portends the advancement of fields. Specifically, in US science and technology work, researchers identified the need to increase the creativity of scientists and engineers to stay ahead in the post WWII Cold War era and recover from Sputnik shock in 1957 [2]. At the time there were thoughts that the Soviet advances in technology stemmed from their enhanced creativity [3]. To strengthen their lead in the military and space race, the US increased its federal funding and in doing so tasked researchers in identifying the magic elixir that is creativity.

The context of creativity research at that time was that of global competitiveness following a world war. Across different disciplines, these findings on creativity differed due to their contextual environments. For instance, the social sciences in during the Cold War era experienced a different shift regarding creativity. In response to the rising empiricism in the field, "an interdisciplinary group of Harvard social scientists including the anthropologist Clyde Kluck-hohn and the sociologist Talcott Parsons, co-authored "Toward a Common Language for the Area of the Social Sciences," an influential manifesto for unification of the social sciences" [4, p. 79]. The authors' intentions had been to develop interdisciplinarity through shared language to close the widening gap among fields in social science and foster a more unified, but democratic form of the discipline [4].

Through the Cold War era, the "open mind" principle was also tied to American ideals of liberalism, as the open mind became a form of resistance towards "the rising tide of conformity" [4, p. 6]. By filling in the gaps of "narrow-minded" disciplinarians, a common language can highlight implicit assumptions inherent in the epistemology of social science disciplines. Notions of the open mind served to cultivate tolerance as a push against McCarthyism and the military, both of which represented rigidity and conformity. In education, the open mind supported student curiosity and implemented discovery-based learning as a way for students to push back against controlling structures of pedagogy. A push towards the open mind was a push towards "flexibility, autonomy, and creativity," [4, p. 17].

Understanding the background and context described above helps us consider how creativity has impacted the training of engineers. Through the paper, we discuss research in creativity and the challenges in defining and measuring the construct. We reposition creativity as a form of interdisciplinary framing, by which writing serves as the medium of this reframing. Lastly, we end with recommendations cultivate creativity by practicing reframing through writing.

1.1 Creativity as Context-Dependent

Besides agreeing with the notion that it is both novel and useful, psychologists, social scientists, and education researchers have provided many competing and reductionist approaches to identifying creativity. Research ranges from measuring the creativity of products [5] to the creative identities of people [6] to a cultural notion of creativity [7]–[9]. According to Baillie & Walker, “creativity is a convenient label for what is a quintessentially subjective phenomenon” [10, p. 36]. Although creativity is often regarded as having a universal meaning, contextual factors alter the way the construct is operationalized and applied. Creativity as a phenomenon leaves many researchers with the task of redefining the construct such that each definition fits a slightly different purpose. To this end, these different ‘flavours’ of creativity give rise to a deeper understanding of the priorities and gauges of success in the time or discipline in which specific instances of creativity are lauded. By understanding what makes up creativity in different domains, we can deepen our understanding into what is valued in that time period to that discipline.

In engineering, the product or solution is sought to be more creative, whereas, in fine art, problem finding carries more ‘creative’ weight. These values can change. Galenson asserts that the art world used to value problem-solving in the 19th century but has shifted towards problem finding in more recent years [11]. He gives the example of Picasso and Cezanne, in which their work is valued concerning the time that they were painted. Cezanne’s older paintings are more expensive whereas Picasso’s younger paintings are more valuable. These differences are rooted in the values held by the domain of fine arts at the time [11]. The differences of value held by disparate domains is one barrier to accepting the domain-general view of creativity. Because of the social context in which creativity surfaces, positing that there is one general view of creativity reduces the contextual constraints that give it different forms. However, we would argue that using these differences in contexts outside of their original context is how to achieve both novelty and usefulness in a domain.

In the example of problem-finding as a type of creativity, Getzels and Csikszentmihalyi conducted several studies with art students that showed that those who used more problem-finding also provided more viable solutions [12]. In science and engineering, a focus on problem-finding can similarly result in the addition of novel problems and increased solutions to existing problems that have been reframed, yet without the realization that problem-finding plays an important role in the creative process, shifting what is valued as creative would not be recognized. Because of the different societal implications that the arts possess, problem-finding is stressed more than that in domains like engineering. Through an understanding that different disciplines add different but widely applicable content to the theme of creativity, we can begin to form more encompassing insights that comprise creativity.

1.2 Creativity Cultivation from Other Disciplinary Knowledge

From a constructivist paradigm, learning is a creative process [13], but when training programs are developed to elicit behaviourist responses, the creativity inherent in learning and consequent transfer cannot take form. One of the major ontological assumptions of creativity underlying domain-specific perspectives is its conflation of domain expertise and creativity applied in a domain. Creativity can manifest in the domain by way of creative problem-solving or individual self-expression. Still, this is not to say the creativity is dependent on domain expertise to flourish. Baer continues to state that expertise could aid pursuits outside of one's field. However, he maintains that this is the "exception, not the rule" [14]. What of the opposite, in which domain expertise is enhanced by the introduction of knowledge from other domains? When extending this issue to that of language, Goethe has written that without knowing a foreign language, one cannot truly know their own language (Goethe cited in Vygotsky, 1986, p. 160). Experimental studies corroborate this claim, which show how children use the tools of language with more deliberation. Vygotsky extends this argument to algebra and arithmetic, in which knowledge of arithmetic enhances that of algebra by turning it into a concrete application of algebraic methods [15, p. 160].

Another facet of creativity that Csikszentmihalyi discusses in his book, Creativity is that of 'borrowing' from other disciplines [16]. Multi- and interdisciplinary pedagogy has been used to foster flexible thinking by encouraging students to apply knowledge from other domains to their understanding of the course material [17]. Metaphorical and analogical thinking are two ways used to promote creativity; they emphasize connections between disciplinary content that can ultimately yield the generation of novel and effective solutions. Waller describes one instructor who teaches electrical circuits and draws out his students' ability to use the input/output relationship between signals that is specific to electrical engineering to also explain mechanical components, chemical components, economic components, social psych components and so forth [17]. Research has pointed to ways to help students use analogical thinking describe the "functions of a product (e.g., a design artefact) or process (e.g., a way to measure something, a procedure for solving a complex problem)," with related functions from different domains. From a constructivist paradigm, this process of framing and re-framing concepts enables students to gain a better understanding of concepts, internalization, such that they can use and communicate them in applied work, externalization [15]. Creativity is enhanced by a more comprehensive understanding of domains, which is what metaphorical and analogical teaching strategies provide.

Through metaphor and analogy, researchers use language to expose patterns of science that may not have been evident before [18, p. 153]. In disciplines ranging from computer science to biology, scholars have used local and distant analogies to relate problems outside of their domain to ones in their domain to reach solutions. Because of the implicit definitions in domain language, many of the problems can be overlooked or framed in expected ways; analogical thinking helps divulge the nuances that may come with translating one problem to another domain [19, p. 308]. Moreover, language has been said to mediate our pursuit of knowledge, thus expanding this language to include that of different disciplines will better guide processes of problem finding and solving [20].

In one example, a plant biologist, Monica Gagliano, pushed her field in an ostensibly non-biological direction when she used educational metaphors to explain plant behaviour [21]. Her knowledge of working memory and decision making affected the development of her studies, ranging from evoking a response of fear, then training the plants through experience, and testing whether they recalled this ‘lesson’ up to 28 days later [21]. By recognizing characteristics of working memory and decision making in a field seemingly bereft of such qualities and to the scepticism of her colleagues, Gagliano unveiled a different avenue of plant biology that had previously seemed improbable. As for the transfer of creativity, education and plant biology seem quite far from one another in Sternberg’s spatial multidimensional domain space, yet the recognition of established concepts from one can result in an incredibly creative accomplishment established in the other. Consequently, learning to be creative in another domain might be more accessible when framed as learning cross-disciplinary content.

Csikszentmihalyi offers a plethora of examples of the creativity transfer that exists for deemed ‘creatives’ in his book, *Creativity: Flow and the Psychology of Discovery and Invention* [16]. After interviewing several established writers, he highlights that each of them draws from a wide array of knowledge outside of their domain expertise. Ranging from the knowledge of many languages to the synthesis of music and geometry, to the incorporation of quantum physics and microbiology, each of these writers finds a way to express their creativity by framing “together ideas and emotions from disparate domains” [16, p. 263]. Similarly, when Csikszentmihalyi interviews biologists, he finds that their main goals after having been established in their careers were to synthesize cross-disciplinary knowledge--to connect their domain-expertise to other domains. Jonas Salk, in an interview by Csikszentmihalyi, described that he focuses on intuitive and analogical leaps between the different processes in the arts and sciences. Wilson, another interviewee, focuses on the collinearity between biological and cultural processes and Klein connects biological knowledge across domains that proceed independently, for example, virology, genetics, and oncology [16, p. 289]. By expanding their domain expertise by studying across disciplines, many seek more of a holistic than a linear approach to understanding problems. Commoner, a biologist by training, states that the “prevailing philosophy in academic life is reductionism, which is exactly the reverse of [his] approach to things.” [16, p. 285]. By adopting an interdisciplinary approach to their domain expertise, these researchers embed themselves in a continuous cycle of idea to action through reflection and incorporation of domains seemingly outside of their own. Csikszentmihalyi uses these examples of cross-disciplinary integration to show that studying disciplines can help scholars reframe existing problems or yield diverse solutions.

2 REFRAMING KNOWLEDGE THROUGH WRITING

The notion of reframing that has come up through the research on creativity is a by-product of language itself. Language is a tool that we use to frame ideas. Vygotsky has studied how language is used as a tool in constructing knowledge. Language also acts as a symbolic system that allows us to transfer and apply this knowledge [15]. Metaphors and analogies are used to reframe disciplinary problems and ideas in other disciplines [22]. For students, the notion of reframing can be cultivated from an emphasis on writing.

Learning already exists as a form of reframing content. Students acquire new knowledge that they then fit into existing mental models; students go through their own process of reframing to build their mental models [24]. Writing can be used to further this process of constructivist learning. According to Janet Emig, in a landmark essay published over twenty years ago, “writing is unique mode of learning… [it] is not merely valuable, not merely special, but unique… Writing is a process of discovery” [7]. In the classroom, students “wrestle with ideas and modify their understanding” of concepts [3, 4]. However, in traditional engineering courses, many of the teaching paradigms are to deliver knowledge through a one-way path from instructor to student. For students to *wrestle* with ideas and *modify* their understanding, the instructor must also understand where students are in their process of knowing to then encourage deeper levels of understanding that allow students to wrestle and modify their knowledge [24].

2.1 Writing in the Engineering Curriculum

In engineering, “writing is viewed as a part of an engineer’s job but not as a part of engineering, which presumably happens in some separate, prior realm” [26, p. 58]. As language is used to shape and mediate disciplinary knowledge, it becomes critical to the creation and application of knowledge. Within the engineering culture, “writing is incidental to the project at hand,” in which the product rather than the document shows the culmination of engineering work [26, p. 61]. But, as Windsor shows, the final product of an engineer may not be perceived as a form of writing, but “it is an essential means by which that product is created because it is the essential means by which engineering knowledge is created” [26, p. 61].

Advocates for writing in engineering courses point to the cultivation of critical thinking skills in students [26], reflective thinking skills which are central to design, [28]–[30] and the ability to adapt knowledge across disciplinary boundaries [22]. But if cultivated intentionally in the engineering classroom, writing can braid the entire engineering process from problem finding to problem solving [23].

One example from UT Austin describes a chemical engineering course that is accompanied by a reflective journal assignment that acts as a form of communication between the instructor and student [30]. The journal is a means for students to come up with analogies of the technical content from the class. The instructor also highlights the most ‘creative’ analogy with a class vote during each class meeting to motivate students to ‘struggle with their analogies and journal entries in order to gain “anonymous” recognition from their instructor and classmates” [31, p. 144].

Another form of writing that helps students to become more aware of their creative processes is reflection [10], [32]. Reflection offers more ways in which to define and situate engineering problems without immediately proposing solutions. According to

Dym, “design cannot be done in vacuo: independent of context” [33, p. 4]. Ongoing reflection has been shown to aid in the understanding of context as well as offer a platform in which instructors can give formative feedback and also receive feedback on where the students are in their learning [32], [34], [35]. Schön asserts that reflections are a key part of practicing design, for the reflexive designer learns to think of the problem and its environment before possible solutions to understand the situational consequences of a solution [30]. Developing a more critical and holistic stance in which to frame problems also contributes to the ability for students to use flexible thinking which enhances creativity.

3 CONCLUSIONS AND RECOMMENDATIONS

Creativity has become wide shoes that we fill with coveted attributes. From constructs leading to success, to flexible thinking, to imagination and curiosity, creativity is constantly flexed in its definitions. Consequently, the essence of what we mean by creativity falls to the social context in which it is housed. In this space, that social context becomes a disciplinary home. Creativity in engineering must take on effective problem finding and solving qualities to yield a novel and useful contribution. Reframing the understanding of these problems and knowledge from other disciplines as novel and useful solutions is a form of creativity. This notion of reframing is a manipulation of language and thought that is pivotal to writing, thus for engineering students to be ‘taught creativity’ perhaps we need to engage them in intentional writing exercises that cultivate this ability to reframe new knowledge into existing mental models.

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Student Assessed Impact of Active Learning Methods and Andragogy

I.V. Pavlova
Kazan National Research Technological University
Kazan, Tatarstan, Russian Federation

P.A. Sanger
Purdue Polytechnic Institute
West Lafayette, Indiana, USA

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ABSTRACT

This research work is aimed at demonstrating active learning techniques and soliciting student input on their effectiveness. Active methods of teaching stimulate the thinking of students and are characterized by a high degree of motivation and emotional engagement in the learning process. That is why active forms of training can provide a more complete inclusion of students in the learning process and a more effective transfer of knowledge. This paper reports on a course for organizing and planning a chemical laboratory in which a variety of active learning techniques were applied. A team project provided the continuous thread on which to apply the course content. Individual and collaborative assignments supported the team project and gave the course a highly inter-active structure. Following the course, the students responded to two written surveys and a guided discussion session to explore the impact of this approach. Overall, the active learning approach was viewed very positively by 2 out of 3 students. However some students pointed out that this approach required more effort and time from them and therefore was not preferred.

Corresponding author: P.A. Sanger
psanger@purdue.edu

1 INTRODUCTION

At present, scientists are very interested in the challenges of modern engineering education, as evidenced by numerous international forums and conferences that gather a huge number of scientists interested in this problem [1]. While lifelong learning is essential to professional growth, the motivation and knowledge necessary for a person at every stage of his life changes. The main challenge for the educator is not only to assimilate this constantly increasing volume of knowledge, but to integrate this knowledge into technical areas that did not previously exist. Furthermore, the professional engineer must recognize that this new knowledge is important and it is necessary to keep current with new developments. Rapid obsolescence of scientific information makes it necessary to search for new sources of knowledge and to form skills around this knowledge in real production situations. The newly acquired design skills should facilitate the timely adaptation of a specialist to changing production tasks [2].

The development of the economy of any state is not possible without continuous advanced training of specialists in the field of technology and technology capable of solving the tasks of innovative development. This training must take into account not only the current needs, but also the long-term needs of industry and society as a whole. This means that future engineers must continuously grow new competencies allowing them to set and solve new tasks, and offer innovative engineering solutions [3].

Universities have defined a set of key competences (professional and societal) that a graduate must possess for satisfactory completion of an educational curriculum [4]. However, industry often expresses dissatisfaction with the quality of training received by new engineers, noting that the level of the formation of key competencies is insufficient for many new graduates to carry out complex engineering activities without a long period of adaptation and additional maturation. In addition to technical knowledge, other skills such as communication, teamwork, problems solving and life-long learning are critical to success in the technical world.

In present day Russian engineering education, there are both systemic and social obstacles within the engineering education community to achieving these learning outcomes:

- Failure to acknowledge that graduates are not meeting expectations,
- Failure to recognize that the learning outcomes include more than technical knowledge but must include psychological and social skills.
- Failure to acknowledge the deficiencies in the traditional pedagogical approaches in achieving the full spectrum of these learning outcomes
- Resistance by the university faculty to adopt modern learning technologies needed for the new generation of learners.
- Failure by the university structure to drive the change that is needed.

The application of active teaching methods can play an important role in overcoming these issues. The most prevalent teaching methods in Russian pedagogy is lecture, test work, independent work, test, oral questioning, story, explanation, exercise, laboratory work and practical exercises. Most often, the teaching is unidirectional presentation of content. Active teaching methods, on the other hand, require the student to participate in the learning process. Typical activities include problem-based lectures, lectures with pre-planned errors, interactive and visually stimulating presentation of material (accompanying lecture with slide presentation, information stand, illustrations, posters), student-teacher inquiry-based discussions, business game, brainstorming, and open ended laboratory activities with group discussion and assessments. The goal of these activities are to bring students into the context of their future professional life.

2 APPROACH

This study involved 50 undergraduate, fourth year, students majoring in polymer engineering. These students were predominantly traditional students ranging in age from 22-23 years old and enrolled in a course entitled "Organization and Planning of the Operation of Chemical Laboratories". Many of the students are already working in industry and this class was given in two classes with one being in the evening. The context of this chemical laboratory to support the production of rubber including processing, additives, and vulcanization. The syllabus of this course covers a wide range of topics applicable to the operation of a chemical laboratory including fire safety, personnel protection, storage, treatment and recycling of reagents, containers and glassware, ventilation, work organization and planning. In previous years of their study, the students rarely encountered active teaching methods with the most frequent method being the traditional lecture.

A collaborative team project was the key learning thread in the course. This team project is supported throughout the course by both individual and collaborative assignments. A project was created that applies the principles of laboratory organization to a specific chemical laboratory situation upon which the specific course topics can be applied. The same project topic was given to the whole class and the class was divided into subgroups/teams in accordance with the number of stages of production. After dividing into groups, the students received a set of recommended readings from the literature. Students independently studied the production schema in accordance with the received tasks followed by group discussion. The group created a schematic diagram of their specific production stage. At this point, students saw the composition and structure of the whole production process.

The next stage of the project took the form of an instructor-guided seminar. The subject of the seminars was some aspect of rubber processing derived from the project focus. The lecturer acted as a coach and therefore did not interfere in the discussion, impose an opinion or correct errors. Note that if students have chosen a wrong course for the technological process, the analysis revealed this error in the subsequent course work at which time the group must correct them. Based on the results of the seminar-discussion, the instructor issued an assignment to the subgroup to perform the technical calculations of each separate stage, and assigned each student to the technical calculation of a particular apparatus. In effect, the lecturer served as project administrator but did not give technical direction. [Note that these students have not been given any formal training in project management, an issue for another discussion]. Each student provided technical calculations that confirmed satisfactorily meeting regulatory requirements.

The next phase of the project focused on the graphical design of each stage of production. Brainstorming took place on possible design solutions where each student acted both as a generator of ideas and as a critic. As the team approached the preparation of the graphics for the project, students came together and agreed on the development of the graphic part of the production process. When safety and personnel protection was treated in the course, each student prepared a presentation and a report on his/her part of the technological scheme. Finally the whole team discussed the merits and weaknesses of the developed technological scheme of production.

This integrated approach of progressive, project development applying course subject matter to the project scenario creates a model with the real world context of today's engineering world. The goal of this approach was to stimulate the thinking of students, to push them to seek additional information in literary and internet-sources, and to contribute to the development of engineering thinking of the future specialist.

3 STUDENT ASSESSMENT OF ACTIVE LEARNING

The primary focus of this paper is on gathering and evaluating student opinions on the active learning techniques used in the course. The impact of active learning techniques in this course from the student point of view was evaluated using two written, multiple choice surveys and a recorded, instructor guided, oral group discussion.

3.1 Impact on Learning

The first survey is shown in Table 1 and explores the impact of the active learning approaches. This sixteen-question survey is divided into three thematic groups regarding impact of the active learning methods: 1) impact on learning 2) impact on interpersonal interactions and 3) impact on knowledge retention. 100% of the respondents gave answers to all questions of the questionnaire.

Regarding the impact to learning, the students expressed good support (approximately 75% of the students) for the ease of understanding, recalling, and reproducing the content of the course (questions 2,3,4). Furthermore, improved attention and interest in the class was also evidenced by the same percentage in question 5.

Survey 1 Questions				
Functionality of Active Learning Methods	Strongly Disagree, %	Disagree, %	Agree, %	Strongly agree, %
1. Are the active teaching methods used in the course relevant?	0	0	0	100
2. Is it easier for you to understand the material of the lecture course if it is accompanied by a slide presentation, information stand, illustrations, posters, group discussions, brainstorming sessions?	8	15	25	47
3. Is it easier to remember the material of the lecture course if it is accompanied by a slide presentation, information stand, illustrations, posters, group discussions, brainstorming sessions?	4	20	30	46
4. Is it easier for you to reproduce the material received in the classroom if its central positions and problems were discussed in group discussions, business games, seminars, practical and experimental studies?	16	10	30	44
5. Are you more interested in classes that take place in active and interactive modes (problem lecture, practice, group discussions, group discussions, experiment) in comparison with classical lectures, practical exercises, laboratory work?	10	18	32	40
Influence of Active Learning methods on Improving of Ability to Interpersonal Interactions				
6. Do you observe the improvement of individual cognitive activity in discipline due to participation in active studies?	7	40	15	38
7. Do you observe the improvement in academic performance by participating in active studies?	10	40	10	40
8. Does participation in problem (active) classes develop a sense of responsibility to a greater extent than classical ones?	10	54	3	33
9. Do these classes develop a sense of self-confidence and their own strength in comparison with the classical ones?	26	50	2	22
10. Do active activities develop friendly feelings for classmates?	2	20	3	75
11. Do the activities develop friendly feelings for the teacher?	24	50	1	25
12. Do they bring up a feeling of respect and tolerance to someone else's opinion?	6	10	4	80
13. Do active classes contribute to the development of professional qualities, skills, and abilities to a greater extent than classical methods of teaching?	10	62	2	26
Impact of Active Learning Methods on Knowledge Retension				
14. Do you think effective methods of training are effective?	6	30	2	62
15. In your opinion, does the use of active teaching methods promote the increase in the effectiveness of the educational process, along with classical methods?	6	30	2	62
16. Do you think there is a need to use active teaching methods in the educational process, along with the classical ones?	4	30	0	66

Table 1. The results of a student survey regarding the impact of active techniques on student learning (self-assessment). The dominant opinion direction is shaded.

The impact of the active learning on personal performance was mixed and not as strong, with only 50% of the class observing improvement. Only a third (36%) of the students felt that they gained a sense of responsibility or self-confidence from the active learning approach as compared to the traditional lecture. On the other hand, the students expressed a strong improvement in their appreciation and respect for their classmates (78% and 84% respectively in questions 10 and 12). Not surprisingly, only 26% of the students felt the relationship with their instructor was improved since most of the active technologies adopted in this research takes the focus off the instructor and onto their classmates in a collaborative manner. In question 13, the vast majority of the students (72%) did not recognize that their interpersonal skills were an integral part of their required professional skills and they will be important in their professional lives. In future surveys, the wording of this question will be improved since the topic may not have been sufficient clear.

Finally, the students confirmed their feelings (2 to 1) that the active learning approaches that were used in this course were effective and would enhance the effectiveness of the traditional lectures approach. Nevertheless, the support for active learning was not unanimous. Reasons for this will be discussed in the following sections.

3.2 Preferred Active Learning Techniques

The second, eight question survey explores the student's preferences on specific active learning techniques and methods. The survey and the student responses are shown in table 2.

The most preferred method of lecture, for 54% of respondents in question 2, was the lecture-presentation. This mode of lecture allows focusing on the main material of

Survey 2	
Survey Questions	**Response, %**
1. Rank the presented active forms of conducting classes relative to those you liked and remembered more, 10 being the most liked	
a) experiment	18
b) lecture-presentation	18
c) demonstration / practice	12
d) brainstorming	6
e) business games	8
e) problem lecture	2
g) student-teacher	10
h) lectures with pre-planned errors	10
i) workshop	10
j) small circles of knowledge (group discussion)	6
2. What method of lecture do you like more?	
a) a classical lecture	33
b) problem lecture	14
c) lecture-presentation.	54
3. What method of intermediate knowledge control do you like more?	
a) test	68
c) oral interview	12
d) colloquium	10
e) lecture with errors.	10
4. What form of practical and experimental activities do you like more?	
a) active (practice, experiment with group and individual discussion of problem situations);	44
b) passive (practical and laboratory work of a standard type).	56
5. Which teaching method allows you to fully represent your point of view in a problem situation?	
a) brainstorming	14
b) group discussions	76
c) business game	10
6. In what kind of classes are you most interested in presenting the material to the whole group, to make a report?	
a) seminar;	10
b) student-teacher;	10
c) group discussion;	55
d) do not like to submit the material yourself.	25
7. Which of the training methods has the most motivating effect on you? Select one.	
a) classical	34
b) active.	66
If you chose position b), then answer the following question:Which of the active teaching methods has the most motivating effect (develops motivation for learning)?	
a) experiment	16
b) demonstration / practice	6
c) brainstorming	14
d) business games	2
e) problem lecture	10
f) student-teacher coaching	14
g) lectures with pre-planned errors	2
h) seminar /working session	24
i) small circles of knowledge	12
8. Is it worthwhile to apply active teaching methods or is it better to conduct classes using the classical method?	
a) it is worthwhile to introduce active teaching methods;	58
b) classes will be more effective when using classical techniques.	42

Table 2. A student survey regarding their preferences of active learning techniques

the lecture enhanced with tables, diagrams, explanatory drawings and drawings. This lecture type was preferred over the verbal only lecture prevalent at this institution. The most challenging problem lecture format was least preferred.

These results might be explained as follows. For students who want to understand the material of the lecture, it is most effective to obtain the information in a succinct but informative way (with visual presentation slides). Classical lecture provides a large amount of undigested material while a problem lecture requires more involved student participation in the lecture and discussion of the problem.

The most preferred form of knowledge assessment/exam was the classic test with 68% favourable. Lecture with errors and oral/colloquium type exams selected by only of respondents respectively. This preference is understandable since students find it easier to feedback lecture information rather than have to formulate a response in their own words. The use of a lecture with pre-planned errors does not enjoy the success of the adult student environment possibly because this method is not yet widespread and is more challenging. Oral exam formats are less predictable than the standard written formats.

Practical, laboratory exercises are an essential component of the student's learning activity. For traditional classes, students perform the assigned tasks individually and present a conclusion in the form of a report. In the active approach, after completing the technique or experiment, students discussed the results in small groups, drew the main conclusions and defended them in front of the whole group. The passive or individual method was favoured 56% to 44%. The preference for individual activities, whose results are not dependant on other students, is quite common among students particularly the higher performing students.

The ability of a student to justify his own opinion is an important personal skill. According to respondents in both question 5 (76%) and question 6 (55%) , group discussions allow to fully disclose the individual attitude of each student to the question posed, to prove one's own point of view in the problem situation, to justify the idea of solving the problem, or to develop these abilities. From question 6, it is clear that a significant portion of the class (25%) may not be confident in their presentation abilities. This suggests that this is an area for intentional improvement perhaps not just in this class but also within the entire curriculum.

Active methods of training, of course, are able to motivate students to a successful educational process. It is also interesting to find out which of the active forms of training are of the greatest motivating nature and contribute to the work of the students involved. The responses from question 1 and 8 have been examined together in order to get a more coherent picture.

Clearly, the hands-on dimension of experiment and seminar/workshop resonated with the students and this result was satisfying for the instructors since this type of hands-on pedagogy requires more instructor effort. Participating in a seminar, delivering a report and presentation to classmates, sharing their own experience are critical communication skills and highly desirable in the workplace. The second tier of preference were four activities: student/teacher interaction, brainstorming, small group discussions and demonstration. The least favoured approaches were the problem lecture, business games and lecture with errors.

Overall, it can be concluded that the most motivating methods of active learning for this class are hands-on and inter-personal participatory orientated. By active participation in the classes students are rewarded and credited with points that form an individual rating system.

3.3 Instructor Guided Oral Discussion

Finally, in this research, a recorded, instructor guided, oral group discussion was used to clarify the student’s views on the effectiveness of the active learning methods. The conversation was held at one of the final seminar sessions in a lecture room in an atmosphere of mutual trust. The answers of students were recorded, analysed, structured and summarized. The discussion was structured with specific questions to stimulate student responses.

1) Do you consider the active teaching methods used in the discipline in question relevant and why?

Participant opinions were divided on this question.

On the positive side:

“We believe that the use of active forms of education is really important, as they make it easier and more productive to learn the material, less time to learn it”

“These classes encourage students to work through participation in the work of reflection groups and making presentations. In addition, in the discussion groups it does not matter whose answer is more accurate”.

“It is important to take into account the opinions of each on the question posed and the ability to prove their point of view.

From the negative side.

“For us, the traditional methods of classical training are more relevant, since active forms of instruction require increased attention, greater participation, and take more preparation time. It should be remembered, though, that we are a group of the evening department and sometimes come to classes already tired. For example, it is easier to prepare for a test or a colloquium than do the same actions, supplementing them with the preparation of seminar reports and reports for the "student-teacher" form in their spare time”.

From the instructor’s point of view, the question becomes whether the learning outcomes were better achieved. Often students are not interested in increasing their workload even though they will have learned better and more. Unfortunately, an assessment of the preparedness of these students relative to others was not available.

2) Due to what factors does your cognitive activity and degree of interest increase with participation in active forms of learning?

"Accompanying the lecture with examples from life and demonstrative posters, pictures, illustrations, sharpens attention and facilitates understanding of the material".

"It is interesting to listen to…our classmates who have direct experience of work in this or that sphere, considered in the class as a topic."

From an instructor's point of view, this last comment serves an important academic function and answers the student's question "Why am I learning this?" and the answer was coming from their cohort and fellow students.

3) Why do you think that active forms of education do NOT lead to increased sense of responsibility?

"We believe that active forms of training DO increase the responsibility, since students should perform more independent training at home. This takes time".

"Much depends on the nature of the person: If the student is unprincipled… then he will not participate in the class, "just be left behind or follow along".

"Active forms of education leads us to be more to responsible, have a sense of proper behavior, but so much depends on the moral qualities of the individual learner."

4) How do you compare the lecture-(slide)presentation with the classical lecture?

"On the slides accompanying the lecture, the most important information is shown, pictures and illustrations allow you to better understand the essence of the topic".

5) Indicate the positive or negative aspects of the multiple choice exams, the method of lecture with errors and essay exams.

"Multiple choice allows you to choose the answer option from the available ones. Even if the student does not know the exact answer to the question, then the method of logical thinking can come to finding (the correct answer)".

"A lecture with pre-planned errors requires increased attention and a higher degree of intelligibility, accompanied by a joint analysis with the teacher and the team". "Essay exams requires the memorization of lecture material and the solution of problems that are easy or complex".

6*) Describe why you like/dislike the following methods of actively solving problem situations - brainstorming, group discussion, business game.*

"Brainstorming involves collecting a certain number of ideas within the given time, requires a high degree of promptness, mental work, which in conditions of post-work time is difficult.

"Group discussion allows the group to find or suggest ways to solve the problem and justify its choice to other participants in the communication groups. It's easier to work in a group than independently."

"Business games, in our opinion, are not an appropriate form of training for older part-time students (example when the student is working, 35-40 years old). This form of training would be more suitable for full-time younger students".

7) Why are active forms of learning motivating / not motivating you to learn?

"Active forms of instruction motivate for training, since classes conducted in this form allow you to get more credit, provided you take a little more active participation, in comparison with the classical ones.

"Motivated, because you understand the course material easier and faster"

"(Active forms) do not motivate, because, when using active forms of education, students must spend more free time".

The authors are not surprised by these last comments and they are consistent with the fact that almost 1/3 of the class still preferred the standard, spoon-fed lecture and multiple-choice exams. Students most commonly choose the easiest route but not the most productive one from the standpoint of learning.

4 CONCLUSIONS

This paper describes an implementation of active learning technologies in a course of "Organization and Planning of the Operation of Chemical Laboratories". with a comprehensive suite of student feedback tools used to gather feedback: surveys, observation and personal interviews. This class with active learning methods elicited a strong positive response (2 to 1) from students, including effective collaboration with peers, development of teamwork skills and enhanced oral communication skills. The preferred techniques were lectures enhanced with visual stimuli, hands-on experimental work, and group discussions. For students, the benefit of this approach was the acquisition of technical knowledge in its applied context while experiencing decision-making, negotiating and working together. For teachers this approach required significant preparation, since it was necessary to develop a new teaching plan for the course, as well as new educational material. Because of this study, it is clear that there was not much gain in developing lectures with errors, and business games that are poorly received. However directing the development effort toward enhanced lectures, seminars and hands-on activities would be beneficial. Furthermore, the instructor had to learn the new role as mentor and facilitator.

Unfortunately the authors were unable, due to administrative constraints, to link a higher performance in the standard exams with this active form of teaching but look forward to connecting to this crucial, outcomes based comparison in future publications.

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Interactive Online Modules – Impacting the Individual Learning Success in Engineering Mechanics?

M. Pelz
Technology and Didactics of Technology, University of Duisburg-Essen
Essen, Germany

M. Lang
Technology and Didactics of Technology, University of Duisburg-Essen
Essen, Germany

Y. Özmen
Institute of Mechanics, University of Duisburg-Essen
Essen, Germany

J. Schröder
Institute of Mechanics, University of Duisburg-Essen
Essen, Germany

F. Walker
Didactics of Technology, Technical University of Kaiserslautern
Kaiserslautern, Germany

R. Müller
Chair for Applied Mechanics, Technical University of Kaiserslautern
Kaiserslautern, Germany

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ABSTRACT

The collaborative research project FUNDAMENT (Improvement of individual learning success by the use of digital media in civil engineering) of the University of Duisburg-Essen and the Technical University of Kaiserslautern, which is funded by the German Federal Ministry of Education and Research (BMBF), has developed and evaluated so-called interactive online modules (IOM) for the introductory phase of the civil engineering studies (EM), more precise in the courses of engineering mechanics. The IOM consists of learning videos, online exercises and online forums.

These IOM have the objective of increasing the individual learning success of civil engineering students and therefore to minimize the high drop-out rates in engineering sciences in the long term. In this paper the effectiveness of the IOM will be determined on the basis of a longitudinal study in a classic experimental and control group design in the EM 1 course in the first semester. Paper and pencil tests (multiple-choice-single-select test design – multi-matrix) are applied at two measuring points (MP): beginning (MP 1) and end of the first semester (MP 2). Initial analyses of the data are presenting an increase of the mean person ability (dichotomous Rasch model) regarding the achieved scores at both MP. The cause of this increase cannot be defined exactly, an allocation to the IOM is currently not possible due to a small number of participants in the control group.

1 INTRODUCTION

At German universities, an increasing number of first-year students has been recorded in recent years. However, not all of them finish their studies with the intended degree. Records show a high number of student dropouts especially in engineering disciplines for many years. Current studies indicate that 35% of engineering students (relative to the number of first-year students 2012/2013) in Germany finish their studies without a degree [1]. Considering only civil engineering students, a dropout rate of even 42% can be observed [1]. This is not only an issue in Germany, but also a rather common problem in other European countries [i.a. 2,3] and in the United States [4] as well.

According to Heublein et al. [5] dropping out of university in general cannot be reduced to one motive, it is rather a complex and multi-dimensional dropout process that ultimately leads to the students decision to disenroll. The dropout process can be divided into several phases, which are influenced by different factors [5]. In a closer examination of the engineering sciences, performance problems are the main reason for dropping out of university [5]. The performance problems especially emerge in basic subjects like engineering mathematics or engineering mechanics (EM) [6] and are often resulting in failed exams [5]. A possible cause regarding performance problems may be a decrease of special and mathematical knowledge among first-year students [7,8]. In the introductory phase it is extremely difficult for the students to address such knowledge gaps [9]. The importance of the introductory phase is illustrated by the fact, that students without study success in the first semester describe the biggest part of the disenrollment [7].

Heublein & In der Smitten [8] developed a reference model for quality assurance at faculties of engineering sciences to prevent the aforementioned problems. The reference model implies that the use of preventive support measures at different times during the course of the studies may be helpful. The support measures are applied in the preliminary phase (self-assessments and prep courses) as well as in the introductory phase (additional learning offers). At many universities such support measures are already available in different variations, but in most cases only subject-unspecific topics are covered. For instance, engineering application contexts - like those of the EM - remain untreated. Also, only very few prospective or first-year students attend respectively make use of these support measures, further consideration of those who are absent indicate that these are mainly those who urgently need such assistance or offers [5].

2 IOM IN THE INTRODUCTORY PHASE

To oppose the named problematic the collaborative research project FUNDAMENT (Improvement of individual learning success by the use of digital media in civil engineering) was initiated by the University of Duisburg-Essen and the Technical University of Kaiserslautern in 2017. The objective of FUNDAMENT is to support the individual learning processes in civil engineering studies by the use of digital university teaching. A digital support concept was developed based on the previously presented reference model. For this purpose, support measures – focusing on the EM – for the preliminary phase (online self-assessment and online prep course) as well as for the introductory phase (interactive online modules – IOM) were developed.

This paper will only address the introductory phase. Prusty and Russell [10] have already shown in their research – on closer examination of the introductory phase – that first-year students have difficulties in understanding the key core concepts of the EM. A possible reason for this could be the fact that students do not succeed in linking the lecture content with the corresponding key core concepts. Attempts to achieve this connection in physics by additional illustrations of the theoretical facts - e.g. by means of demonstration experiments within the lectures - have no positive effect [11]. No research relating to the EM is available yet.

Individual lecturer-student discourses in tutorials or exercises could achieve an improvement of the conceptual knowledge. Many universities offer such activities, but the need can hardly be met due to increasing numbers of students. At this point the so-called IOM could be helpful. IOM have already been developed in the Anglo-Saxon area, also applied and evaluated, but the individual learning processes are not considered and there are research methodological deficits as well [i.a. 10,12].

Therefore, research on the efficacy of IOM especially in the EM and whether they contribute to the understanding of the corresponding key core concepts is incomplete and needs to be continued. Based on a three pillar concept the IOM have been developed. This concept consists of three digital elements used in the introductory phase specially for the EM 1 and EM 2 courses: learning videos, JACK exercises and anonymous moodle[1] discussion forums.

The first pillar (learning videos) contains two areas of application: On the one hand, the videos provide experiments that were already presented in the lecture in order to illustrate the key core concepts of the EM for self-study or rework. On the other hand, a second category of videos were created: animated slideshows, whose focus is on the teaching and learning support in the area of arithmetic problems. The processing of such exercises requires a conceptual approach and the understanding of basic concepts of the EM. Both types of videos allow students to process the contents of the classroom events regardless of time and place. In this way, a high-quality addition and flexibility to the existing teaching and learning is achieved.

The second pillar of the IOM is described by the implementation of exercises in the server-based system JACK [13], which enables parameterized computer-aided testing with automated feedback generation. The students have the opportunity to work time and location independent on parameterized exercises of different levels of difficulty and receive feedback on the submitted solutions. The feedback function also offers the opportunity to comment on the results. Especially if the results are wrong, hereby the students can be motivated to search for their error in a particular partial result.

[1] https://moodle.org, accessed July 11th, 2019.

A stronger involvement of students in the academic community will be supported with online-based communication channels as the third pillar of the IOM. For this moodle forums are used to facilitate communication between students and lecturers, or students among themselves, to clarify content and organizational issues. Mainly in the introductory phase this is a major problem in study programs with large numbers of first-year students and therefore considered a factor for dropping out of university [5].

The created learning videos and JACK-exercises[2] were developed for the different topics of the EM 1 and EM 2 lectures (EM 1: vector analysis, system of forces, gravity calculation, support, truss, internal force variable, principle of virtual displacements, friction; EM 2: geometrical moment of inertia, tension, bending line, oblique bending, kern, shear force or torsion, stability, composite cross-section, hydromechanics). For the EM 1 lecture four videos and 77 exercises, for the EM 2 lecture seven videos and 60 exercises were developed.

3 METHODOLOGICAL APPROACH

This paper deals with one of the research questions of the collaborative research project FUNDAMENT: Are the IOM contributing to an increase of the individual learning success of students in the field of the EM in the first semester of the civil engineering studies. In a classic experimental and control group design this research question will be answered longitudinally (*Fig. 1*). At two measuring points (MP) paper and pencil tests are applied to answer the named research question: beginning of the first semester (MP 1) and end of the first semester (MP 2). In the control group are students who attend the EM 1 course in the conventional concept. In contrast, the experimental group differs by the inclusion of the developed IOM in the EM 1 course. The data were collected in the winter semester 2018/2019. Another paper and pencil test will be used at the end of the second semester (MP 3) to assess the effectiveness of the IOM in the EM 2 events, but this is not part of this paper.

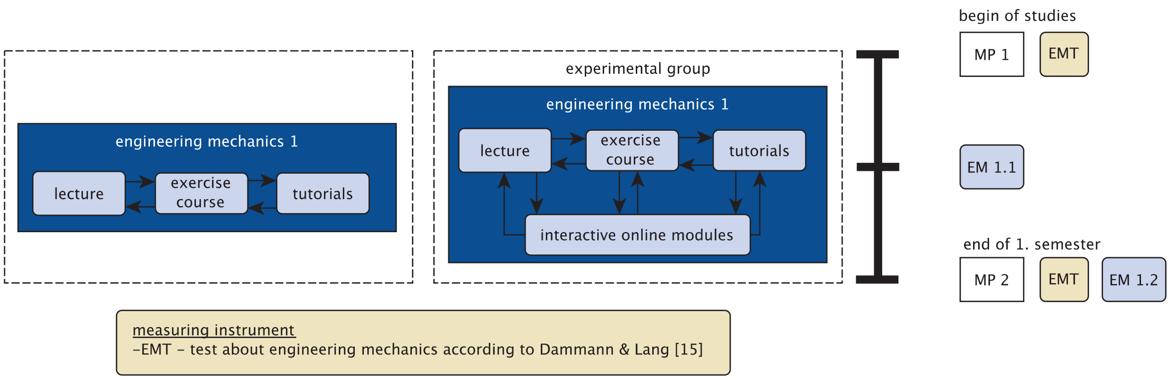

Fig. 1. Longitudinal design of the FUNDAMENT – focussing on the first semester [14]

The results of the applied knowledge tests and the exam grades are used to determine the efficacy of the IOM. The developed test instrument is based on the item pool of the engineering mechanic test (EMT) by Dammann & Lang [15] – technical knowledge, subject-specific modeling ability and mathematical knowledge. It is applied in paper and pencil tests in a multiple-choice-single-select test design (multi-matrix). The EM 1 exam was split in two parts which were written in the middle (EM 1.1) and the end of

[2] JACK exercises are hereafter abbreviated as JACK.

the first semester (EM 1.2). The usage of the IOM is operationalized by recording the clicks on links that forward to the videos and JACK in the EM 1 moodle environment.

The first MP includes the gathering of demographic variables like gender, final school exam grade, last school grades (math, physics, chemistry, computer science and technology), native language and further information on the educational background.

The structure of the study as a collaborative research project permits conclusions like the generalizability of the results with regard to the effectiveness of the IOM.

4 RESULTS

The results regarding the usage of the IOM presented in this paper originate from the University of Duisburg-Essen. The gathering of the data took place in the winter semester 2018/2019 in the cohort of first-year students of the civil engineering studies. A consent from the students was necessary in order to track the number of clicks on particular parts of the IOM (videos and JACK). Due to the EU data protection directive, this consent form is required for the recording and storage of the relevant data.

A compensation of 20 EUR per student was paid to motivate the students to take part in the paper and pencil tests, in addition, they got bonus points for the second partial exam (EM 1.2) when achieving 50 % of the possible number of points at MP 2. Nevertheless, it has not been possible to persuade a large number of students to participate consistently in the tests. While from the entire cohort 143 students participate in MP 1, only 46 attended the following MP 2. As already mentioned, we can only access corresponding IOM usage data if the consent of the students is on hand. Therefore, the mentioned numbers are reduced to 78 at MP 1 respectively 38 at MP 2. A further reduction occurs in the execution of a longitudinal analysis, then 34 students remain (participation in MP 1, MP 2 and IOM consent).

The remaining students were split into groups in terms of their usage of the IOM. It was differentiated whether the videos and / or JACK were used: This resulted in four user groups: 1. *videos and JACK*, 2. *(only) videos*, 3. *(only) JACK* and 4. none (of both). The user group that only used videos is not represented in the collected data, the entire classification can be seen in *Table 1*. Here it can be stated that there is no student who has only used the *videos*, so the group is not listed. Most of the students used both the *videos and JACK*. Remarkable is the small number of students in the group *none*, which is intended as the control group.

Table 1. Classification into IOM user groups

IOM user groups	n	%
videos and JACK	23	70.3
JACK	9	24.3
none	2	5.4
total	34	100.0

The effectiveness of the IOM usage is checked by the achieved person ability in the applied knowledge tests at the beginning (MP 1) and at the end of the first semester (MP 2). The person ability was calculated according to the dichotomous Rasch model. At both MP different test books were used with 68 (MP 1) respectively 59 items (MP 2), which were anchored by 28 items. The tests showed satisfactory reliabilities and separations for the entire cohort (person reliability = .86, person separation = 2.45, item reliability .94, item separation = 3.93).

Table 2 shows the Pearson correlation between the achieved person ability (MP 1 and MP 2) and the achieved grades in the partial exams (EM 1.1 and EM 1.2). High correlations can be consistently found. A high correlation between the person ability at MP 1 and at MP 2 can be found, as well as regarding both partial exams. There is also a high correlation between the person ability and the partial exams, which leads to the conclusion that the used test instruments are able to reproduce the corresponding knowledge tested in the exams. No correlation between the IOM usage and the person ability respectively the partial exam grades can be found.

Table 2. Correlation (Pearson) between knowledge tests and achieved grades in the part exams

		person ability MP 2	grade EM 1.1	grade EM 1.2
person ability	MP 1	.742**	-.551**	-.567**
	MP 2		-.622**	-.686**
grade	EM 1.1			.627**

** < .01

The descriptive statistics concerning number of clicks on the videos and JACK are shown in Table 3. As well as the achieved person abilities at both MP and the corresponding achieved grades in the partial exams (characteristic 1 - 5 – best: 1). The person ability increases, as well as the part exams are getting better. However, this cannot be attributed solely to the IOM since we cannot make any conclusions in this regard due to the small control group. Thus, statements about the effectiveness of the IOM are not possible at this time.

Table 3. Descriptive statistics regarding IOM clicks (videos and JACK), person ability achieved in the knowledge tests (MP 1 and MP 2 and *achieved grades in the part exams (EM 1.1 and EM 1.2)*

	n	M	SD	min	max
clicks videos	34	3.26	3.74	0	15
clicks JACK	34	86.50	73.47	0	271
person ability MP 1	34	.05	.60	-.93	1.73
person ability MP 2	34	.73	.76	-.90	2.51
grade EM 1.1	31	3.58	1.25	1.00	5.00
grade EM 1.2	30	2.63	1.52	1.00	5.00

No detailed results can be presented regarding the anonymous moodle forums. The forums were not used at all. In a survey (applied after the second semester) currently under evaluation, the students were asked why they did not use the forums. It has often been stated that they did not know that the forums exist. This is surprising as they were introduced in the lectures as well as the arrangement in the moodle course was chosen that they can be found right at the top. Detailed results of this survey are still pending.

5 SUMMARY

The results evaluated so far in the collaborative research project FUNDAMENT show that students very well accept the IOM (except the anonymous moodle forums). Both the videos and JACK are widely used.

In the considered group of 34 students, an average of 3.26 clicks can be found on the videos, with four videos available. Jack recorded an average of 86.50 clicks at 77 available, with a maximum of 271 clicks, thus an average 3.5 clicks per exercise. After the second semester, the students were given a survey to evaluate the IOM, it is currently being evaluated. One of the questions was related to why the students are not using the anonymous moodle forums. First evaluations show that students did not know that the forums exist. In principle, the forums were pointed out in the lectures and they were positioned prominently in the moodle course. However, it was not clear to the students that they exist, which shows that the IOM have to be advertised more frequently and more actively in the future.

First analysis of the available data show difficulties in the execution of the study. In the longitudinal analysis of the data, it is extremely problematic to get the students to participate in all MP. Already several changes in the execution of the tests brought no long-lasting success. For example, 187 students took part in the test at MP1, but it was only one-third at the subsequent MP at the end of the same semester. In order to evaluate the IOM usage afterwards, the consent of the students is also required. This again reduces the remaining number of students in the study significantly. Subsequently, the control group consists of only two students. Starting points must be found in the future for possible follow-up examinations in order to motivate students to continuous participate in the study. With regard to the pilot phase, changes were already made in the test execution, as the numbers of participants in the pilot phase were even lower. For example, the implementation of the tests was switched from online to paper and pencil. Also, the awarded compensation is now paid after each MP and not as in the pilot phase after the successful completion of the entire study. These changes have led to significantly higher numbers of participants, but the figures at MP 2 are still not satisfactory.

The next steps in FUNDAMENT are the evaluation of the before mentioned survey and the IOM usage in the second semester (MP 3). There will be profound analyses of the data. In order to give generalizable statements regarding the developed digital support concept, the data will be approached both site-specific as well as across both locations.

ACKNOWLEDGMENTS

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Combined project-based learning and teacher-practical demonstrations to help acquire global engineering skills

N. Peyret[1]
Laboratoire Quartz - Supméca
St Ouen, France

S. Courtois
Supméca
St Ouen, France

G. Chevallier
Univ. of Bourgogne Franche-Comté - FEMTO-ST Institute
Besançon, France

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ABSTRACT

This article outlines the development of a Project-Based Learning (PBL) course for first-year students at SUPMECA, a French engineering school. In the French Grande Ecole system, engineering students are recruited after a two-year preparation, which is equivalent to the first two years of a degree course. The objective of this form of pedagogy is to engage the students throughout the module and to illustrate the theoretical contributions by solving a technological problem. The course covers mechanical dimensioning methods. The course includes a part of teacher-practical demonstration which decreases as the course goes by. This pedagogical scenario is based on the cognitive load theory and Bruner's constructivist theory. It has been developed by relying on the six points of the encouragement process defined by Bruner, with a concrete objective, to allow the students to go beyond the basic skills of dimensioning and to allow them to acquire the more global skills of engineering.

The implementation of project-based teaching combined with teacher-led instruction makes it possible to compensate for the lack of experience and autonomy of freshmen, while at the same time engaging them within the first few minutes of the module. Since this approach was adopted, an acceleration in the mastery of basic skills has been noticed and a longer period of time is dedicated to the acquisition of engineering skills, namely the convergence of each dimensioning in order to obtain a validated mechanism.

[1] Corresponding Author
N. Peyret
nicolas.peyret@supmeca.fr

1 INTRODUCTION

This article outlines the development of the Project Based Learning (PBL) at the level of a last year's Bachelor's Degree. The objective of this form of pedagogy is to strongly involve the students throughout the module and to justify the theoretical contributions by solving a technological problem. The module in question is the module of mechanical dimensioning method of Supméca a French engineering school. This school issues a Master's Degree.
While the teaching methods used in primary and secondary education are frequently renewed in France at the instigation of teachers and inspectors, higher education remains relatively traditional in its practices. Recently, some colleagues have felt the need to put the application back at the heart of their theoretical teaching. This need is induced by the difficulty of covering all the knowledge deductively before its application. The statement by B. Raucent [1] illustrates this purpose: « As a result of the increase in knowledge, it has becoming practically impossible for students to learn all that they need before being able to design a machine ».

It is therefore tempting to make the students "learn by doing", even if it doesn't cover some parts of the theoretical knowledge. The other argument that supports this type of learning is the lack of motivation the students have for the magisterial courses. The role-play allowed scenarios favouring interaction between students and teacher [2]

2 METHODOLOGICAL APPROACH

The dimensioning module has existed for a few years and evolved to tend more and more towards a teaching by project.

However, teachers involved in this module tried to answer these few questions:

- How to more closely link the contributions of knowledge to the project;
- How make the students strongly invest efforts at the beginning of the module and avoid learning obstructions;
- How to allow students to understand the dimensioning as a whole in the given time for this module...

Project based learning and problem based learning are widely used in educational approaches [3, 4]. For our project we follow globally theoretical and applied principles of Project based learning [3]. But in point of view of our experience and taking into account the prior formation of our students (preparatory courses for engineering school contest), we estimate that

The pedagogical form known as "pedagogy by project" is difficult to apply in the first years of university studies because of the low level of autonomy and individual responsibility that the students have. The question of what the student actually learns from the initial program as well as the evaluation of the competences acquired by the students in this type of pedagogy also remains an open problem.

Thus we propose to combine two pedagogies. To the pedagogy by project format, we add a pedagogy by example based on a regressive part of intervention by the teacher along the project.

This pedagogical scenario is based on the cognitive load theory and Bruner's constructivist theory. It has been built by relying on the six points of the encouragement process defined by Bruner [5], with a concrete objective, to allow the students to go beyond the basic skills of dimensioning and allow them to acquire the more global skills of engineering.

So the author decided to promote learning by manipulating cognitive load because for students with little prior knowledge, solving problems seems to cause significant cognitive load that can interfere with learning [6]. To remedy this difficulty, one of the solutions is to propose to the learner, problems solved to analyse or to complete [7], [8]. The initial state of the problem, the goal to be achieved and a partial solution are given, the solution must be completed by the learner [9]. These problems to complete facilitate the transition between the study of the examples and the complete resolution of problems they are also a source of progress.

Bruner's constructivist theory, refers to a definition of the guardianship process: « It is the means by which a specialist helps a person less specialized than him ». The constructivist theory is linked to the concept of "proximal zone of development" defined by Lev Vygotski.

A part of the objectives of this theory is to make the learner able to:

- Solve a problem,
- Carry out a task,
- Reach a goal that would have been, without assistance, beyond its possibilities.

Teacher support is about taking over the elements of the task that initially exceed the beginner's abilities, and allowing them to focus on the elements that remain in their area of expertise and bring them to achievement.

J. Bruner details this six-point support process:

1 - **Enlistment**: engage learner interest and adherence

2 – **Reduced degrees of freedom**: the tutor fills the gaps and lets the learner develop the constituent sub-routines that he can achieve.

3 – **Maintain orientation**: the tutor must maintain the pursuit of the defined goal. (Deployment of enthusiasm and sympathy to maintain motivation)

4 - **Signalling of the determining characteristics**: the task of the tutor is to make aware of the differences between the achievement of the student and the success criteria.

5 – **Control of frustration and understanding**: try to maintain the interest and motivation of the student. However the risk is to create too much dependence on the tutor

6 - **The demonstration or presentation of solution models**: it is the presentation, of solution models to solve a problem, which requires more than just the execution, it requires the students' presence.

This pedagogical scenario has been built by relying on these six points of the encouragement process, and the authors tried to respond at each by a defined solution:

1 - The chosen format of the project allows students to makes sense of the given theories

2 - The structuring of the project, allows the dimensioning process to be tackled throughout several steps. This, makes it possible to realize part of the process before a total taking into account of the entire problem.

3 – A parameters table allows monitoring and convergence of dimensioning and so maintain orientation

4 - The follow-up of students in each session allows the signalling of the determining characteristics.

5 – The follow-up of students in each session allows the control of frustration and understanding

6 - Solving examples using the basic configuration before applying this on their configuration serves as the demonstration or presentation of solution models.

3 DIMENSIONING PROJECT

This dimensioning project has as support a vertical wind turbine and more particularly on the wind turbine multiplier, see *Fig. 1*. This project concern more than 140 students distributed in 48 groups. At each session, 4 teachers supervise 24 groups.

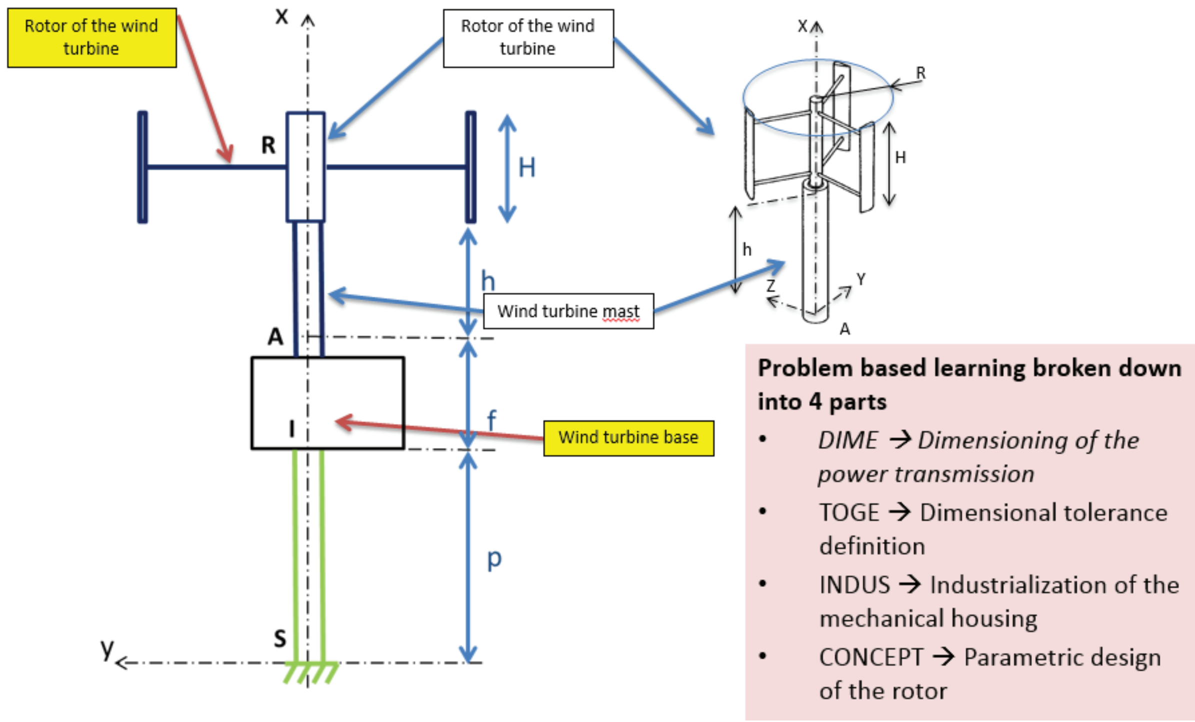

Fig. 1: Main components – Framework of the study

The project follows the following structure:

Definition of the current situation and of the problem to solve, the problem has as support the multiplier of a wind turbine (see *Fig. 2 and 3*) for a given configuration

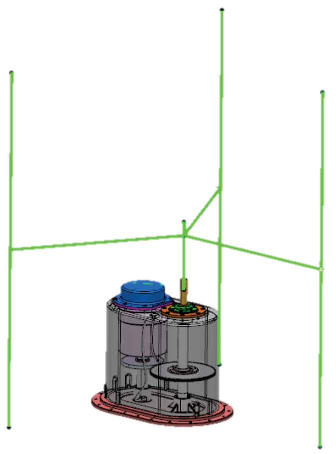

Fig. 2: Wind turbine

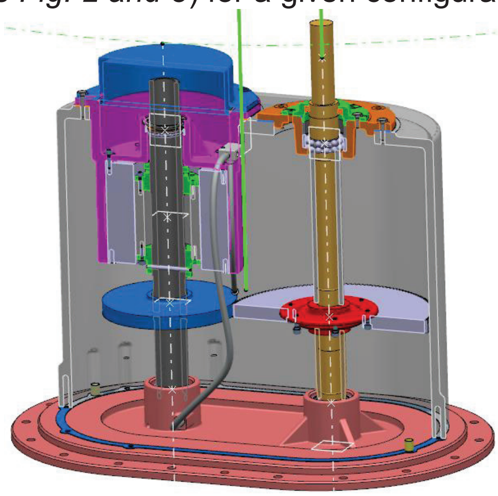

Fig. 3: Multiplier

Definition of the desired situation, the objective for students is to dimension the two multiplication stages, bearings, the drive shafts and the mechanism casing to a given configuration of an alternator's range, see *Fig. 4*.

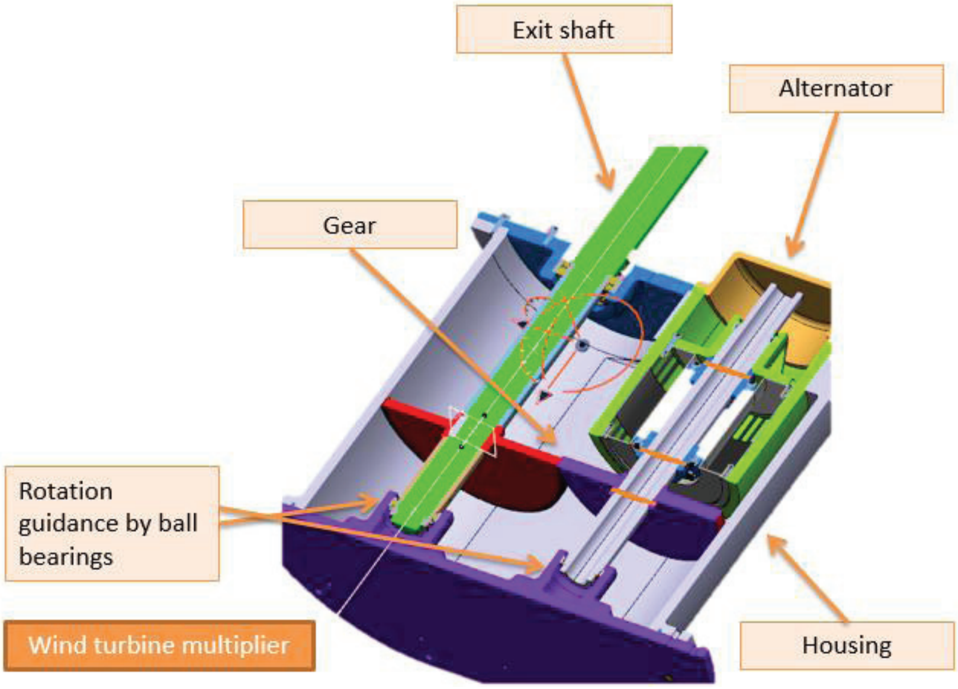

Fig. 4: Components of the wind turbine multiplier

Planning of the student's actions, a global vision of the future works is given to the students, as much on the dimensioning of each component as on interactions of each dimensioning on the system and on the necessity of a global convergence.

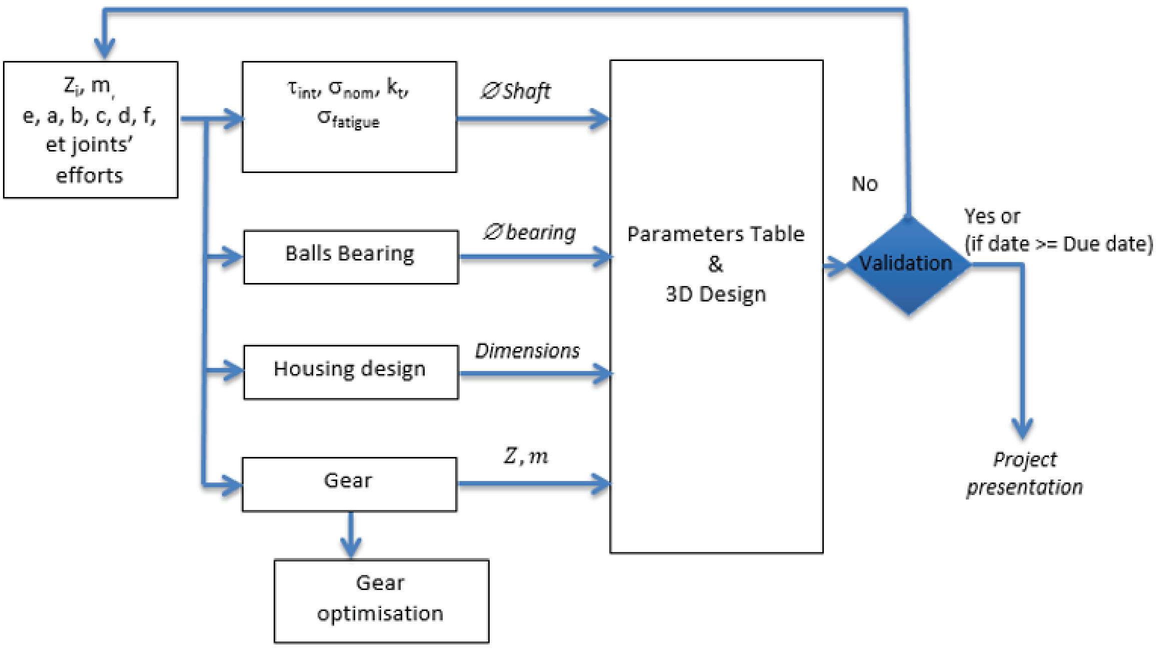

Fig. 4: Flow chart of the project

Actions, the students' work (10 sessions of 4 hours) is based on courses and project resource documents available on the Moodle platform and on "examples interventions" of the teachers showing how they would size the elements of the given configuration. These short interventions are disseminated throughout the project and represent 3/8 of the global time spent on the training. Based on all this information, the students must re-enact these actions taking into account the whole system and the interactions between each dimensioning. The monitoring and the convergence of the dimensioning are done through a parameter table. This table is completed at the end of each sequence on Moodle, which allows teachers to monitor progress, possible mistakes and to intervene at the next session with the student groups presenting difficulties.
Parallel to the dimensioning of the students have to modify the basic CAD model on CATIA V6 (Dassault Systèmes) with their determined parameters

Evaluation of the action: two intermediate project reviews, in session, make it possible to evaluate the progress and the autonomy of the group (in addition to the follow-up, session by session via Moodle). The differentiation of marks between students is based on certain tasks assigned to each student. A final presentation and the writing of a calculation note on the basis of examples provided by the teachers are integrated in the assessment of skills.

The question of what the student really learned from the initial program [10] as well as the assessment of the skills acquired by students in this type of pedagogy remains an open problem [11]. But, through the parameters table, it is possible to follow precisely the work of each group, at each session and to evaluate the encountered difficulties. It is easy, for example, to detect if the problem is about solving mathematical problem, a lack of understanding of mechanical model or a bad dimensioning choice.

4 CONCLUSION

The implementation of project-based teaching coupled with pedagogy by example makes it possible to compensate for the lack of experience and autonomy of first-year students, while at the same time involving them strongly in the first few minutes of the module. In this project, students have been confronted with the real dimensioning problems and are able to understand the links and influences between parameter variations and dimensioning, an objective that we did not reach in classical teaching. The fact of solving a detailed example allows the student to have a better abstraction of the task and allows students to have a better overview of the significance of the concepts taught by the teacher. The structuring, as a problem solving task, and the activities which happen during the convergence phase, allows for an overall comprehension of the dimensioning methods. It is this form of pedagogy which allows to accelerate the mastery of basic skills and so spend more time on the engineer skills namely the convergence of each dimensioning in order to obtain a validated mechanism.

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Mission-framed Project-based Learning and Teaching

Integrating an Electric Powertrain into a Motor Glider

D. Pourtoulidou[1, a]
F. Steger[a,b]
U. Burger[c]
H. Göllinger[c]
L. König[c]
E. Obermeier[a]
H.-G. Schweiger[a]
A. Frey[a]

[a] Faculty of Electrical Engineering and Computer Science,
Technische Hochschule Ingolstadt
Ingolstadt, Germany
[b] School of Engineering, Royal Melbourne Institute of Technology
Melbourne, Australia
[c] Faculty of Mechanical Engineering, Technische Hochschule Ingolstadt
Ingolstadt, Germany

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ABSTRACT

Technische Hochschule Ingolstadt (THI) started in 2015 implementing mission-framed project-based learning (PBL). Instead of getting a task, which can be completely finished in a typical one-semester period, the students are working on a small part of a complex and interdisciplinary system. More genuine to professional life, they are required to meet a strict time-frame with expected results. Such mission-framed projects create an industrial working environment for project modules to deepen practice-oriented technical knowledge.

As case study, THI initiated the cross-faculty project E-Falke (e-falcon). Goal of this project is the substitution of the internal combustion engine of a glider airplane with an electric motor. Over 130 students were involved in this project, reaching for the fulfilment of pre-defined goals, such as the feasibility evaluation of the project, ground bench testing, integration of the system into the airframe and the official flight certification from the German Federal Aviation Office.

Like in conventional projects, students learned the handling of technical tasks in teams and developed their personal competences. The extensive technical

[1] Corresponding Author D. Pourtoulidou despoina.pourtoulidou@thi.de

complexity of the airplane required practical knowledge and thorough documentation for ensuing groups. This challenged the students and highlighted the need for intensive supervision and technical support during the semester projects.

This paper outlines diverse goals of all stakeholders (teachers, university, external partners) and advantages and disadvantages experienced during the implementation of this mission-framed teaching method. The lessons learnt through the years with planned optimizations for the ongoing project are presented to allow other educators to improve PBL.

1 INTRODUCTION

Universities of Applied Sciences focus on practical approaches to learning. They aim to provide to future professionals the necessary soft skills, technical and theoretical knowledge for their career. The need for educating students closer to real-world situations is lately more often expressed, when discussing the necessary skills of future employees [1-5]. The importance of learning by doing under real circumstances, initiated by Dewey more than 100 years ago, is still considered up-to-date while underlying in the term of project-based learning (PBL) [6, 7]. PBL distinguishes itself in the current teaching practice, as it is capable of reducing the gap between university and industry and meeting the demands of the growing job market. The concept of a project represent an engineer’s working procedure in daily working life [8, 9].

The THI as a University of Applied Sciences consequently aims for practical orientation. Thus the university offers practical placements and projects to the students as well as collaborates with regional companies. PBL occurs multiple times in THI study programs: First, in short-term as part of seminars or in long-term as full semester-projects. To gain knowledge and competences, students are offered to work and investigate a problem, an idea, or a question inside classrooms / laboratories or outside in the field [7, 10].

After introducing the E-Falke as an example for a long-term project, this paper presents the advantages and disadvantages both for the students and the educators comparing this mission-framed project to traditional one-semester projects. These are described as arose through the implementation of this project to allow other educators to improve their implementations of PBL.

2 E-FALKE PROJECT: A CASE STUDY

2.1 Description of the project

In 2015, THI launched E-Falke as a cross-faculty project to enable additional projects modules. Technical aim of this project is to substitute the internal combustion engine of a glider airplane with electric traction and receive official flight certification from the German Federal Aviation Office. Since THI purchased the airplane (shown in Fig.1) in 2015, the work progress began.

Fig. 1. E-Falke

The primary didactic aim of this project is to create a genuine industrial working environment for project modules to deepen practice-oriented technical knowledge. E-Falke (e-falcon) came to enhance the functions of PBL with a wider range among different faculties and a challenging purpose. Students of the electrical engineering and computer science faculty as well as students of the mechanical engineering faculty and the business school participated in this project. The individual tasks were chosen according to their field of studies. By getting a common aim, these different groups of students teamed up to reach the defined requirements for flight certification. More in particular, the feasibility evaluation of the project, the ground bench testing, the integration of the propulsion and battery system into the airframe and preparing the necessary documents for the official flight certification of the German Federal Aviation Office were some of the cross-faculty goals.

Until now, E-Falke offered mission-framed student projects to most of the bachelor and master programs in the faculty of electrical engineering and computer sciences. Under the general topics of: electrical engineering and information technology, electrical engineering and electric mobility, aircraft and vehicle informatics and user experience design, students worked on concepts around Human Machine Interface, Battery Pack, Battery Management System, Electrical Interface to legacy components. In the faculty of mechanical engineering, four bachelor programs derived project: mechanical engineering, aerospace engineering, energy systems and renewable energies. Students of this faculty engaged particularly in following topics: Construction and Design of the cowling and the construction of an electrical motor and battery mount. Additionally to these marked one-semester group projects, students of all three faculties worked individually on research topics related to E-Falke-tasks as part of their bachelor or master thesis.

By far the most challenging part of the modifications is to install a redundant electrical energy storage into the plane. Certain special limitations as mechanical integration, weight, safety and budget were to consider. Student groups were working on the concept and simulation model of the energy storage. For example, one task was to determine if a low-voltage system is efficient enough to allow the minimal required performance for the certification of the plane. Here, the project demonstrates a very realistic situation for system engineers: while high-voltage systems are more efficient, the effort to install them in safe manner is higher compared to low-voltage systems. Several following groups were working on building and testing the energy storage systems, which needed to be compatible with the rest of the purchased electric components of the traction system.

Another example of interdisciplinary teamwork was a joint project of aerospace informatics and user experience design students: without a mission-framed project both would finish their projects individually. In the frame of E-Falke both worked together to solve the problem and create the pilot interface. Pilots are used to operating combustion engines that allows maximum power at all times, e.g., to abort a landing and initiate a go-around. With battery powered drivetrains the provided maximum power depends on the state of charge of the battery systems, thus it was necessary to a) develop a user interface explaining this behaviour intuitive to the pilot and b) make the necessary algorithms working to feed the user interface with data.

2.2 Stakeholders

Apart from to the students view, several perspectives need to be considered. Such is the university management of THI that supported the project from the beginning. Numerous educators (professors, research associates, lecturers) and external industry partners have been involved in this mission.

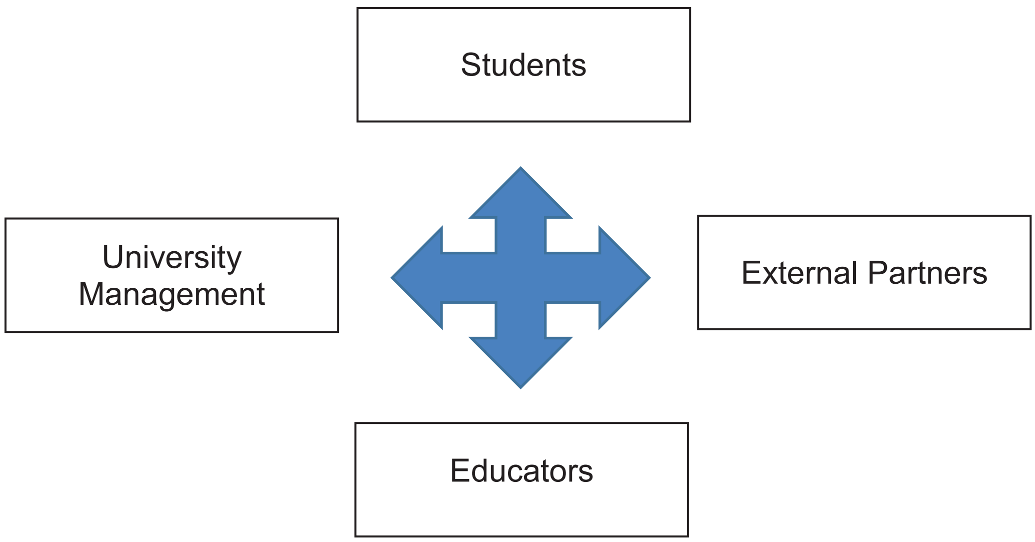

Fig. 2. Stakeholders

2.3 Goals

As stakeholders' role and impact differs, their goals vary. Like in every project, continuous collaboration needed to be organized (Fig. 2).

- The mission-framed project style enhanced realistic environments for the project modules that were offered to students, which was (and remains) the common goal of all stakeholders. Real requirements and a clear purpose (official flight certification of the German Federal Aviation Office) ensure authenticity of student projects and increase the practical learning inside the university.

- The perspective of the university management included public relations regarding the university (in particular the aviation study programs) inside Germany and internationally. The management additionally intents an increase in aviation-related activities through supporting this mission-framed project.
- The university aims for interdisciplinary collaboration between the different faculties. This collaboration allows for knowledge gains during the practical research in order to evolve the area of E-mobility and E-flying.
- Another desired outcome from this project is to implement the E-Falke aircraft as a platform / working area, where further research and projects could be integrated. On behalf of the university, an environment with numerous potentials for future projects will be available, with which students are already familiar with. The possibility of a student group that will be capable of controlling, planning and promoting the future of E-Falke is an underlying goal.
- The external industry partners aim for the recruitment of future employees. They use the E-Falke project as a platform to promote their working facilities directly to students and get to know their potential employees in a professional working environment are substantial advantages.

3 LESSONS LEARNT

The methodology used in this research to enlighten the lessons learnt is qualitative and empirical. The stakeholders, excluding the students, observed simultaneously to their participation the interaction inside this mission-framed project. Through interviews, data about the experiences of the stakeholders with this mission-framed project were collected and are presented as follows:

3.1 Advantages

Several positive effects have been noticed since the beginning of E-Falke:

1. Students, who participated in the mission-framed project, come with higher motivation, not only because of their interest for the technical topic, but moreover because of the realistic job-related situation they experienced. For typical projects, the university teacher usually selects achievable tasks for the single student group that can be completely finished in a one-semester period. In this mission-framed project, students of different programs, fields, and faculties are working to achieve the overall goal of the project. Thus, all student groups face realistic problems, for which they are in charge. Finding solutions, verifying these solutions, and - in case they are not suitable - continue trying to find better ones, always having in mind the responsibility for the whole project. Therefore, all aspects are more authentic when participating in E-Falke. The students need to cooperate within and outside of their group. Even more they cooperate with preceding and following groups by reading and writing reports. Actually they can easily imagine the person who reads their own reports, instead of “writing it for the teacher”.

2. Like in an industrial environment, different kinds of engineers need to cooperate for the desired outcome. Here, students from different fields and faculties work together and exchange findings and ideas. Future engineers collaborate with students of the business school. Particularly, the students of business administration and management examine the value, the possibilities for sustainability and economic growth of E-Falke. The commercial aspect is not left behind; marketing students are responsible for the promotion and advertisement of the project. They are engaged in attracting more students, in terms of a student-project or volunteer work, and promoting the project to the local and international community. The extent of the cooperation and the number of the participants highlights the necessity of documentation of every aspect in the project (e.g., working process, research, team meetings etc.). Collaboration and exchange of knowledge occurs in this cross-faculty project beyond roles and positions, over "student identity". Students of different semesters, educators with different "position" combine their knowledge, motivation and ideas to pursue their goals. In equal terms, undergraduate students work side by side with their professors and have the opportunity to experience their professionalism outside of the "strict" classroom environment. Moreover, students doing research on specific complex topics, own an "expert" role for the whole team. These experiences benefit both students and educators in interpersonal and knowledge level.
3. The collaboration of the student groups exceed the time-limitations of a one-semester-project. The need for collaboration between the students that participate in the different project modules exists not only for the student projects that are being simultaneously executed in one semester but also through the semesters. In addition, this increases the necessity of documentation and the possibility for students to stay engaged. This mission-framed project affords continuity, so that students that want to, can participate in more than one semester. There have been students that took part in E-Falke through the project module in their bachelor's degree, concluded their bachelor thesis regarding E-Falke and registered for a project module again in E-Falke in their master's degree. This setting offers the ability of development within familiar and interesting topics.
4. Another advantage for the student groups that were from the beginning in this mission-framed project was the freedom in the decision-making level. They were the pioneers that were responsible for planning the working progress and the further evolution of the project. No obligations, other than these of the German Federal Aviation Office for the official flight certification, were restricting the students. These obligations match to their assignment and fulfill their university credits by writing reports that will be used for official certification. Hence the assignments are kind of a duty for the achievement of the mission for the students and not a must-to-do paper they are obligated to write.

3.2 Disadvantages

The above-mentioned advantages came with some difficulties and complications that will be presented as experienced by the different stakeholders of the project.

1. More than 130 students have been involved in this long-lasting project since 2015. The guarantee of continuity requires that future participants need to be informed about the actual state of the project. Also the inquired knowledge needs to be maintained and forwarded to future students. As the project modules duration in a study program is only one semester, usually no overlap of groups in duty is given. Thus, except for the verbal transmission via the teachers, this information transfer needs to be done fully by documentation. This was a triggering point in the beginning, as some results were not precisely described. The expertise and the reason for specific decisions and steps during the developing process were vaguely illustrated. This increased the required training-time and support for the newcomers by the supervisor. Consequently, the role of every supervisor, lecturer and stakeholder that introduces the project to the students or explains a misunderstanding becomes more important. The “mediator”, the person that stands in the very beginning and through the whole project between the students and the project affects their knowledge, their interest and passion for the project. The human factor cannot be completely predicted. Inevitable changes of the teaching personnel caused deficits in the knowledge base of the project. Research assistants and lecturers have a relative short academic life. Their inquired knowledge had also to be conveyed or thoroughly documented by their absence.
2. Another inevitable consequence that appeared with the progress of E-Falke was the rising difficulty on the knowledge level. The realistic situation of this mission-framed project demands higher knowledge and skills as the project progresses. In traditional short-term projects, the demands can be relatively adjusted to the students’ background knowledge by choosing the topic of the project. The conditions of this mission-framed project create rapid evolution of the required background knowledge, which undergraduate students are lacking. Therefore, more time on training and informing the students about the subject was necessary to be dedicated at the beginning of every student project. In cases where a student group was not able to achieve its tasks in the expected timeline, somebody else had to continue their work. In a mission-framed project, the unfinished tasks remain important and become another person’s or group’s responsibility.
3. Last barrier for the teachers of the student-projects was that international students could not be involved entirely into all mission-framed tasks. The final documentation needed for the official flight certification of the German Federal Aviation Office had to be formulated in German. The international students could execute and prepare the required documents, but their documents needed translation prior to submission. This downgraded their work and minimised the authenticity of the process.

The underlying goal of the university to build an independent student-group, where a student-club would be in charge of this mission-framed project and will be organizing the research and working progress, is not achieved thus far. The commitment of the students ended by submitting their essays for getting the ECTS. Although, self-motivated and enthusiastic about E-Falke, none took the initiative to organize a team. On the other hand most of the students who participated in the bachelor programs, later in master choose the E-Falke projects again. The reasons from the students' perspective explaining this have been only verbally researched so far. As great interest relies on this, the stakeholders of E-Falke seek to gain insights through future surveys among the students.

4 CURRENT STATE AND FUTURE WORK

This paper addressed the gains of applying PBL in higher education and the problems through this process. THI evolved this method through the years to minimise the disadvantages and keep the gain as high as possible for all participants.

Regarding rising difficulty and remaining unfinished tasks, students of master project groups were able to undertake the remaining tasks as they had the required knowledge. In comparison to lower semester bachelor students, they can execute demanding tasks and convey the required knowledge and skills to younger students. By starting such projects as bachelor modules and continue when this effect applies with master groups can this mission-framed project overcome this obstacle to a certain extent.

The answer to the need of the students for further support and guidance came outside of the university. Three retired engineers with long and valuable experience in the aerospace industry were included as support to the student groups and serve the role of an external advisor for the student projects since 2017. Additionally to their support for the students during the manufacturing phase, they sporadically attend the assessment-presentations during the semester and provide the students with useful feedback on their content and presentation skills. The fact that they are timely flexible smoothed their entry into this mission-framed project and enhanced the positive feedback from the students.

The complete substitution of the combustion engine of the powered glider airplane with electric traction and the official flight certification of the German Federal Aviation Office are ongoing processes thus far. Even though we faced problems, implementing a mission framed PBL we succeeded in bringing students closer to future working conditions and supplying them with knowledge and most importantly with a repertoire of competences. In order to develop the approach of mission-framed PBL we will evaluate the opinions and experiences of the students that participated in this project through the years. Our wish is to find ways to overcome the experienced challenges engaging the students.

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“Washington Accord” graduate attributes and its implication for the engineers’ cultivation in local universities and colleges

Qi Shuyu

Beijing University of Technology, Institute of Higher Education;
Capital higher Engineering Education Center, Beijing 100124

Abstract: The quality of engineers’ cultivation is the concrete embodiment of the training objectives of local colleges and universities. As the most authoritative and influential mutual recognition agreement of Engineering Education in the world，the Washington Accord and its graduate attributes provide the standard for the cultivation of engineering talents in Colleges and universities in china. In June 2016，China became the eighteenth official member of the Washington Accord，which aims to recognize engineering literacy through multilateral accreditation，to promote mutual recognition of engineering degrees and international mobility of engineering and technical personnel. In contrast，our engineering education in local universities and colleges’ talents cultivation situation presented some problems，like the traditional concept of talent cultivation: teacher-centered and investment-oriented mode; homogeneity of cultivating mode of engineering talents as well as the backward educational technology and teaching strategies which need to be changed urgently; practice education system and school enterprise cooperation mechanism are not perfect; deficiency of the input-and-output dynamic evaluation system. In order to improve the quality of talents cultivation，local universities and colleges need to carry out a series of reforms: the practice the OBE oriented training model for the future; the classification of local colleges and universities’ development planning; the introduction of market forces and engineering group to perfect enterprise practice of constructing education system; the dynamic optimization of engineering talent evaluation system to cultivate prospective engineers all-round development.

Key Words: Washington Accord; graduate attributes; local universities and colleges; engineers’ cultivation

The Washington Agreement is the most authoritative international engineer agreement in the field of engineering education attestation at present. China undefined successful accession to the Washington Agreement shows that the certification of higher engineering education in China has been recognized by the international counterparts. At the same time, it also provides a basic paradigm for the development of engineering education certification work in the future, which is based on the (Graduate Attributes) export-oriented (Outcome-based) framework of graduate quality framework of the Washington Agreement, which is essentially equivalent to (Substantial Equivalence) certification. It is beneficial to the improvement of the quality of engineering education and the transnational flow of engineering talents. The National medium-and long-term Education Reform and Development Plan (2010-2020) and the National medium-and long-term Talent Development Plan (2010-2020) have been issued in succession in China, which have put forward new requirements and challenges to the training of engineering talents in China. How to establish a talent training system in line with the international equivalent certification system of engineering education specialty, cultivate a number of strong innovative ability, adapt to the development of local economy and social internationalization, Various types of engineering technology and management personnel with international competitiveness have become an important research topic. Based on the export-oriented evaluation theory (OBE) and the Washington Agreement on the principle of substantive equivalence, this paper analyzes the current situation and problems of local engineering talents training in China. This paper analyzes its enlightenment to the training of engineering talents in local colleges and universities in China

1. The requirements for the quality of graduates in the Washington Agreement

The Washington Agreement, mainly aimed at four-year undergraduate higher engineering education, recognizes the substantial equivalence of engineering training programmes certified by the signatory States. Recognizing graduates accredited by any Contracting Party to meet the academic requirements and basic quality standards for the practice of engineers, the core of which is mutual recognition by international engineers, This is also the basic paradigm for the Washington Agreement to promote and practice on a global scale. The Washington Agreement highlights the participation of users in authentication assessment, emphasizes the effective docking of industry and education, and establishes an effective coordination mechanism for school-enterprise cooperation. Advocating that member States should be industry-oriented and incorporate industry enterprise representatives into the revision of school training objectives and encourage the establishment of industries that include industries, Personnel training committees of people from all walks of life, such as employers, and so on. Since the 21st century, the member States of the Washington Agreement have continuously increased their international influence and gradually become a standardized rule for international engineers to recognize each other. It has also become an important trend to establish China undefineds engineering education professional certification system with international substantive equivalence.

In the 1990s, some of the signatories to the Washington agreement decided to adopt uniform results-based standards in their respective certification systems, and they began to study fundamental issues related to the education of professional engineers. For example, what can our graduates do? Can specific content be specified? How does the existing evaluation system deal with the new training standards? the signatories to the Washington Agreement are committed to defining the consistency of the quality of the graduates and redefining the connotation and standard of the quality of the graduates in the last ten years. The "quality of graduates" standard adopted by the signatories to the Washington Agreement is of a general nature and is generally applicable to the education of professional engineers in all engineering disciplines. It regulates the professional knowledge that graduates should possess and the professional skills they should demonstrate. And should have the professional attitude. The Washington Agreement does not include the quality of graduates as a mandatory criterion, but rather develops results-based certification standards applicable to their national circumstances for contracting countries and promotes services in their jurisdictions, And to provide guidance for certification bodies and associations of signatory countries.

The Washington Agreement states that the quality of graduates should consist of "knowledge that must be mastered" and "problem-solving levels", with the core feature of emphasizing the ability of professional engineers to solve complex problems and deal with uncertainty. Graduates are required to provide comprehensive solutions to complex engineering problems through abstract thinking, creative analysis and scientific judgment. In the framework of this quality, member States of the Washington Agreement, on the basis of the principle of "substantive equivalence", flexibly formulate certification standards and procedures applicable to their countries for the quality of graduates, All member countries have their own requirements for their graduates of engineering education, and set a more reasonable standard system for the training of engineering education students flexibly. This is a reflection of the commonness and individuality between Washington Agreement and member states on the quality requirements of higher engineering graduates under the principle of substantive equivalence.

2. Analysis on the present situation of Engineering Education talents training in Local Colleges and Universities in China

Since China applied for accession to the Washington Agreement, from the first 61 pilot colleges and universities, 133 in the second batch and 14 in the third batch, the coverage has now reached 208 universities in 30 provinces, of which local universities account for more than 70%. Local colleges and universities have become the main force in the internationalization of engineering education certification. Take Beijing as an example. From 2006 to 2014, there were 15 universities, 22 specialties and less than 30 percent of the local colleges and universities that passed the certification of engineering education. Judging from the frequency of the schools passing the certifications, there are only four local colleges and universities which account for less than

30 percent of the total number of local colleges and universities. The local colleges and universities account for only 12% of the eight times. It can be seen that local colleges and universities are still in a weak position in the certification and construction of engineering education throughout the country. At present, the training quality of engineering talents cannot meet the needs of the current regional economic and social development. The systematic reform of engineering education needs to be carried out urgently.

2.1 The idea of cultivating talents in local colleges and universities is backward

Local colleges and universities mainly follow the concept of science teaching, ignoring the characteristics of engineering science, unable to clarify whether science education, technical education or engineering education, and often follow the first-class research universities to train academic talents. Ignoring its own characteristics and positioning, the Fudan consensus on New Engineering Construction in February 2017 clearly proposed that local colleges and universities should play a supporting role in regional economic development and industrial transformation and upgrading. To train applied and technical talents who are competent for the development of the industry. With the upgrading of local industrial structure and technological structure in China, enterprises especially need technical and skilled talents who are engaged in direct production work and rely mainly on intelligent skills on the spot of production activities. Local colleges and universities should change the cultivation concept to train high-level engineering technology application-oriented talents as the goal, abandoning the traditional drawbacks of "emphasizing scientific analysis, light comprehensive innovation, emphasizing individual research, and neglecting team cooperation". The concept of engineering education should be reformed in combination with the characteristics of local colleges and universities and the law of development of engineering science, so as to meet the needs of local society and conform to the cultivation concept of the era of knowledge-based economy.

China undefineds engineering education certification has begun to draw lessons from the OBE framework, but local colleges and universities have for a long time focused on the investment-oriented and subject-based reform and evaluation of the training of engineering talents in the aspects of curriculum system, teacher manpower, hours of study, and so on. Although the curriculum is the most basic unit and the most important "product" of universities, the results orientation emphasized in the Washington agreement is not the same as curriculum orientation. The excessive pursuit of scientific research results by local colleges and universities has led to teachers spending too much time. It is impossible to focus on the effect of the students undefined learning because they focus on the knowledge points, courseware and other details of the course teaching. At the same time, teachers undefined lack of professional training still exists the traditional concept of "curriculum-only" and "curriculum-only", which makes it impossible to decompose the requirements of graduates undefined quality into the curriculum and implement them effectively in curriculum teaching. Teachers should be encouraged to exercise in high-tech enterprises, which are closely related to the development of local economy, so as to improve teachers undefined engineering ability and comprehensive quality. And guide all teachers to understand and implement the OBE-oriented education to implement the practice of OBE into the teaching of each class, and gradually shift the focus of teaching and certification to the training results.

2.2 The homogenization of Engineering talents training Mode is serious Education Technology is backward.

In order to meet the needs of the development of education popularization, many local colleges and universities have developed into "new undergraduate colleges" through integration and upgrading. By 2015, the number of Newly-built Undergraduate Colleges and universities in China has expanded to 403, accounting for 42.69% of the general colleges and universities, and nearly one million talents are transported to the society every year. At the same time, the development of these colleges and universities meets the needs of the popularization of education, and gradually produces the problem of homogenization of education. Graduates trained under the same mode have similar thinking mode and knowledge structure, lose their creative passion and innovative ability in their study and work, and also cause the waste of school educational resources and suppress the characteristics of school development. Moreover, the mode of talent cultivation in local universities tends to cultivate academic and research-oriented talents, which results in the structural disconnection between the talent cultivation in local universities and the actual needs of society. Engineering education is a professional education aiming at solving complex engineering problems. Colleges of different types and levels should have engineering education models that meet social needs and highlight their own characteristics. Local colleges and universities should integrate scientific and engineering models to solve the problems of lack of technical knowledge and weak engineering practice in personnel training, so as to cultivate practical exercises for serving local social and economic development. Personnel of type.

In the Internet era, college students are accustomed to immerse themselves in information resources and digital networks for learning experience and feedback. Universities are also exploring new teaching strategies to adapt to the characteristics and needs of contemporary college students. However, in the teaching process, it is easy to find that engineering majors in local universities do not have an advantage in applying modern educational technology. There are great differences in the ability of introducing modern educational technology among colleges and universities, which are basically manifested in the higher level of economic development, the stronger ability of introducing modern educational technology and the higher quality of introducing it; the weaker level of economic development, the lower application of modern educational technology in the teaching process of colleges and universities. It can be seen that colleges and universities are greatly influenced by the level of local economic development, and their development is uneven. Lack of sustainability. The weak foundation of modern educational technology is not conducive to the implementation of new engineering teaching strategies such as virtual learning environment and interdisciplinary collaboration. The interaction between teachers and students and the cultivation of students' practical ability are the trend of teaching strategy reform in local colleges and universities in the new era.

2.3 Imperfect Practical Education System & Insufficient Collaborative Innovation Mechanism between School and Enterprise

At present, local colleges and universities have not yet formed a perfect practical education system. First of all, in terms of concept, local colleges and universities generally believe that practical teaching is only an auxiliary link of engineering education. Engineering practice links are not paid attention to in the personnel training of local colleges and universities, lack of engineering education characteristics serving local economic development, comprehensive training and experimental practice, etc. are replaced by professional education. It is impossible to form engineering practice education that integrates different teaching plans and corresponds to the training objectives of various departments, resulting in the lack of engineering design and analysis ability and practical problems solving experience for graduates.

Secondly, in terms of methods, the main body of teaching practice is dislocated. Students enter the laboratory mainly by passive practice according to teachers' requirements. There is a lack of active practice teaching to determine experimental objects, methods and procedures by students' design, which is insufficient for the cultivation of practical innovation ability. The instructors themselves lack engineering experience and enterprise experience, and can not grasp the frontier knowledge of technology in time. Colleges and universities should encourage teachers to enrich their practical experience in relevant industries and improve their practical ability to solve engineering problems.

Third, in terms of resources, local colleges and universities can not keep up with the hardware and software, and lack of advanced and efficient training platform. Due to the influence of local government policies and funds, there is still a gap between the scale and level of engineering training platform in local universities and the first-class universities. Local university graduates have poor hands-on ability and lack of relevant experience. Their own foundation is difficult to meet the requirements of enterprises in engineering practice and management. Enterprises also need additional training for graduates, which leads to enterprises unwilling to participate in the training of engineering talents in Colleges and universities. In order to solve this problem, the state carries out the cooperative innovation strategy of "government, industry, education and research", but there are many obstacles in the implementation process. Therefore, local governments should introduce relevant incentives and local colleges and universities should reform the training objectives of engineering education. Otherwise, the phenomenon of disconnection between engineering education and industrial production will lead to the lack of sufficient practice training bases for talent training in local colleges and universities, thus affecting them. Training quality of engineering education.

2.4 Talents training is mainly based on outcome evaluation , Input-output dynamic evaluation system is not connected

Talent training evaluation is an important system to test the quality of talent training in local colleges and universities, which runs through the whole process of education and plays a decisive role in optimizing teaching reform. In recent years, local colleges and universities have reformed their evaluation methods and methods. Nowadays, the accreditation standard has changed from "input" to "output", but the traditional result evaluation is still the main method. The lack of process evaluation and feedback links from output to input is not conducive to timely discovering and solving the quality problems of personnel training.

Firstly, the evaluation system of talent cultivation in many local colleges and universities is not compatible with the training objective of Applied Undergraduate talents. The evaluation method is single and one-sided. The evaluation system guided by scientific research results is not conducive to technological innovation in local colleges and universities. It can not reflect students' learning results and talents, students' social evaluation and feedback, and the contribution of research to the country and society. It hinders the training of Applied Engineering talents. Secondly, the evaluation system lacks the feedback information of communication and communication between the training results of colleges and universities and the social docking links. It is unable to learn the objective evaluation of schools and students by the society and employers, and the extent to which the training results contribute to the social and economic services, which makes the evaluation results not be applied to the continuous improvement of the training quality from time to time. Thirdly, most of the evaluation subjects of local colleges and universities are experts and leaders on campus. We should invite outside-campus subjects, especially representatives of enterprises in high-tech industries, professional entrepreneurs and senior engineers in front-line work, to participate in the evaluation of personnel training, and integrate their needs into all aspects of personnel training, so as to ensure diversified evaluation subjects inside and outside schools, which is conducive to promotion. The scientificity and effectiveness of the evaluation results. Fourthly, the evaluation method is still simple or single, without setting different evaluation objectives according to different teaching contents and links. The organizational structure and management system of the traditional "University-College-Department" in local colleges and universities also results in the evaluation system being confined to the training of talents and discipline construction of their own specialty, which greatly limits interdisciplinary communication. Flow and knowledge production.

3. Enlightenment to the Training of Engineering Education Talents in Local Colleges and Universities in China

Joining the Washington Agreement is a milestone for the development of Higher Engineering Education in China. Local colleges and universities should base themselves on the requirements of modern engineering education era and the needs of social and economic development, seize the opportunity to improve the talent training plan. The reform of Engineering Education in local colleges and universities is a systematic project. Based on the current situation of Engineering Education in local colleges and universities in China, as well as the "Washington Agreement" and the quality requirements of graduates, the following suggestions are put forward:

3.1 Practice the future-oriented OBE training mode, focusing on training applied engineering and technical personnel

OBE has become the mainstream concept of education reform in the United States, Britain, Canada and other countries. The Washington Agreement accepted the concept of OBE in an all-round way and put it through the certification standards of engineering education all the time. In accordance with the framework of the Washington agreement, local colleges and universities should adhere to the emphasis on meeting the needs of students in the aspects of curriculum design, teaching process, practical practice, student management and so on, and should be guided by the qualities of future engineering talents. Output applied engineering talents who meet local social and economic needs and can flexibly use theoretical knowledge to solve practical problems. In terms of cultivating ideas, local colleges and universities should change from cultivating students undefined solid theoretical foundation and professional ability to cultivating students undefined keen social insight, spontaneous creative thinking and global vision, and teaching design should be based on students undefined knowledge. The allocation of teaching resources, such as ability, quality and teacher curriculum, should be guided by ensuring the achievement of students undefined learning goals, and quality assurance and evaluation should be based on the unique criteria of students undefined learning results.

In terms of training models and strategies, local colleges and universities should further focus on the knowledge, skills and behaviors acquired by students after graduation, and encourage teachers to recognize the concept of OBE education and (PBL), cooperative learning based on project-based learning. Cross-disciplinary cooperation and other related training strategies, in the teaching process to actively become a cooperator, motivator, and effective guidance and coordination to the students. On the one hand, teachers are required to study continuously, to improve their professional level and comprehensive ability, and to contact with enterprises to introduce relevant cases for teaching. On the other hand, students are required to actively participate in the guidance of teachers and improve their autonomy, cooperation, communication and cross-cultural learning ability in group cooperative learning.

3.2 Based on the characteristics of regional economic and engineering disciplines, enhance the service functions in the implementation of the Washington Accord.

Washington Accord and its graduates undefined qualities also emphasizes the training of students undefined ability and technology to use professional engineering knowledge to solve practical problems in future engineering, Its aim is to provide excellent engineering talents for the development of new technology and new economy. However, the social environment of different local colleges and universities is different, and there are differences in regional economic development. Industry economic benefits differences and urban and rural economic regional differences and other objective issues.

First of all, in order to better serve the local social and economic development, local colleges and universities should carry out classified development planning according to their own superior disciplines and scientific research resources, and highlight their own educational characteristics and advantages. Different types of schools put forward different school objectives and evaluation indicators, and carried out a series of reforms around the training objectives, curriculum system, teaching ideas and methods, learning atmosphere, teacher assessment, and so on. Provide engineering technical and technical innovative engineering technical talents for social and regional development. Secondly, according to the framework of the Washington agreement and the requirements of new engineering construction, local colleges and universities should take the initiative to meet the needs of local economic and social development and the technical innovation requirements of industry enterprises, and refine their own characteristics and geographical advantages through the consolidation of their own characteristics and geographical advantages. Take the demand of industrial enterprise as the guidance innovation talent training mode, strengthen the interdisciplinary cooperation and the school-enterprise cooperation.

Thirdly, while serving for regional economy, local colleges and universities should also design teaching and curriculum according to the system and characteristics of engineering science. The new paradigm of engineering education should advocate integration and innovation, the curriculum system design of local colleges and universities should increase the proportion of innovative courses such as engineering design, system integration and so on, pay equal attention to the foundation and practice, strengthen the information technology, biotechnology, nanotechnology, and so on. Intelligent systems and other cutting-edge contact engineering nature of the discipline, the introduction of interdisciplinary learning to cultivate students undefined practical innovation ability.

Development of learner autonomy in student-centred learning environments in engineering

D. Reyes-Viviescas[1]
PhD Researcher
University of Strathclyde
E-mail: diogenes.reyes-viviescas@strath.ac.uk
Glasgow, UK

E. Ventura-Medina
Senior Lecturer
University of Strathclyde
E-mail: esther.ventura-medina@strath.ac.uk
Glasgow, UK

T. Anderson
Senior Teaching Fellow
University of Strathclyde
E-mail: tony.anderson@strath.ac.uk
Glasgow, UK

C. Mio
Lecturer
University of Glasgow
E-mail: Cristina.Mio@glasgow.ac.uk
Glasgow, UK

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ABSTRACT

Engineering graduates are required not only to have strong communication, problem-solving and teamwork skills but also the ability to face and adapt to new situations [1]. Hence, there is an evident need for developing life-long learning skills and particularly in fostering self-regulation of learning in engineering programmes. Project-Based Learning (PjBL) is a teaching pedagogy that supports the development of intellectual skills and autonomy through self-regulation.

Individual self-regulation of learning has been studied over the years in a range of education situations [7,14]. As teamwork becomes commonplace in education, the need to study team regulation has become apparent and models that include social and cognitive processes during teamwork have emerged [2]. However, new empirical evidence is still required to develop models of shared regulation in groups.

This study builds on the body of empirical evidence about shared regulation focusing on Project-Based Learning environments. It investigates how teams of engineering

[1] D. Reyes-Viviescas
E-mail: diogenes.reyes-viviescas@strath.ac.uk

students actually develop shared team regulation and how this is related to individuals' self-regulation. The study uses data from students' project meetings during a one-semester long project as part of a Chemical Process design course.

As the emphasis of the study is in describing and analysing how shared regulation takes place within a group context, focusing the attention on verbal and non-verbal mechanisms as indicators of shared regulation displayed by the students; naturalistic data of teams of students are gathered while carrying out PjBL meetings (~5) via video recording (~10 hours). Transcripts of conversations/actions are coded in the first instance to describe what takes place and then to support the analysis. These data enable the identification of elements of regulatory behaviour as displayed through language.

1. INTRODUCTION

With the rapid and unstoppable evolution of technology and current market conditions, society is facing unprecedented and increasingly urgent challenges [3] that clearly need to be addressed and solved using reasonable solutions by well-versed professionals. In addition, the flexibility and ability to face new situations are imperative in a fast-paced and dynamic working environment, which requires the development of life-long learning skills.

Thus, the role of Higher Education Institutions (HEI) is vital in delivering the appropriate training, in accordance to the current and forthcoming necessities of the world. The constant communication between professional bodies, industry and HEI has served as an important bridge to get significant input into the key skills required [4]. The most prominent skills reported are problem-solving and teamwork [5].

It is a fact that skills need to be kept up to date, as the tasks, methodologies and activities are rapidly changing in any working environment. The university is the scenario where students can be trained hands on using the latest developments and techniques to come up with logical solutions to real problems [5].

In this context, the capability to self-regulate our own learning is essential [6]. Self-regulation refers to the set of abilities to plan and monitor our own development, which are fundamental for learners' progress towards building new capabilities and improve the ones they have already developed or inherited [7].

In terms of learning processes, student-centred learning pedagogies are teaching strategies that support the development of intellectual skills and autonomy through self-regulation [8].

Besides, the importance and application of pedagogies such as Problem-Based Learning (PBL), provide the perfect setting to investigate and later describe how shared regulation is displayed by the students, as a group of individuals. Noting that they who work in teams toward a common goal under some limitations and, having to manage and organize a series of tasks and processes [9].

A number of studies have been done in different learning environments, which support the idea that shared regulation can be developed [2]. However, more empirical evidence is needed to make a stronger and better description of the mechanisms which clearly described interactions (e.g. perception and negotiation of common goals, definition of strategies to succeed with the tasks, and evaluation of goal progress); which ultimately will provide clear directions on how students can be aware of the regulatory processes that are taking place, consequently be able to adjust what could be out of track [9].

At this stage of this research, the clear identification of elements connected to team self-regulation is essential to understand better, how they take place while students undertake a project assignment, which later, will be used as the most important source for the construction of a model that clearly reflects on the findings. In addition, there is a space that needs more investigation, how team self-regulation is linked, direct or indirectly, to the enhancement of students' task performance, which could potentially be identified along the video as the analysis takes place.

The aim of this study is to find how students effectively develop self-regulation while working in teams, at both, individual and group level when dealing and undertaking Project-Based Learning (PjBL) activities in a Chemical Engineering design course.

The research questions addressed here are how students use reflective strategies to progress towards team goals, and what self-regulatory strategies the team as a collective use to fulfil their goal.

2. BACKGROUND

Problem-based learning (PBL) is a pedagogical approach where a defined problem is used as preliminary point of the learning process. Typically, the problem is defined according to the specific learning needs and could be based in real-life problems, and sometimes in hypothetical ones, to meet the educational purposes and be solved potentially using investigation, explanation, and resolution [10].

Project-Based Learning is a pedagogy that builds learning process around projects [11] with professional skills development, disciplinary knowledge, and independent and flexible learning, while accommodating a wide range of students' learning needs [12] with the final generation of a genuine product or outcome [11].

De Graaf and Kolmos [10] distinguish two models in educational PBL practices; Problem-based and Project-organised learning. In Project-organised learning, they point to the fact that, the scope (breadth and complexity) of the project (problem-based) can determine the level of student involvement.

This work will be focused on the use of Project-based learning (PjBL) as the main learning pedagogy. It also makes a distinction here between PjBL and more general PBL as it use a wide scope project (i.e. broad and complex). PjBL encompasses a series of goals that aim to help students develop knowledge and skills that can be used across different subjects, for effective problem-solving and for collaboration [8]. Project-based science also promotes the activation of intrinsic motivation to improve performance when dealing with problems [13].

Self-regulation of learning (SRL) refers to the process as the self-generation of thoughts and emotions, which are applied methodically and strategically as required to generate an effect on the learning process [3]. It is said that PjBL supports and promotes the self-regulation process, due to the nature of the learning progression while students are constructing mental representations for giving feasible solutions to address a diverse type of problems [8].

Zimmerman [14] developed one of the first and principal self-regulated learning cyclical models, where he tried to explain the different strategies taking place and influencing the self-regulated learning process. In his studies, Zimmerman identified three main phases, represented in his model (see Figure 1), that usually are displayed while students are attempting to solve a problem or an assignment, and that ultimately will help learners to be focused on the actual tasks and as a result enhanced their performance [15].

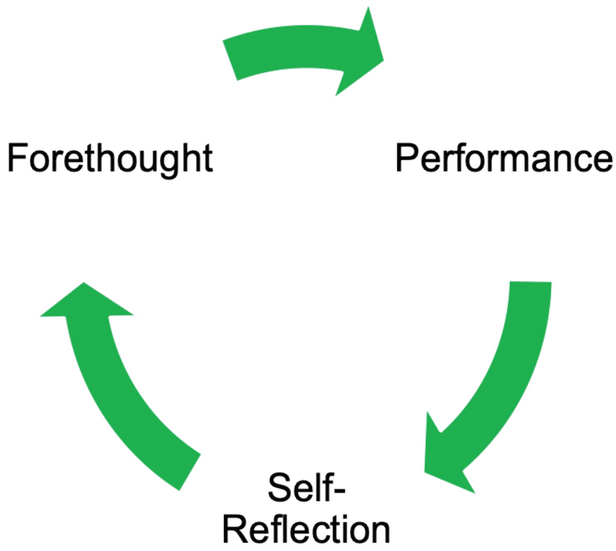

Figure 2. Zimmerman Model. Adapted from Zimmerman [15].

The first stage in the Zimmerman's model is known as the forethought phase, which is the moment when the student faces the task at first, analyses it, sets goals and establishes a plan on how to reach them. Once the previous stage is completed, the second (the performance phase) starts. During this phase, learners attempt to carry out the task while monitoring their progress using a series of self-control strategies, so to maintain themselves completely involved and determined to finish the task. In the third stage, the self-reflection phase, learners evaluate how their performance was, making a clear judgement of their failure or accomplishment [16]. This stage has a significant importance and relevance to the cycle, for both, the conclusion of the current sequence. First, because of the impact that could have caused to the learner's experience and learning efforts, and second, a direct influence on the forethought phase, as this is the starting point of an upcoming cycle, in the case a new challenge is due to be faced [15].

When students are dealing with an assignment, tasks, or even projects, they normally require the continuous support of a tutor, who can give them indications or insights that could lead to the successful development of the work [13]. Therefore, there is still much work or training to be deployed with the students so they could reach a point where self-regulation and autonomy becomes the rule; subsequently, the right use of the available tools (e.g., books, online contents) and teaching elements, can become a regular activity as part of the learning process, so the tutor' support could be less while the student's independence is high [17].

It is important to mention and make clear that the self-regulation strategies, as proposed by Zimmerman [14], might vary when they are applied by individuals within a group or even when taking place in a group context, due to the limitations and constraints that students can face when working with others.

In different studies and analyses that have been done, SRL models provide a reasonable picture of the processes taking place [7]. However, there is still much to do to comprehend SRL mechanisms in detail and see how they take place, when they are used or how they are activated by learners along the interaction and cognition stages [14].

Stefanou et al. [18] have used mechanisms in teaching environments (e.g. choosing group members, setting deadlines for assignments, seating arrangements, and providing materials) which have demonstrated to lead to independent learning. In spite of this, whether or not independent learning lasts in the longer term depends on the learners being engaged in deep learning and being highly motivated. However, it has been found that organizational and procedural autonomous strategies tend to support the process to a lesser extent than cognitive strategies (e.g. discussion of multiple approaches to the problems, justification of solutions or having sufficient time for the decision-making stage) that may take students to a self-motivated and unlimited participation in learning [19]

Perels et al. [20] conducted a study where a full training related to self-regulation and problem-solving skills was given to a group of students in a German grammar school, it is worth to say that the study was done in a senior children school rather than in a university with undergraduate participants. In this study, they adapted Zimmerman's model focusing their attention on the motivational aspects that influence students' performance the most. The training combined self-regulatory components such as goal setting, motivation, volitional strategies, self-efficacy and self-reflection, and problem-solving approaches to coach experimental tactics (working forward and backwards, what keep constant). A series of preliminary pre-tests were applied to the students to establish a base line and allowed comparison of their performance before and after the training of their current performance. It was found that after this intense training an effective improvement in students' performance when applying problem-solving skills. However, this was not the case for the self-regulation component, where results gave indicators of enhancement, but not as strong as those in problem-solving skills. This is a clear indication that these self-regulatory strategies are more difficult to teach compared to problem-solving skills. Nevertheless, the combination of both pedagogical strategies appears to be beneficial to learners' performance.

Hadwin, Järvelä and Miller [2] have worked together in self-regulated learning, focussing their attention on groups, and how the team members cooperate efficiently to accomplish group work; establishing a collective setting, conveying and allocating tasks and formulating strategies. They developed a model that proposed the existence of three modes of regulation in a group working environment: self-regulation (SRL), co-regulation (CoRL), and shared regulation (SSRL) (see Figure 2).

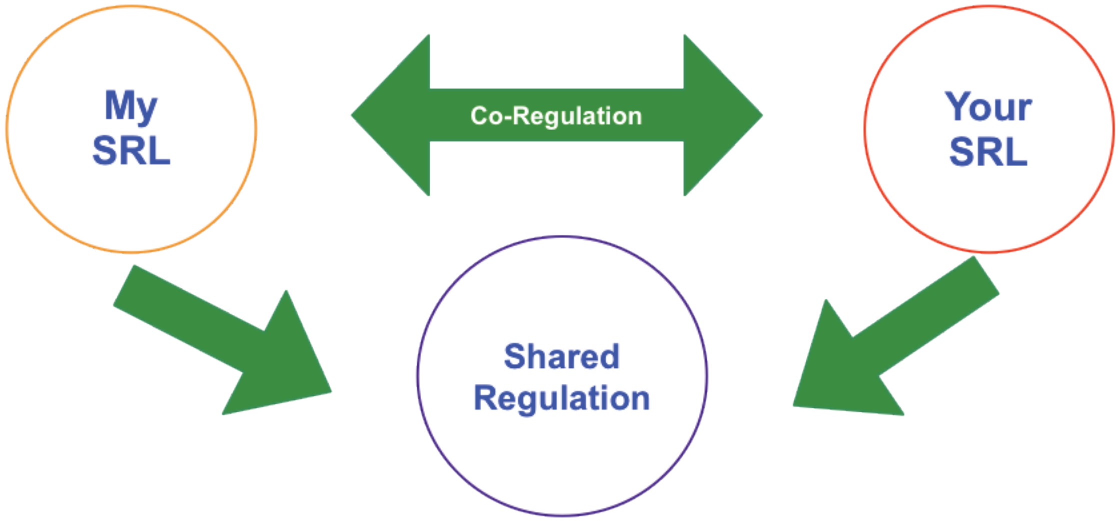

Figure 2. Regulation in a group working environment. Adapted from Hadwin et al. [21].

These modes are defined as followed [21] and [9]:

SRL in a collaborative setting refers to the individual's action within the group that is connected to the way adaptation is performed while there is an interaction with other participants of the team.

CoRL is defined as the affordances and restrictions that motivate the students' allocation of planned activities, performing, deliberation, and adjustment that usually occur when there is interaction with other learners or members of the group, so temporary help may appear when any of the team members needs support in order to solve his/her assigned task.

SSRL is the manner when the diverse perceptions, adaptations, tasks, and goals and plans are taken across the whole group.

3. RESEARCH METHODOLOGY

One advantage of studying teams is the fact that they are frequent not only in academia but also in companies and real life. Thus, they create the perfect framework to be able to identify patterns of how students develop shared regulation, via common behaviours that individuals show when dealing with tasks to that involve mechanisms of regulation.

The study centres on exploring the function of reflection and self-regulation in the development of intellectual skills that have the potential to foster autonomous learning. Thus, the study uses data from students' project meetings during a one-semester long project as part of a Chemical Process design course. The class has been divided into groups, which are made of 6-7 members each, for the development of the project assignment, which is the proposal and basic engineering design of a plant for Nitric Acid production for the data currently under analysis. In the group that has been video recorded there are 5 students, being slightly smaller.

The research questions mentioned earlier are explored by collecting and analysing data using a qualitative approach. The data consist of video recordings of student-group work meetings as well as students' reflections on the class: either written or oral and individually and as a group. In addition, the study will also seek to use video recordings from a previous study done during 2016 and 2017 within the SkIL Research Group of the Chemical and Process Engineering department from the University of Strathclyde, using the same setting (i.e. participants in PjBL groups during project meetings). The study has been granted Ethical approval by the Departmental Ethics Committee. Furthermore, students' participation in the video recording sessions was volunteered.

Due to the nature of the data that will be analysed, two analytical methodologies are going to be explored, namely thematic and content analysis. Thematic analysis is a method for the identification, analysis and later report of common patterns inside data [22], which is known as a qualitative descriptive method [23]. Content analysis is a more "strict and systematic set of procedures for the rigorous analysis, examination and verification of the contents of written data" [24].

Furthermore, self-regulated learning strategies such as self-evaluating (i.e., I check my assignment to make sure it was right), goal setting and planning (e.g. I start preparing my exams 2 weeks before they happen), organising and transforming, seeking information, keeping records and monitoring, among others [16], that potentially could be shown by participants are going to be analysed and compared. The previously said will help describe common characteristics which indicate learners' autonomous behaviour.

The core source of data for this research is video recording of students' project meetings. To this point, 5 meetings have been video recorded with an equivalent of 10 hours of filming. Here, the importance of capturing naturalistic data as is, is an essential element to recognise features of autonomous behaviours, which might be displayed by the students in a setting where the absence of a tutor is of significant relevance, since they can behave normally as they are. Equally important is the fact that video recordings allow a better comprehension of the dynamics that could emerge as students work through the diverse tasks.

Since video recordings give an unfiltered reflection of action they are more powerful than merely human observations [24]. Moreover, video recordings can be played numerous times, allowing to obtain detailed evidence from students' interactions [25], which can be analysed using categories identified within the literature. Finally, video recording also allows the coding of actions, for example, non-verbal behaviours. The use of video footage will allow a broader range of teams to be studied as the video recording process can be done with more than one team in the same academic year, and subsequently, provide conclusions for a wider range of cases.

Transcription is one of the most complex tasks to cover as part of the research. Here a speech representation of the participants' talks is going to be written, where verbal (full transcription of speech, including errors) and non-verbal data (i.e., gaze and gestures) will be collected.

Once the transcription is done, the next step is to group the video transcription elements into defined SSRL categories identified as codes. This helps to analyse the spectrum as a whole, and in this way, build a robust model that has enough elements that supports the SSRL models.

4. PRELIMINARY FINDINGS

Preliminary findings indicate that use of these pedagogies does promote regulation but there is still a need to comprehend clearly how the mechanisms take place [26]. From the data, it has been observed that the phases described in the literature by Hadwin, Järvelä and Miller are displayed by the students and emerged as they undertake the project tasks.

In regards to whether the changes in students' level of SRL is linked to improvement in their overall academic achievement, researchers claim to see an enhancement in students' performance, however, more field research needs to be done to obtain a clearer picture of the relation between the strategies applied and the outcome generated as a result of them [27].

Even though, SRL models provide a quite specific picture of their processes, there is still much need to understand SRL mechanisms more precisely as to identify when they are applied or performed by learners [16]. Further, there is a need to understand the continuum of self-regulation, co-regulation and shared-regulation of students working in teams by using data that captures students working together over long periods of time [2]. The present study contributes to develop precisely the empirical basis on which Shared-regulation models can be informed.

5. NEXT STEPS

As the research advances through the continuous transcription process, a preliminary coding structure will be stablished which would serve as an analytical scheme, being refined and tuned based on the information that is extracted from the transcripts, giving place to a coding scheme for a later analysis of the elements present. Some of the codes are pre-defined based on current concepts available in the literature about SRL while others might emerge from the data itself.

Thus, the SSRL model could be understood, and a full justification of the analytical framework could be given, leading to a stronger and mature structure, which will reflect the findings and draw significant conclusions from the investigation. Hence, a link between pragmatic and meta-analytic evidence on SSRL could be established that directly connects self-regulated learning and academic performance with a totally new perspective [26].

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Curricular Network Analysis

U. Riedel
Center for Teaching and Learning, Hamburg University of Technology
Hamburg, Germany
uta.riedel@tuhh.de

S. Jakobtorweihen
Institute of Thermal Separation Processes, Hamburg University of Technology
Hamburg, Germany

S. Bornhöft
Center for Teaching and Learning, Hamburg University of Technology
Hamburg, Germany

Conference Key Areas: New Complexity Quest in Engineering Sciences, Strong demand for democratic involvement in educational

Keywords: curriculum analysis, curriculum development, network visualisation, chemical engineering

ABSTRACT

Academics usually have a good overview of their discipline which allows them to rapidly integrate new knowledge into a general context. Students often lack this overview and need to develop an own picture of their discipline and the connections between different subjects and courses.
For an analysis of the bachelor program in chemical engineering at the Hamburg University of Technology (TUHH), lecturers wanted to know how their students perceive the cross-links between different lectures.
Therefore, a method was developed to analyse students' perceptions of the links between lectures, called curricular network analysis. Attending a lecture, students take structured notes on topics, formulas or facts if they either recognise them as parts of other lectures or if the lecturer points out the connections. All notes are added to a database which is subsequently analysed with regard to the connecting topics and the frequency of their occurrence. Graphical illustrations of the results give a vivid impression of connections between single lectures and of the network of contents that characterise the whole study program.
The visualisation can rapidly spark a discussion between lecturers because it allows them to compare their own concepts with the perceptions of the students. Since it facilitates identifying redundant repetitions and missing references between courses, it enables a learner-orientated restructuring of the study program.
This paper describes the method in detail, presents results of an investigation with a group of students and shows how the obtained data were used for restructuring the bachelor program in (bio-)chemical engineering at TUHH.

1 INTRODUCTION

1.1 Curriculum Development

When developing curricula, different points must be taken care of, for example the following criteria:

- successive building of a network of knowledge,
- increasing difficulty of scientific methods, e.g. used in the laboratories,
- increasing level of independency of students work, and
- variability of exams.

Usually lecturers create a curriculum that fits as many criteria as possible in order to develop a concept that allows students to learn in the best way possible and finally meet the goals of the study program, usually a university degree [1, 2].

Concerning the first factor mentioned above, the building of a network of knowledge, a number of graphical methods exist that depict the interdependency of the different topics within a study program, either on course level or on a level linking contents. They usually visualise the intended knowledge network but do not take into account students' perceptions. For example in [3], first-year students derive their study map based on the study handbook and given content-related interconnections, which is useful to get an overview of the overall program right at the start.

1.2 Students' Perceptions

Lecturers of our technical university wanted to know whether their effort in the curriculum development was successful and whether they met their intended objectives of creating a course that builds a successive knowledge network. The questions asked were: How well do students perceive the cross-linking between the study topics? Do they recognise the links we intended them to see? To answer these questions, a method was developed to analyse the students' perceptions of the interconnection of content details within a study program.

2 METHODOLOGY

2.1 Approach

Right from the beginning, our aim was the primarily *automatic* generation of a graph or concept map which would show the interdependent structure of the collected data. To achieve this, we needed a data structure allowing for automatic processing. Having sorted this out, we successively developed the data collection and analysis methodology.

2.2 Data collection

Students from different semesters of a study program take notes during their lectures as soon as they detect a fact which they remember from a previous course. In each course they attend, they note the name of the course, the course format (i.e., lecture, exercise, laboratory work) and the fact itself they recognise (i.e., a formula, a natural law, a physical property, a method etc.). They also write down whether they themselves recognised this fact or whether the lecturer made a corresponding remark, and they additionally mark this entry if there was a repetition of a whole topic rather than a brief mentioning of fact. For follow-ups, they also note their names and the semester week. The data is then verified and collected in a data table.

2.3 Data Processing

Since students are free to use their own words while making notes, they might use different terms for the same topic. Those similarities are best recognisable by an expert in the courses and have to be matched by hand. Thus, to process the collected data, the first step is to match the facts that are named differently by different students, but refer to the same concepts.

Following this, true duplications are automatically eliminated. Only one incident per fact and lecture remains. The aim is to avoid a duplication of entries due to a larger number of students attending the same lecture.

We also noticed that it is useful to group different courses when students did not exactly remember in which previous lecture they learned about the facts. For example, courses in mathematics from the first three semesters (“Mathematics I”, “Mathematics II” and “Mathematics III”) were grouped to “Mathematics”.

2.4 Data Analysis

Different questions can now be answered by an automated analysis: How many references and which references were found between two courses? Did the students recognize them by themselves or did the lecturer mention them? With regard to this, what is the lecturers share? Or with regard to a single course: To which other courses and to how many other courses do references exist? Which course repeats most topics? How many references between courses exist overall in the whole study program?

2.5 Graphical Visualisation

The obtained data from the database can be plotted in different graphs for ease of recognition of the results.

In *Fig. 1*, an exemplary overall graph for an entire study program is given. Courses are shown in ovals, the identified connection between courses are shown by lines. The width of the lines corresponds to the number of connections between two courses. Hence, wide lines mean that a large number of references between courses were found and slim lines indicate a smaller number of references. The percentage of links identified by students is depicted in black, the percentage of links mentioned by lecturers is depicted in orange.

In *Fig. 2*, an exemplary graph for a single course - shown in red - is given. Courses are shown in ovals. The recognized references are listed in boxes attached to the connections between the courses. Boxes with grey background show comprehensive repetitions whereas orange borders mark the connections mentioned by lecturers.

Fig. 1: Graphical visualisation of the course interconnections within a study program. Courses are represented by blue ellipsoids. Wide lines correspond to large numbers of references between courses, slim lines to small numbers. The coloration of the lines indicates the percentage of links found by students (black) or mentioned by lecturers (orange), respectively.

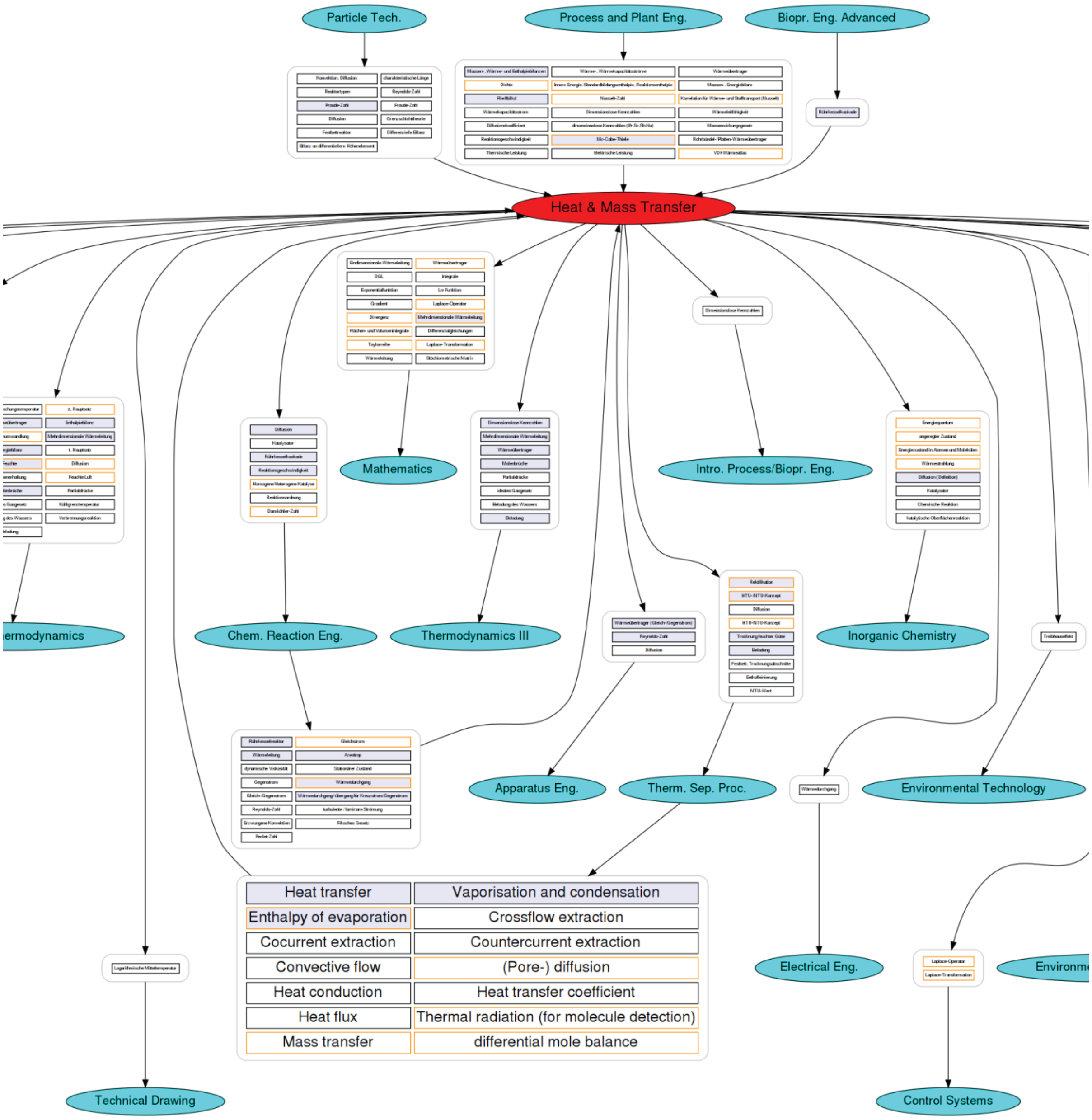

Fig. 2: Section of the graphical visualisation of the connections and referential topics between a single course (in red) and other courses in the study program. Grey boxes mark topics that were thoroughly repeated in the lecture and orange borders mark references to other courses mentioned by the lecturer. For better understanding, one detail showing links between two courses is enlarged.

2.6 Data Formats and Software Tools

The collected data were saved to an *Excel* file. The data sets were subsequently analysed by a *Python* script which produced data for network analysis and network visualisation. For the latter the open source graph visualisation software *GraphViz* [4] was used, therefore the *Python* script created a file in DOT format.

3 APPLICATION

3.1 Investigated courses

The curricular network analysis was applied to two bachelor programs that have a number of courses in common - the bachelor of chemical engineering and the bachelor of biochemical engineering.

3.2 Participating students

The data collection took place during the two semesters of the study year 2017/18. In the winter semester, courses of the third and fifth semester of both bachelor programs were investigated and in the summer semester, courses of the fourth and sixth semester. Connections between the basic courses within the first semester and from the second semester to courses of the first and second semester were of no higher interest and therefore omitted. It was made sure that at least two students were attending each course. Overall, about 10 students participated in the data collection.

3.3 Setup and practical aspects

Within the first weeks students tested two different methods to take notes. For one method students were asked to tick references in a prepared sheet listing all references possible and to write down additionally found references into the list. For the other method students rather took free graphical notes in the format similar to a concept map [5]. After three weeks of trial, we discussed the methods and finally omitted the prepared lists. Students took free notes either in an empty sheet or in a personal concept map. Each week, students handed in their notes which were then verified and transferred to a data table. *Fig. 3* shows an exemplary section of the resulting table.

My course			Link found to			Semester Week
Course	Topic	For-mat*	Course	Mentioned by Lecturer	Repetition	
Str	Reynolds number	Lec	PC		x	2
Str	Basic equation of hydrostatics	Exe	Ph			4
T3	Enthalpy	Lec	T1	x		2
T3	Taylor expansion	Exe	M1			5
GBVT	Viscosity	Lec	Str			9
GBVT	Stirrers	Lec	Str	x		9
Inf	Energy flow	Lec	T1			1
PAT	Thermal capacity flow		TGO			3
PAT	Boiling point, melting point		KA	x		4
PF	Continuous, disperse phase	Lec	TGO			1
PF	Gibbs free energy	Lec	CRT			1
TGO	Rotameter	Lab	MT			2
CRT	Laminar, turbulent flow	Lab	Str			7

Fig. 3: Data table with notes of courses (abbreviations are used) and referential topics between courses. (Lec: lectures, Exe: exercises, Lab: laboratory work)*

4 RESULTS AND DISCUSSION

4.1 Collected Data

Overall, 1616 references between 30 courses were identified which were plotted in full graphs for the overall study program and in individual graphs for each course (see *Fig. 1* and *Fig. 2*). The highest number of reference topics between two courses was 373. Courses with a high affinity of topics and courses with rather low affinity can easily be identified from the graphs. It can easily be seen where a lecturer refers quite often to another course or, where a lecturer decided to often repeat contents of other courses.

4.2 Discussion of the qualitative and quantitative analysis

Qualitative analysis involves *finding* the references between courses. Even though the students participating in the study showed a high commitment, we were aware that the findings might not be complete. Due to the rather small sample size (about two students in each course) and the free choice of references, there will undoubtedly be references that were not found. However, as inspection of the data by the experts showed, the main topics were covered.

Quantitative analysis involves *counting the number of* references between courses. Equally due to the individual choice of topics by the students, the references range from physical properties to natural laws and therefore are not easily comparable. When discussing the results of the analysis this must be taken into account. It is therefore not feasible to use the data to compare the number of references between courses or establish a “ranking”. However, the numbers can be used as indicators and initiate a closer look at the lists of references.

4.3 Interpretation of results

The results visible in the graphs spark a number of questions and can be discussed in different ways.

Strong connections between courses with a large number of references (shown as wide lines in *Fig. 1*) indicate large overlaps, but are there (too) many redundancies and could they possibly be removed in favour of other topics?

Frequent occurrences of repetitions can lead to the question whether all of them are required, e.g. for a consolidation of difficult learning matters or to reintroduce a topic after a longer break. It could also open space for thinking about new themes.

Weak connections between courses with a low number of references (shown as slim lines in Fig. 1) can indicate that this course is a special course with unique features. Here it could possibly be helpful to think about introducing examples to strengthen the interconnection with other courses.

Based on the analysis, the content connections between two courses can be discussed: Are the results consistent with the expectations of lecturers? Do students detect all relevant references, or are references missing? Those discussions can lead to further development of courses or setting of priorities within the curriculum.

Are courses given by lecturers of other faculties well embedded within the program? Are there possible ways to enhance their integration?

As can be seen, the curricular network analysis is not necessarily a tool that yields defined numbers and results, but - largely due to the visualisation - can be used as a trigger for discussion about a study program.

4.4 Use of the results for further development of the curriculum

At our university, the results of the analysis were presented at a large meeting of all faculty lecturers. Posters with network graphs were on display and were vividly discussed. A subsequent meeting between several lecturers and students was initiated to overcome some of the challenges of the curriculum. As a result, a number of courses were shifted between semesters, and contents of courses were adapted.

For the participating students, the study also had a strong effect. During the study they continuously recommended improvements of the method. And to see the final results of their work made them feel proud about their contributions and led to understanding and discussions about the cross-links within their study program.

5 CONCLUSIONS

The results of the curricular network analysis are a very helpful source for a reflection about a study program. The graphical visualisations yield intriguing pictures engineers cannot withstand to discuss. The method also involves students directly and fosters their participation in the process of curriculum development.

Since the resulting data need interpretation, the method should at best be embedded into a larger project of developing a study program.

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Application of Data Analytics on Improvements in Standardized Visualization Test Scores

J. Rodriguez
Western Michigan University - EDMMS
Kalamazoo, MI - USA

D. Bairaktarova[1]
Virginia Polytechnic Institute and State University - DEE
Blacksburg, VA - USA

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ABSTRACT

Visualization skills have been identified as critical competence for success in STEM disciplines, particularly in engineering and technology fields. Several academic institutions in the United States implemented a policy to have first-year engineering students tested on such competence, and several initiatives to improve visualization skills have been implemented. A standardized visualization test (i.e., PSVT:R), which is widely accepted as indicator of visualization skills, is used as one of the indicators to evaluate students and it is the one used in this study. In this work we applied data analytics techniques to a dataset (N=185) to compare pre- and post-test scores, with the aim to identify factors in the PSVT:R test that are most influential in predicting score improvement. The PSVT:R standard test is a set of 30 questions that can be grouped in several subsets based on the number of manipulations that need to be performed in order to get to the correct answer for each question. In this study, a group of first-year engineering students were tested and three different pedagogical interventions were utilized. Results from this study, obtained by the application of data analytics techniques, confirmed previous conclusions for single-instance test scores and identified influential factors in a predictive model. Further, results show a level of similarity, but not fully consistent results, thus demonstrating the usefulness of data analytics in this type of analyses. The identification of influential factors (i.e., specific questions) in a predictive model for score improvement can aid in the definition of content needed in pedagogical interventions.

[1] Corresponding Author
D. Bairaktarova – dibairak@vt.edu

1 INTRODUCTION

1.1 Spatial skills and STEM education

Spatial reasoning is important for success in many STEM fields. Spatial reasoning is defined as human ability to encode and maintain spatial information in working memory while transforming it (Carroll, 1993). There is a vast amount of research providing evidence for individual difference in spatial reasoning as well as evidence that spatial thinking skills can be improved through training and experience (Uttal & Cohen, 2012). Training is particularly important for incoming engineering students to develop strong spatial visualization skills early in an academic program, as many incoming engineering students need remediation in spatial visualization.

Higher education initiatives in the United States have been implemented to develop and enhance spatial visualization skills of engineering students. For example, one of the first programs, The EnVISION (Enhancing Visualization Skills-Improving Options aNd Success) project was introduced in 2007 to test and enhance the spatial visualization skills of incoming engineering and technology students. The EnVISION approach has been used by a variety of U.S. universities, including Michigan Technological University, Penn State, The Behrend College, Purdue University, University of Iowa, Virginia State University, and Virginia Tech. The EnVISION course is targeted to students who have been identified as needing remedial instruction. By helping students with low spatial visualization skills to success, particularly women as research shows that they are outperformed by their male peers on spatial related tasks (Voyer, 1995), the EnVISION project leaders hoped to improve the retention of these students in STEM disciplines and to enhance their success (Veurink et al., 2009). Comparing the pre-initiative and the post-initiative performance of students enrolled in remedial programs, measured by their scores in a standardized visualization test, serves as an indication of the effectiveness of the implemented initiative.

1.2 Measuring spatial skills

In the United States engineering educators typically use spatial visualization tests to screen first-year engineering (FYE) for spatial ability. There is no definitive spatial visualization test, therefore variety of assessments, including the Purdue Spatial Visualization Test with Rotations (PSVT:R; Guay, 1976), the Mental Cutting Test, the Revised Minnesota Paper Form Board Test, and the Differential Aptitude Test are used to screen FYE students for spatial ability (Maeda, Yoon, Kim-Kang, & Imbrie, 2013). While useful in identifying students, who would benefit from remedial spatial instruction, these tests are limited in their value to support remedial spatial instruction (Cohen & Bairaktarova, 2018). There are several reasons for these limitations.

Many standardized tests that are currently used to screen for spatial ability were developed out of the factor analytic procedure, with the goal of measuring skills that are likely to predict performance in skilled trades and crafts. Consequently, these traditional psychometric spatial ability tests use domain-general stimuli that bear little resemblance to authentic engineering tasks. In addition, these tests lack subscales to identify difficulties faced by students who are challenged by spatial visualization tasks (Cohen & Bairaktarova, 2018).

2 RATIONALE FOR THE WORK

2.1 Application of spatial skills tests

Numerous studies have investigated the relationship between students' demographics, spatial visualization skills, and academic performance. Spatial skills have been linked to abilities to do engineering and technology work, and subsequent studies have provided a relationship between those skills by students and their performance in engineering courses, particularly for engineering graphics and design courses. Additionally, there are reports that indicate the importance of improving spatial visualization skills when looking at students' performance in technology and engineering courses (Kozhevnikov and Thornton, 2006). Other reports indicate the value of improving such skills as the complexity of the problem increases (Titus and Horsman, 2009), which is one of the reason to take a closer look at pre- and post-scores in a standardized test such as Purdue Spatial Visualization Test with Rotations (PSVT:R). The PSVT:R consists of 30 questions with increasing degree of difficulty in terms of number and sequence of spatial rotations that need to be applied to a 3D object in order to end with a desired configuration.

2.2 Predictive analytics

In this study we utilize data analytics, more specifically predictive analytics, which is not commonly used in spatial reasoning research. This type of modelling helps in the identification of factors, i.e., question number or demographic, that have significant impact in the prediction of test score improvement. Predictive analytics is a topic in Data Analytics (DA), which is a generic term used to refer to a set of quantitative and qualitative approaches that are applied to provide the basis for decision making (Rodriguez and Bairaktarova, 2019). Objectives typically pursued when performing modelling with DA techniques are identification of options/factors to increase productivity, boost business profit, or accomplish a given behaviour or performance. Predictive analytics is extensively used in business environments, particularly consumer sciences and where service/ product customization is pursued. It is as well an approach that has gained acceptance in its application to engineering and technology practices, and there have been applications in academic settings, but its application on pedagogical approaches is something novel with high potential.

The software package used in this study is RapidMiner, a commercially available DA software that offers different approaches for the analysis and visualization of datasets, thus allowing comparison of the results, and some level of model optimization. Data analytics techniques help in the identification of dominant factors in a dataset that result in the prediction of a specific performance or behaviour. In this study it means identification of dominant questions in the standardized spatial visualization test and/or demographic parameters, that have a direct positive impact in test score improvement by students. The technique being utilized in this study is Decision-Tree, which has been identified as a good general-purpose algorithm, with acceptable reliability in predictions models. This approach allows for graphical output that is very helpful in envisioning the predictive model that is developed. A decisiontree is a collection of nodes in a root-branch sequence that defines selection paths based on specific class or numerical value of selected parameter (e.g., test score). Each node represents a splitting rule for one specific attribute (e.g., answer to a test question). This analytic tool has as well the option to reduce predictive errors by searching for an optimal decision-tree development, according to a specified criterion (RapidMiner, 2017).

The objective in this study is to search for dominant factors that predict positive test score improvement when comparing pre-intervention to post-intervention evaluation of students' spatial visualization skills. Findings from this study can help in the development of pedagogical approaches with the aim of improving spatial skills. Of interest as well is that results from the predictive models obtained for each subset of data (i.e., pre- and post) will be compared to the results of the predictive model for global score improvement, with the expectation that possible relationships can be established, thus having a more robust pedagogical intervention.

3 METHODOLOGICAL APPROACH

3.1 Study settings

Data was collected from first-year engineering students in a large public Southeastern university in the United States. A popular spatial visualization test – Purdue Spatial Visualization Test with Rotations (PSVT:R) was administered to the students at the start (pre-) and at the end (post-) of the semester. All participants were enrolled in a one-credit Spatial Visualization course that provides preparation on fundamental spatial skills for an engineering curriculum.

Students are divided in all three sections of the first-year engineering course participated in this study. The course was designed for students with low spatial skills as measured by PSVT: R. Students enrolled in the Spatial Visualization course scored 18 or below (out of 30) on the Purdue Rotation Visualization Test: Revised (PSVT: R) administered to them during summer before their freshman year.

All participants received the same instruction through sixteen weeks-length of the semester, but they were split into three groups, each one having a different set of tools to work on assigned homework. The assigned homework (spatially-related problems) was similar for all three groups, with Group 1 having access to an augmented reality app, Group 2 using a spatial visualization app, and Group 3 utilizing free-hand sketching. The first two groups were required to use the apps for approximately the same time, including time in class and outside of class. Students in the third group were required to do hand sketching activities in class and outside of class, also with roughly the same completion time as for the sections with the apps. Students grades were not affected by using the three different approaches as grading was based on completion only.

All three groups received the same instruction in class through the whole semester. Students in all three groups moved through the course in three modules: 1) sketching, 2) CAD, and 3) 3D object design and creation. During the sketching module, students were introduced to orthographic projection theory, sectional views, and learned how to interpret engineering drawings. During the second module, students learned how to navigate the new user interface and features of the CAD software used in the course (Inventor) and practiced designing simple solids for four weeks. In the final module, all students were introduced in class to additive manufacturing, a stepby-step guide on developing stereolithography (stl) files in order to 3D print each basic solid they designed.

The difference between the three sections was in the methodology that students practiced the above described instruction, and particularly in the rotations of simple solids. During weeks 6 to 16 of the semester, the participants in Group 1 and Group 2 used augmented reality and Spatial Vis apps respectively as part of their class interactive spatial visualization training; Group 3 used sketching techniques. Training time with the apps targeted 40-minutes, starting with 10 minutes in class, followed by 30 minutes required homework time outside of class. Students were graded on completion of and time spent on the tasks.

3.2 Analysis

The complete dataset only consists of valid cases, meaning students that have taken the pre- and the post- tests and received a score. A total of 185 pairs of scores were used in this study, with 89 female and 96 male students participating. The improvement measurement was basically the difference between the students' post- and pre- test (PSVT:R) scores.

Two sets of predictive models were developed, the first set only uses as input improvement in visualization test results, and the second set additionally includes demographic data. The demographic information used in this study is gender, age, and ethnicity. Table 1 provides some basic descriptive statistics for the participants in the dataset.

Table 1. Descriptive statistics for dataset.

	Group 1	**Group 2**	**Group 3**
Number of students	59	66	60
Split Female/Male	27/32	30/36	32/28
Percentage Female	45.76	45.45	53.33
Split Caucasian/Non-C	29/30	35/31	33/27
Percentage Non-Caucasian	50.85	46.97	45.00
Range Age	17 - 19	17 - 19	17 - 23
Age Average & SD	17.86 ± 0.43	18.03 ± 0.34	17.98 ± 0.77

3.3 Improvement measurements

For the evaluation of improvement in performance, we look at the difference between pre- score and post- score for each participant. We utilized three different ways of identifying the difference, as follows:

a) raw score improvement
b) percentage improvement
c) tier indicator of becoming top-scorer.

The first option is the most direct measurement, the post- score minus the prescore, resulting in a valid indicator, however it might misrepresent the actual improvement. For example, a student with low score in the pre-test has more room to get a high increase, which does not imply automatically that it is at the level of topscore. The second option is a popular technique that tries to minimize the effect of raw numbers, percentage improvement, however it might have some bias for the lowscorers since they might show large percentage of improvement but not indicating that the new score is a top-score.

The third option was defined with basis on the ultimate objective of having improved visualization skills in order to have higher possibilities of doing well in a technical field such as engineering. Therefore, it tries to capture if the post- score is good enough to become a top-score. This indicator is the difference between the 'tier' were the Post-score is, compared to the 'tier' were the Pre-score was. Four tiers were defined in this calculation: Tier 1 – score higher than one Standard Deviation (SD) above average grade for the group; Tier 2 – score between average group score and one SD above; Tier 3 – score between average group score and one SD below; and Tier 4 – score more than one SD below the average group score. Top scores are in Tier 1.

The summary of the improvement indicators for each one of the Groups is given in Table 2. This table gives a better overall picture of the numbers being used under these measurements. These numbers illustrate the existence of students that improved, student that did not improve, and students that showed no variation in their test performance.

Table 2. Descriptive statistics for measurements of score improvement

	Group 1	Group 2	Group 3
Score Improvement			
Negative	-6	-6	-12
Positive	9	11	10
Average	1.389	2.318	1.830
S.D.	3.600	3.758	3.878
Percentage Improvement			
Negative	-38.46	-42.85	-70.58
Positive	87.5	100	125
Average	12.305	19.375	16.023
S.D.	27.266	30.587	31.448
Tier Improvement			
Negative	-2	-2	-2
Positive	2	2	2
Average	0.084	-0.196	0.067
S.D.	0.794	0.808	0.806

4 FINDINGS AND DISCUSSION

4.1 Predictive models

The aim is to identify factors in the PSVT:R test that are most influential in predicting score improvement. The predictive models for improved performance yielded multi-level decision trees, with all of them with at least three levels (Figure 1).

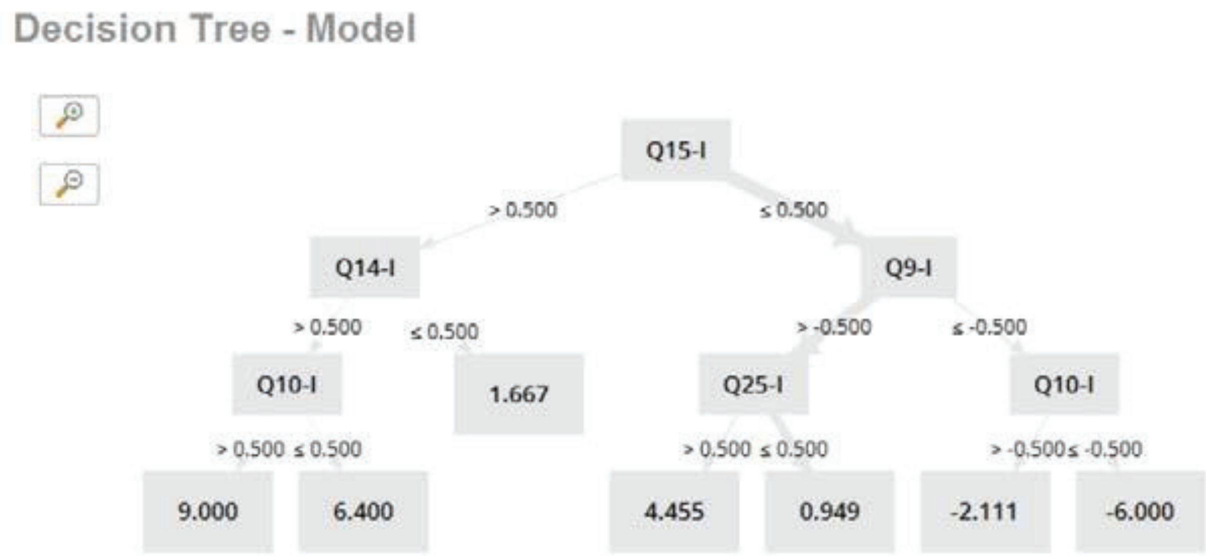

Figure 1. Decision tree for predictive model – Group 1, raw score.

4.2 Summary for groups

The results in terms of the identified most dominant factor that serves main predictor of performance are summarized in Table 3. It can be observed that in all three groups the models have a primary predictive factor that is in the middle of the test (Q13 to Q16), which implies a degree of difficulty in the question that is not the easiest one or the hardest one. Even at the second level, most of the predictive factors are as well in the middle of the test, with the few different cases having as factors a harder question and an easier question (e.g. Q28/Q9 in Group 3). This situation is related to the specific branch were these factors are utilized, remembering that one branch is for positive outcome of the improvement indicator, and the other branch is for a negative outcome.

Table 3. Main predictors of performance – question number.

Only Q's	Group 1	Group 2	Group 3
Score Improvement			
Level 1	Q15	Q16	Q13
Level 2	Q14/Q9	Q21/Q4	Q4/Q14
Percentage Improvement			
Level 1	Q15	Q16	Q13
Level 2	Q11/Q9	Q21/Q4	Q16/Q19
Tier Improvement			
Level 1	Q14	Q16	Q21
Level 2	Q28/Q9	Q10/Q13	Q13/Q14

Regarding the degree of difficulty in the test, the middle questions are related to questions where two rotations are required to get to the correct answer. All primary factors identified are in this region. There are some cases for secondary factors (Level 2), indicated with colored background in the table, where the dominant factor belongs to different degree of difficulty, with the blue background indicating one more degree of difficulty, and the brown background with more significant change in the degree of difficulty.

5 SUMMARY AND ACKNOWLEDGMENTS

Improvement of spatial visualization skills were analysed in this study. A group of first-year engineering students were tested and three different pedagogical interventions were utilized. Based on the analyses performed, there is no significant difference among the three groups regarding performance. Furthermore, predictive models are consistent on defining dominant factors of average degree of difficulty, with identification of the same factors for the raw and percentage improvement indicators. Lastly, our findings suggest that demographics variables are not primary influential factors for performance, and therefore for prediction; these factors do have a secondary (minor) role.

Applying data analytics techniques in our study, confirmed previous results for single-instance test scores and identified influential factors in a predictive model. The results show a level of similarity, but not full agreement or consistency, which is expected. This study demonstrates the usefulness of data analytics in this type of analyses. The identification of influential factors (i.e., specific test questions) in a

predictive model for score improvement can aid in defining the content needed in pedagogical interventions and provide a new perspective in the field of engineering education, and specifically in the development and enhancement of spatial skills of engineering students.

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Project in Mechanical Engineering, an Experience in the Involvement of students in the Development of Biomechanical Devices in Partnership with Paralympic Athletes

Roseiro, Luis [1]
Coimbra Polytechnic – ISEC,
Coimbra, Portugal

Ferreira, Pedro
Coimbra Polytechnic - ISEC
Coimbra, Portugal

Amaro, Paulo
Coimbra Polytechnic - ISEC
Coimbra, Portugal

Conference Key Areas: Diversity in Engineering Education

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ABSTRACT

In cycling sport, motor-disabled athletes can only develop their practice if they have compensation devices allowing them to a practice with comfort, safety and performance. However, this type of devices does not exist in a standardized way, and should be developed on a tailor basis. The challenge of collaborating in the development of these biomechanical devices can be placed in engineering schools, involving students in their development, learning a set of important competencies. This work presents a collaborative experience among several students from mechanical engineering, the most important field in this context, and two adapted cycling athletes, from the Portuguese National Team. Students participation was inserted in the curricular unit of Project, part of the degree in mechanical engineering, and real biomechanical prototypes have been developed and implemented. The biomechanics devices radically changed the practice of cycling by the athletes, highlighting the importance of the school in the context of its social involvement. A survey has been defined for the students involved, showing that this kind of collaborative work, with a need to go out of school and develop a solution to be implemented in this type of real situation, allowed them to acquire a set of important skills in the context of their engineering apprenticeship.

[1] Luis Roseiro
L. Roseiro
lroseiro@isec.pt

1 INTRODUCTION

The history of civilization can be associated with the history of engineering. The civilizations considered as more advanced are in general by their achievements in this domain of knowledge and development. And it was so over the time, being simply to see the testament left in the cities and pyramids of the Mayas, Incas and Aztecs, the acropolis of Athens, the great wall of China, among many other examples. The man began to be an engineer when he dared to stop being quadrupedal. At this stage of development, he extended the brain to two of its members, hence superior and fundamental in the art of developing and doing.

Several definitions of what is engineering can be found in literature, normally associated with the problem-solving challenge. S. E. Lindsay (1920) defined engineering as “the practice of safe and economic application of the scientific laws governing the forces and materials of nature by means of organization, design and construction, for the general benefit of mankind”. James Kip Finch (1960) defines the engineer as a maker of history.

1.1 A Mechanical Engineer

In many situations, the mechanical engineer is perhaps wrongly associated only with automobiles and auto shops. The automotive industry is just one example of the mechanical engineer's domain. Traditionally, the metallurgical sector has been the great employer of this profile of engineers; however, its activity may cover various sectors of activity, which include the textile industry, agricultural equipment, chemical and petroleum industry, aeronautics, molds and glass, the design of industrial buildings and facilities, electronics and computers, banking and insurance, among many others.

Mechanical engineering can be framed at the level of the development / processing of a product, it can be said that its activity takes place in stages of an essentially technical nature, but where the competences linked to the management and administration also play an important role and where the ability to exchange ideas and results is vital. Typically, engineers communicate both upstream and downstream, writing proposals and technical reports, making presentations and interacting with elements of their team or external teams. In this particular, language at the technical level, where sketches, drawings, graphs and data tables prevail, is reason enough for the mechanical engineer to develop skills in the capacity of teamwork, writing and communication, but clearly and concise.

Methodology and organization are important characteristics for a mechanical engineer who, must possess logical reasoning skills, consistently understand of physical phenomena, perform mathematical operations correctly, know how to idealize and analyze problems but, more and more, manage and present simple, practical and effective solutions. The mechanical engineer performs part of his work integrating teams typically composed of engineers from various fields, depending on the type of product under analysis or development. However, their dialogue is not just at the level of colleagues from other specialties.

1.2 A Mechanical Engineer in Biomechanics

Recently, the participation of the mechanical engineers in the health area has been emerging. It’s true that they already participated in some activities, like the management and maintenance of hospital equipment, but the evolution of the dialogue between mechanical engineers and health professionals has been growing in the last decades, highlighting the concept of biomechanics, which derives morphologically from the grouping of "bio" (biological, living beings) with mechanics, and can be defined as the application of the principles of mechanics to living beings. Biomechanics was defined by Hay (1978) as "The science that studies the internal and external forces in the human body and the effects produced by these forces". Biomechanics can be connected to occupational activities, sports, musculoskeletal systems, orthopedic, rehabilitation, cardiovascular, biomaterials, among many others, all with a strong connection to mechanical engineering.

It is clear that the role of a mechanical engineer in this field of applications is extremely important. Here are two statements retained by the author in meetings with medical people, illustrating the significance of knowledge in mechanical engineering for other professionals, particularly in the field of health:

"*I believe that if I had a mechanical engineer in the surgery room with me, in certain situations I would be more successful*," an orthopedic doctor;

"*It would be great to have a mechanical engineer with me who could help develop specific support products for some of my patients*" a physician in physical medicine and rehabilitation.

One of the strongest participations of mechanical engineers is in the rehabilitation context, defined by World Health Organization (WHO) as "the use of all means necessary to reduce the impact of disabling situations and enable disabled individuals to achieve complete social integration." This definition, taken from the White Paper on Physical Medicine and Rehabilitation in Europe, focuses as an important and emerging goal the concept of social participation, highlighting the needs of individuals with disabilities, in order to eliminate social barriers to participation, both socially and vocationally. The term "Technical Aids", also defined as “Support Products”, can be designated as the set of means indispensable for the autonomy and integration of persons with disabilities or motor handicaps, aiming to attenuate or compensate for this disability or limitation and to allow their daily activities and participation in school, professional and social life.

1.3 Teaching Mechanical Engineering

Mechanical engineering has been more focused on engineering science curriculum, that does not include some important practical elements. The courses mainly with strong analytical approach can led students to a gap in design development. Even both, analytical and design thinking are important, they strongly differ [1, 2], and design are more connected to the main activities of a mechanical engineer [3], particularly to create solutions in a creative and innovative way.

Given that the mechanical engineer is perhaps the most diverse of the engineering domain, it will be important to prepare the student for the development of design works with interconnection with other fields, with challenges that motivate him to develop the work, acquiring a set of concept knowledge, skills and attitude toward engineering. Since a mechanical engineer can play a major role in the medical field, and particularly in biomechanics, mechanical engineer students can also develop applied learning work in this field, allowing them to have the opportunity to contact with this reality, develop and improve teamworking skills and broaden other horizons.

This work presents a collaborative experience among several students from mechanical engineering and two adapted cycling athletes, one handless and other trans tibial amputee, from the Portuguese National Team, supervised by the teachers of project and in collaboration with some companies. The participation of the engineering students was inserted in the curricular unit of Project, part of the degree in mechanical engineering, and real biomechanical prototypes have been developed in order to provide safety, comfort and performance to the adapted athlete, allowing them to practice cycling. The projects have gradually been optimized, thus involving a sequence of project developments and several different students. The collaborative work with these athletes has been developed over several years, and some of the students are already included in the job market. In order to evaluate the importance of students' involvement in this type of project and the challenge of development, with a strong innovation and risk component, a survey was defined for the students, whose results are presented.

2 MATERIALS AND METHODS

The project curriculum is an integral part of the 3rd year mechanical engineering course. It has a weight of 7 European Credit Transfer and Accumulation System (ECTS) and aims to develop students' ability to apply the knowledge acquired throughout the course. The unit also stimulates the capacity for analysis and critical/design thinking of students as well as their skills in organization, communication and teamwork. Wherever possible, the project work may be directed towards the development of functional prototypes and also carried out in collaboration with companies or other entities outside the school, looking for its implementation in a real context.

The case presented involves the participation of two athletes from the Portuguese National team of adapted cycling, the collaboration of some industrial entities, as well as the participation of the Portuguese cycling federation. The work begins with the development of a first prototype for a trans tibial amputee athlete. For this athlete, several optimizations of the devices have been developed by the students. Recently, also a handless athlete was involved in this collaboration, having been developed a prototype for his practice of adapted cycling.

The development of this type of project work required the use of several mechanical engineering tools, where the components of 3D modelling, computer-assisted design and manufacturing could be highlighted. Also, the skills at the level of mechanical engineering concepts, especially the strength of materials and reverse engineering can be highlighted. Considering the limitations imposed by the physical conditions of the athletes, creativity were decisive tools for the development of applied solutions. Thus, the specifications of the work theme, methodology to follow and main objectives to be achieved are clearly defined in the initial presentation for students. The students were selected according to their motivation for the proposed work and abilities demonstrated within the curricular units considered relevant to the development of the project type.

Several students were involved in the presented project work. Normally in groups of two (individually in some particular cases), the students work collaboratively with the athlete and sometimes with the cycling team coaches, with the supervision and accompaniment of the project teachers. Some components of the development of functional prototypes were executed in partnership with two companies, in particular in the implementation of solutions in composite materials, allowing the contact with entities outside the school.

The pedagogical methodology used forced the students to a set of important activities in the context of learning in the application of the concepts associated with the project, with particular emphasis within:

- Predefined team meetings with the involved persons (teachers, athlete, coach, companies);
- Meeting reports prepared by the students;
- Identification of weaknesses and strengths in the evolution of the solution being developed;
- For each problem or difficulty, at least one solution must be presented by the students to overcome it.
- Present and discussion of the final solution with a project report.

2.1 Tibial Amputee Athlete and Prototypes

The National Team athlete (TP), suffered an accident that forced him to have a trans tibial amputation in his left leg. Lover of the sport, and with an unshakeable force and determination, after the adaptation to his prosthesis of walking, TP began to practice karate. However, it was the bike to set its Paralympic path.

The support given over the years to the athlete by the Coimbra Polytechnic – ISEC (School of Engineeering) has led to the development of two main compensation devices in order to allow him to practice competitive cycling in safety and with the best level of performance possible, namely: a) Compensation Device - External Trans tibial Prosthesis; b) Compensation Device - Lateral Side Support.

The external trans tibial prosthesis, shown in figure 1, can be divided into three main sectors: longitudinal stem with coupling to the cup, "coupling foot" to the clip and consequently to the pedal and stem-foot connection. The longitudinal rod is composed of a carbon/kevlar tube with two aluminum machined terminals. One of these terminals allows attachment of the prosthesis to an össur® system, coupled to the amputated area (stump) and the other terminal connects the stem of the coupling foot system to the strap, which is designed to have a useful virtual length equal to the athlete's foot. The stem-to-foot attachment system is composed by a set that integrates three synoblock positioned so as to allow adequate dynamic stiffness. This solution, with simple and innovative features allows an angular compensation in the athlete's pedalling, guaranteeing the protection of the knee joint. In addition, the accumulation of energy during the pedalling improves the performance of the athlete. Figure 1 shows the 3d model of the biomechanical system (a), the real prototype (b) and the tests implemented in real conditions. The development of the trans tibial prosthesis have been made in collaboration with a group of three students.

a) *b)* *c)*

Fig. 1. External Trans tibial Prosthesis: a) 3D model; b) Real model; c) Test in real conditions.

Unfortunately, due to medical reasons, particularly for knee protection of the amputated leg, the athlete was forced to stop practicing cycling with both legs, and consequently stopped using the compensating device described above (trans tibial prosthesis), forcing the development of a new device to pedal with only one leg.

The figure 2 shows the first biomechanical model developed to pedal with one leg, based on an adjustable, trough support for the athlete's thigh. For this development a group of students have been involved.

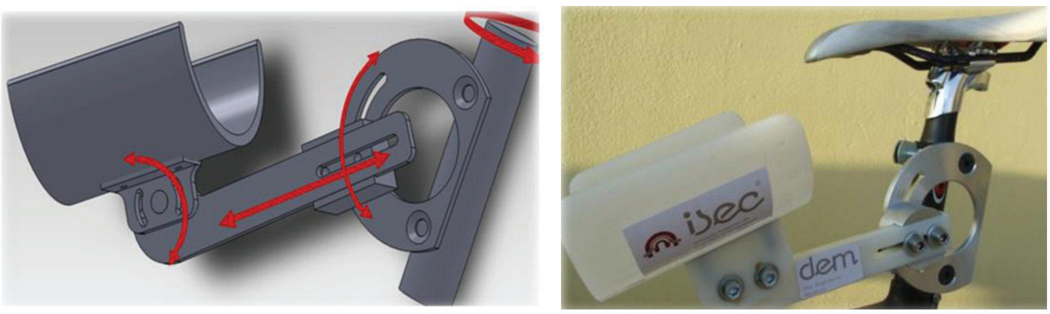

Fig. 2. First Prototype for pedalling with one leg.

Following the optimization of the previous device, there was a project optimization with the involvement of another group of students, which led to a final prototype, shown in figure 3. With this prototype, the athlete participated in the Paralympic Games *Rio2016*, getting a sixth place.

a) b)

Fig. 3. Final Prototype for pedalling with one leg: a) Real model; b) Participation in *RIO2016*.

2.2 Handless Athlete and Prototype

The National Team athlete (MF), was born with agenesis in the left hand, a congenital limitation translated by the absence of the hand. After the identification and characterization of the physical limitation of the athlete, the design of the device was centred on a fitting system, based on the concept of the docking pedal, composed of a set of structural elements, one of them adjustable, and which allows the athlete an adequate positioning in the bicycle, exert force in both directions, that is, push and pull the handlebar, increasing its performance and comfort, without compromising its safety, since in case of fall, the decoupling is guaranteed by the docking system.

The biomechanical device shown may be characterized by three parts, shown in figure 4, an arm-fitting prosthesis, an interface member and an adjustable handlebar attachment system.

a) b) c)

Fig. 4. Handless Prototype for pedalling: a) Arm-fitting prosthesis; b) Interface system; c) Handlebar attachment system.

Fig. 4. Tests with the final prototype.

3 SURVEY EVALUATION

In order to acquire and analyse the feedback from the students, based on their learning experience of the involvement on these project themes and methodology, a survey have been prepared and sent to the students. The questionnaire was developed based in the work of Yu *et al.* (2012) [4]. All the questionnaire was anonymous and provide four main groups of questions, in the form of statements. For each affirmation, the students must answer selecting from four scores (1 - 4):

1 - Strongly disagree; 2 – Disagree; 3 – Agree; 4 – Strongly Agree.

The group of affirmations, placed in the questionnaire as follow, have been answered by a total of five students. The survey, the mean scores and standard deviation, obtained for each statement, are described below.

<u>A. Toward Learning procedures:</u>

A.1 Participation in this project helps me to learning to learn - (mean score 3,8 ± 0,4);

A.2 Participation in this project helps me to learning to do – (mean score 3,8 ± 0,4);

A.3 Participation in this project gives me better Engagement and Reliability – (mean score 3,8 ± 0,4);

A.4 The project type, with a Paralympic Athlete improves my Self-confidence – (mean score 3,4 ± 0,9);

A.5 External connection with the Athlete was very important to my learning – (mean score 3,8 ± 0,4);

A.6 The project type, in a Taylor Basis, due to the athlete characteristics was a motivation factor for the work – (mean score 3,4 ± 0,5);

<u>B. Some Engineering Concept Knowledge have been improved with my participation in this project, namely:</u>

B.1 Physics and Math – (mean score 3,0 ± 0,7);

B.2 Materials and Process – (mean score 3,4 ± 0,9);

B.3 Modelling and Design – (mean score 3,6 ± 0,9);

B.4 Engineering in Society – (mean score 3,8 ± 0,4);

B.5 Professional and Ethical Responsibilities of engineers – (mean score 3,8 ± 0,4);

<u>C. Some Engineering Skills have been improved with my participation in this project, namely:</u>

C.1 Computer Aided Design – (mean score 3,0 ± 0,7);

C.2 Computer Aided Engineering – (mean score 3,2 ± 0,8);

C.3 Computer Aided Manufacturing – (mean score 3,0 ± 0,7);

C.4 Research Methodology – (mean score 3,6 ± 0,5);

C.5 Problem Definition - – (mean score 3,8 ± 0,4);

C.6 Teamwork in Engineering Projects – (mean score 3,6 ± 0,9);

C.7 Communication – (mean score 3,4 ± 0,9);

<u>D. After my participation in this project, my attitudes toward engineering also involves</u>:

D.1 Willing to improve mechanical engineering concept knowledge – (mean score 3,6 ± 0,5);

D.2 Willing to learn innovative concepts/ideas in mechanical engineering - – (mean score 3,6 ± 0,5);

D.3 Willing to learn concepts in other engineering domains – (mean score 3,4 ± 0,5);

D.4 My knowledge about the impact of engineering solutions on society – (mean score 3,6 ± 0,5);

D.5 My enthusiastic in knowledge/skills application in engineering practice – (mean score 4,0 ± 0,0);

4 DISCUSSION AND CONCLUSIONS

The students feedback showed that generally they have a strong satisfaction with the project developed. From the questionnaire it can be highlighted that all the students demonstrate their enthusiastic in knowledge and skills application in engineering practice, obtained from the project development.

Concerning the methodology used, the students strongly agree with the learning procedures associated with the type of project development.

The pedagogical methodology implemented with several predefined project team meeting, with the teachers accompanying the work, as well as with the athlete involved, his coach and the company that may collaborate with the work, played an important role in time management for the development of a solution, contributing to the students' understanding of the labour market, which is very demanding in this regard. As a methodology, the meetings always resulted in a minute of presentation and decisions taken, considered important in learning the record of the evolution of work and its path to the end. The meetings were also important in teamwork improvement.

As a methodology, students always presented the strengths and weaknesses identified in the solution under analysis (evolution of the prototype under development). An important aspect assumed in student teaching and supervision methodology was that for each problem or difficulty encountered in particular in the prototype development, the students should present at least one possible solution to overcome it, and if possible different paths to follow. After the conclusion of the work, and during their discussion, this aspect was verbally mentioned by the students as an excellent pedagogical methodology, which forced them not only to present identified difficulties, but also solutions to overcome them.

The engineering concept knowledge, and engineering skills have an agreement by all the students, with highlighting in understanding the role of engineering in society and the professional and ethical responsibilities, suggesting that the type of project developed contributed to this identification.

It can be stated that this kind of collaborative work, with the need to go out of school and develop a solution to be implemented in a real situation, allows the students to acquire a set of important skills in the context of their engineering apprenticeship.

Finally, the developed biomechanical devices radically changed the practice of cycling by both athletes. This aspect is also relevant, as it allowed the school to participate in the development of applied solutions that these athletes would probably not be able to achieve otherwise, highlighting the importance of engineering education institutions in the context of its social involvement.

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Developing tolerance for ambiguity and uncertainty by interdisciplinary intensive courses

Lotta Saarikoski [1]
HOD Principal Lecturer
VAMK University of Applied Sciences
Vaasa, Finland

Svetlana Rybushkina
Head of International Programmes and Grants
Tomsk Polytechnic University
Tomsk, Russia

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ABSTRACT

Engineers work in fast changing environments with rapid and constant technological advancements. The working environment is increasingly interconnected and global. Thus the engineers have to possess interdisciplinary and multicultural team working skills and the ability to cope with complex and uncertain situations [1]. Engineering education must train the students in skills which enable them to handle those uncertain situations. These soft skills are best being developed while using other instruction models than the standard classroom teaching.

In this empirical paper one instruction method, **international intensive course (IIC)**, will be described and results of two intensive courses developed and conducted in academic years 2018 and 2019 will be described and discussed. The topic of each IIC was chosen so that a multidisciplinary engineering student team was needed to solve the problem task presented in the course. Different types of student team composition models were being tested.

Students` feedback related to their learning and team work was collected and analyzed. The major challenges were caused by the communication issues and the biggest benefits of the courses were the improvement in cultural and team working skills. The internal coach model was causing better student satisfaction than the outside consulting model.

[1] Corresponding Author
Lotta Saarikoski
lotta.saarikoski@vamk.fi

1 INTRODUCTION

1.1 Need to develop tolerance for ambiguity in engineering education

Engineers work in fast changing environments with rapid and constant technological advancements. The working environment is increasingly interconnected and global. Thus the engineers have to possess interdisciplinary and multicultural team working skills and the ability to cope with complex and uncertain situations [1]. Engineering education must train the students in skills which enable them to handle those uncertain situations. These soft skills are best being developed while using other instruction models than the standard classroom teaching. In this paper one method, namely international intensive course, will be described.

1.2 Tolerance for ambiguity – what does it mean?

Tolerance of ambiguity (TOA) means the extent to which individuals are naturally comfortable with ambiguous situations. Tolerance of ambiguity has been defined as: ***"the tendency for an individual to perceive ambiguous situations as desirable"*** [2]. It can be said that a person with a high tolerance of ambiguity is comfortable with ambiguous situations and perceives them as desirable, interesting and challenging and he or she strives to resolve problems or situations that appear to be complex or novel.[3]

Cultivating curiosity is found to be a trait that people could focus on while trying to develop their TOA. These behaviours centre around interacting with others and include effectively communicating and listening to others; when problems arise, asking questions that encourage curiosity and if confronted with resistance from others, asking questions that lead to identifying possible solutions rather than dwelling on the past. Collaboration is also important and it includes behaviours such as encouraging participation from others, question posing, creating strong professional relationships and networks for diversity of thought, idea sharing and being open to connect the ideas of new different people. If we can develop engineering education toward methods that increase the students` curiosity, we are helping them to become more tolerant for ambiguity which in turn helps them in their future working careers.[3]

1.3 Tolerance for ambiguity – how to develop it?

In this paper we report our two pedagogical experiments in which we wanted to find out how to conduct an international intensive course (ICC) as an instruction method in such a way that it would develop students` soft skills related to TOA (communication, problem solving, curiosity, collaboration, idea sharing etc.) and cause good overall satisfaction among the course participants. The first research question was related to the team coaching model of the intensive course. What is the best tutoring model? The second research question was related to the skills and competences of the participating students. What skills and competences will the IIC produce and develop?

2. EMPIRICAL ANALYSIS

2.1 Description of the intensive course settings

Next, the planning and the settings of the two international intensive courses will be described. The first course was kept in Russia at TPU (Tomsk Polytechnic University) in May 2018 and the second one also in Russia at INRTU (Irkutsk National Research Technical University) in March 2019. In both courses BSc students with different engineering backgrounds participated.

Before the courses, intensive planning work took place. First the funding had to be applied as the courses were financed by the Finnish ministry of education. This stage took place in autumn 2017. A network of one Finnish partner university and two Russian partner universities was founded and a preliminary course content and a grant application were written by the partners in September 2017. In *Table 1*, the IIC settings are described for the year 2018 vs. year 2019.

Table 1. Description of the IIC settings

Time period and place	2.5- 11.5.2018 Tomsk	2.3 -12.3.2019 Irkutsk
Course title and duration and credits	International and Interdisciplinary Workshop in Big Data Analysis for Smart City 10 days intensive work including 2 travel days plus pre- tasks and a learning diary credits: 5 ECTS points	Sustainable Design for Smart Regions - Blockchain Application for Sustainable Energy Systems 10 days intensive work including 2 travel days plus pre- tasks and a learning diary credits: 5 ECTS points
Main responsible lecturers and coaches	A team of Finnish and Russian engineering lecturers 4 MSc students as moderators/tutors	A team of Finnish and Russian engineering lecturers 2 PhD students as co teachers/tutors
Learners	3rd year Finnish mechanical engineering BSc students 3rd and 4th year Russian transport, urban sustainable development and IT BSc and MSc students 20 students, of which 8 Finns, 12 Russian students	3rd year Finnish energy and environment BSc students 3rd and 4th year Russian electrical and IT BSc students and two PhD IT students 19 students, of which 9 Finns, 10 Russian students
Learners' backgrounds	Heterogeneous group with different engineering	Heterogeneous group with different engineering

	backgrounds, 3 different nationalities	backgrounds, 4 different nationalities
Task in the course	Big data analysis to solve a transport problem in Tomsk	Develop a blockchain application for sustainable energy system for Olkhon island
Team selection and size	Teams pre-selected by teachers Multicultural and -disciplinary teams of 5-6 persons, a MSc student acting as an expert moderator team member inside each team	Teams pre-selected by teachers Multicultural and –disciplinary teams of 4 to 5 persons. Two expert PhD students coaching BSc student teams as outside experts
Data collection	Open-ended questionnaire in the end of the workshop	Open-ended questionnaire in the end of the workshop

It should be noticed that the major part of the network was founded at the SEFI conference in Orleans in 2015.

Both intensive courses consisted of daily lectures and some excursions related to the students` team task which they had to solve during the intensive one week time. Time was also reserved for the team work itself and for some social activities in order to develop the team spirit. The team tasks of the both intensive courses were quite challenging for the BSc students and there was also a time pressure in order to develop the students` time management skills as well as their tolerance for ambiguity. The team task could not be solved without active sharing of the knowledge between the team members. Before the team task was started some lectures about team development and cultural differences were given to the students and some teaming activities were also performed. The students were also asked to do online- meetings and video-sharing with their teams before the workshop.

The students were tutored by the lectures. As the first research question was related to the team coaching model of IIC:s, two different coaching models were being tested. In Tomsk IIC an **internal coach model** was tried. This meant that the expert moderator student (who was an IT MSc student) was part of the student team and thus the coach student became himself a member of the student team. In Irkutsk another model (**outside consulting model**) was being tested. In this model the two student tutors (who were IT PhD students) were located outside the student teams acting as outside expert consultants, they were not located inside the student teams and thus they were not actual student team members as the MSc students in the Tomsk setting were.

2.2 Analysis and findings from students' feedback – tutoring model

In both courses open-ended feedback questionnaires were used to get students´ opinions and ideas for further development. The students were asked to give an overall grade (from 1= worst to 5= best) for the whole IIC as well as for their team task. The Tomsk IIC got an overall grade of **4,3**. They also gave a grade for the team task and it was **4,2** so it can be concluded that the student satisfaction was quite high here even this was the very first time this kind of intensive course was implemented within this network. The Irkutsk IIC on the other hand got an overall grade of **3,6** and **3,3** for the team task so it can be concluded that the student satisfaction was lower in the latter course than in the previous course even the latter course was planned and developed based on the feedback of the previous course and the latter course included even more interesting excursions etc. than the first one. So this raises the question why this difference exists in the students` satisfaction levels as the settings of the both courses were in general almost the same.

After studying the course feedback in more detail it can be noticed that in the latter Irkutsk intensive course the teaming between the student team and the expert coach student was not very strong and deep (as it was in the first Tomsk course where the expert moderator student was one member of the student team) and this caused some stress inside the teams as the team task was (on purpose) quite challenging but the students did not interact actively with the expert student anyway. As a result, **9** out of **19** students in the Irkutsk IIC claimed teaming and international communication as the area that could be improved; there was no consensus among Irkutsk students on what went well in the whole course (in contrast, **12** out of **20** students gave recognition to international communication and teamwork in the Tomsk IIC).

This happened because the student team members and the expert PhD student did not become very familiar with each other during the Irkutsk course as the PhD students seemed to operate as outside consultants, unlike the Tomsk course, where the moderator (MSc) students were themselves team members. The BSc students were not asking so much questions and help from the PhD students in Irkutsk. This was noticed also by the teachers but no interference into the learning activities of the teams were made by the teachers as the tutoring model was being tested here.

2.3 Analysis and findings from students' feedback – learning outcomes

The students were also asked what they learned in the course. Skills and competences named by students after the Tomsk and Irkutsk courses are shown in Figure 1 and Figure 2 respectively. In the bar charts subject competences are given in blue and soft skills in grey colours. The number of students that stated progress in each skill is given along the x-axis.

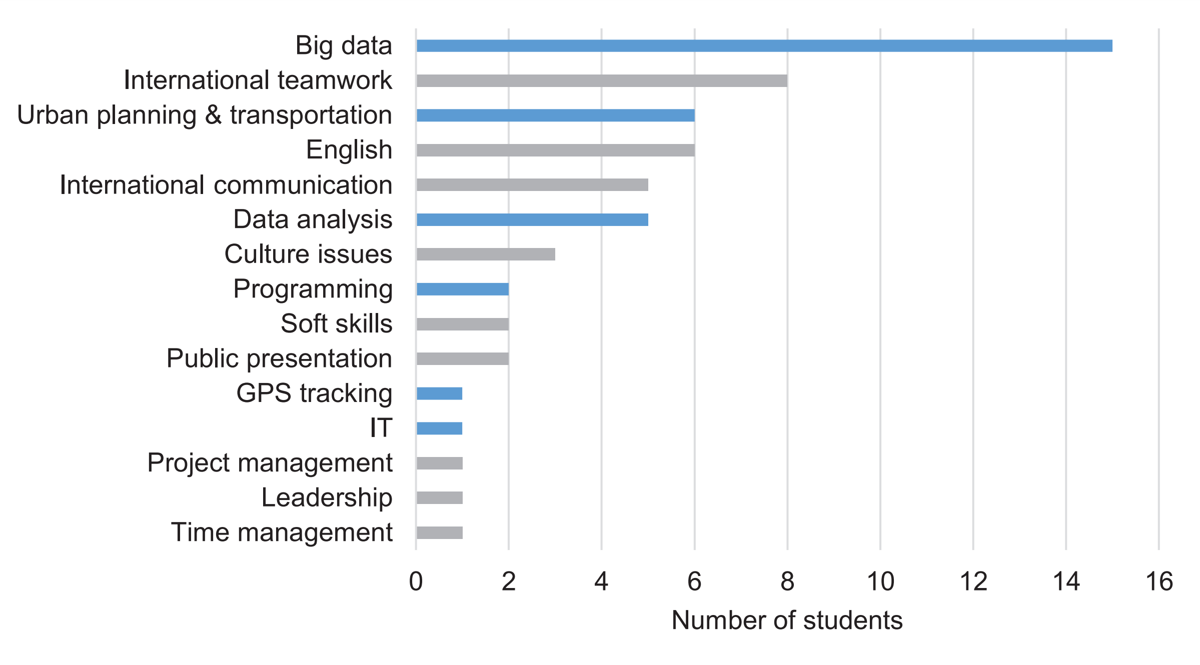

Fig. 1. Soft skills and subject competences developed during Tomsk intensive course

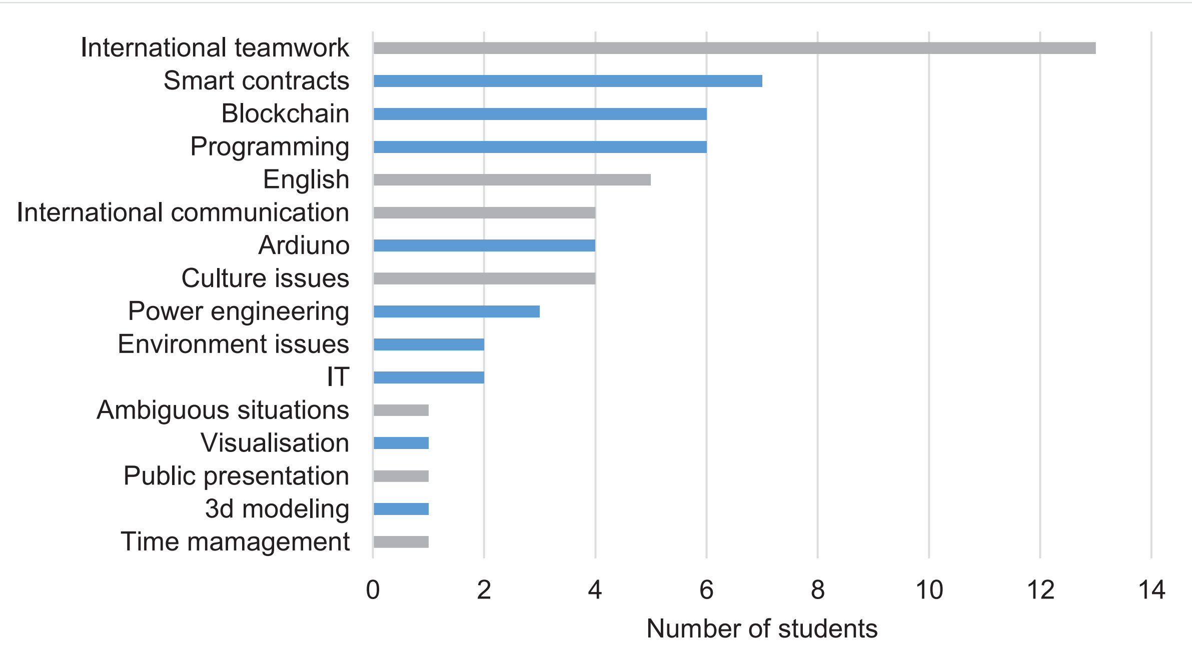

Fig. 2. Soft skills and subject competences developed during Irkutsk intensive course

It can be seen from Figures 1 and 2 above that this instruction method (IIC) develops the expected substance skills like big data analysis, urban planning, power engineering, programming and other IT related skills depending on the topic of the course and the team task. Besides, it also develops team working skills, communication skills, language skills, multicultural understanding skills, time management skills and other soft skills, although they were not explicitly announced in the course programme. Students' feedback further demonstrates a fair distribution of responses between hard and soft skills (30/29 in Tomsk IIC and 32/29 in Irkutsk IIC respectively). Therefore, it can be concluded that the proposed instruction method can be successfully used to help students to achieve such competences which are required in their future working careers and in coping with ambiguity of the work environment.

The students` feedback also shows that the Russian students were more critical while evaluating the team task than the Finns and they wanted to have more exact guidelines for the team task than the Finns. This can indicate that the Russian students had lower tolerance for ambiguity than the Finns but this issue needs further research. Besides, Russian students were more focused on substantial skills rather than teamwork or commmunication skills in their responses, although they recognized the challenges and benefits of team work and communication in multidisiplinary and international teams. It can be assumed, that these two findings are interlinked, although this assumption requires further analysis and justification.

It was an interesting fact that almost all students said that the course could be improved by increasing the time for the team task but only some students reported that they had developed in their time management skills.

3 CONCLUSIONS AND RECOMMENDATIONS

3.1 How to develop tolerance for ambiguity?

Engineers working in the modern work environments have to cope with the increasing amount of task and environmental ambiguity so their tolerance for ambiguity should be increased and developed already during their education phase. In order to develop this important skill it is highly recommended to use also other instruction methods in engineering education than only the traditional classroom teaching in one´s own home university. International intensive courses have proved to be a successful method to teach both substantial knowledge and the soft skills expected by present-day employers. To organize an international intensive course the teacher needs a network of active colleagues abroad, willingness to take risks and to use some extra time in planning too. Of course an external funding source is also vital. But it all pays back in the end.

3.2 Coaching model and virtual teaming

As a conclusion it can be said that the internal coach model seems to be a better model in this instruction method for the team coaching than the outside consulting model, especially when the team is given a challenging task where they really need some deeper expert advice in order to succeed with their team task and to cope with the ambiguity. It can also be concluded that it is not easy to team up virtually. Most of the students did not want to upload any video of themselves before the course, so online teaming should not be counted too much on. Best teaming happens when people meet in real life ftf.

4 SUMMARY AND ACKNOWLEDGMENTS

Engineering students must be trained to face uncertain situations as the uncertainty increases in the working life all the time. To develop the students` tolerance for ambiguity new pedagogy and other instruction methods than the traditional classroom teaching must be taken into use. If universities want to develop radical and new pedagogical approaches they must give their staff possibilities to attend workshops, seminars and conferences even abroad where the staff members can hear about new pedagogical methods, meet other interested colleagues and create new networks. The institutions must also be prepared that sometimes mistakes can also happen so the organizational culture must support innovative ideas and encourage risk taking. Otherwise no new teaching approaches will be tried. We thank our home universities for the possibilities to make these trials (and sometimes even errors) with the new pedagogical methods such as multidisciplinary intensive courses. We also thank the Finnish ministry of education for the financial support for organizing the international intensive courses.

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Designing a Program on Data Science while supporting Faculty Capacity Building in Latin America

A.F. Salazar-Gomez[1]
Massachusetts Institute of Technology
Cambridge, MA, USA

A. Bagiati
Massachusetts Institute of Technology
Cambridge, MA, USA

H. Sive
Massachusetts Institute of Technology
Cambridge, MA, USA

Conference Key Areas: Integrated learning environments for digital native learners, New notions of interdisciplinarity in engineering education, knowledge transfer

Keywords: Data Science, Faculty Development, Blended Learning, Mentorship

ABSTRACT

With the advent of Internet and the rising amount of data new technologies produce, data scientists are in-demand professionals, increasing the need for state-of-the-art, cross-disciplinary Data Science programs. However, many universities do not yet have adequate personnel to staff such programs or lack the methodologies that facilitate the teaching-learning process. To address this need, the Massachusetts Institute of Technology Abdul Latif Jameel World Education Lab (MIT J-WEL) is collaborating with the Government of Uruguay, by supporting development of a framework to guide a blended graduate program in data science, machine learning and entrepreneurship.

This novel framework integrates physical and digital learning environments. It combines asynchronous online material from the MITx Statistics and Data Science MicroMasters®, accompanied by MITx entrepreneurship courses. In parallel it introduces the core concept of synchronous online mentoring session, complemented by a series of in-person workshops. Finally, concurrent with other program elements, the framework focuses on development of expert Uruguayan faculty who will be able to educate data science professionals in the future.

The program is strongly interdisciplinary and the content for online mentoring sessions and in-person workshops is under development by MIT researchers and staff, with

[1] Corresponding Author
A.F.Salazar-Gomez
salacho@mit.edu

attention to specific audience and local context. Target students for the program are digital native professionals, with 60 learners in the first cohort. The program began in May 2019 and lasts 15 months.

This paper describes this multifaceted framework that is particularly designed to educate a new generation of data scientists while in parallel developing expert faculty capacity in Uruguay.

1 INTRODUCTION

We are living in a world where the boundaries between the digital, physical, and biological spheres are becoming more intertwined day by day. “This technological convergence is increasingly being referred to as the 'fourth industrial revolution', and like its predecessors, it promises to transform the ways we live and the environments we live in” [1]. As this revolution already takes place, according to the 2016 World Economic Forum Report (WEFR) on the Future of Jobs [2], Big Data and Machine Learning are considered to be among the most important drivers of change, making the need for advancements in the Data Engineering and Data Science fields critical. Data generation, acquisition, and analysis appear to be at the epicenter of this change and Data Science is already affecting critical development in “healthcare, economic productivity, and security” [3]; and driving changes in work sectors such as Policy Making [3,4], Medicine [5], Commerce [6], Banking [7], and Education [8]. According to the WEFR, in regards to Big Data, “realizing the full potential of technological advances will require having in place the systems and capabilities to make sense of the unprecedented flood of data these innovations will generate” [2].

Moreover, local and global economies, public and private institutions, collective or single users, are generating information that has become a new type of currency in the digital economy: data/currency that is expected to grow exponentially in the future. A report by the IADB (Inter-American Development Bank), suggests that worldwide commercial purchases of data and data-related services are “expected to maintain a compound annual growth rate (CAGR) of 11.9% through 2020, when revenues will be more than $210 billion.” [9]. Also, this report reveals that Latin America and the Caribbean will present the fastest growth in data-related purchases with a “five-year CAGR of 16.2% from 2015 to 2020”.

Within the current digital ecosystem, infrastructure to support Big Data needs to be optimally designed and then Big Data can be generated, harvested, tracked, filtered, analysed and consumed. Data engineers have to carefully understand current and rapidly emerging future needs in order to develop the most efficient products to serve different markets, while data scientists have to keep creating and deploying new analytic models to support and promote appropriate decision-making, in order for their customers to be able to best evaluate past practices and to most accurately project future outcomes. However, although very promising work opportunities for data engineers and data scientists have been predicted and discussed for over a decade now [10], there is already a great shortage of skilled employees ready to lead this change, and although “much has been said about the need for reform in basic education, it is simply not possible to weather the current technological revolution by waiting for the next generation’s workforce to become better prepared.” [2]

Under the current circumstances, universities around the world are already working to rapidly develop this emerging field. However, although a large number of data science and data engineering programs are being developed for both residential and online use, the Latin America region has a deficit in such programs and require faculty that are not only experts in the field, but also in pedagogy innovation and new teaching technologies.

To counter the deficit in a Data Science program suitable for the Latin American region, the Massachusetts Institute of Technology Abdul Latif Jameel World Education Lab (MIT J-WEL) is currently supporting the Government of Uruguay and local universities to develop a blended graduate program across the fields of data science, machine learning and entrepreneurship. The program accepted its first group of students in May 2019, and is offered to professionals with a strong technical background, the desire to explore new entrepreneurial avenues within their companies or outside of them, and the will to become the region’s future leaders in the field of data science. The participant’s median age is 36 years old, one third of them are female; half of the learners are engineers, and a quarter of them are economist. Also, a fifth of the participants are university professors in diverse fields (entrepreneurship, engineering, and economics). The framework, developed to guide program development and implementation has two aspects both designed to expedite and accomplish the intended program goals: educating a new generation of Latin American data scientists and entrepreneurs, while in parallel building faculty capacity and transferring knowledge to the partner universities in Uruguay.

2 THE FRAMEWORK

2.1 Content

Content will be delivered over 4 trimesters and consists of a combination of required and elective courses addressing Data Science and Entrepreneurship. In greater detail, courses will include:

- Four online MITx Statistics and Data Science MicroMasters® courses: Introduction to Probability - The Science of Uncertainty, Data Analysis for Social Scientist, Fundamental of Statistics, and Machine Learning with Python: From Linear Models to Deep Learning. If all courses are accomplished, the learners can take a final proctored exam to obtain the MicroMasters certificate.
- Two online elective MITx entrepreneurship courses (Entrepreneurship 101 and Shaping work of the future).

- Seven different elective online courses taught by Uruguayan universities (Universidad de la República and UTEC), spanning the use of R for data analysis and Machine learning to multiple language learning.
- Three residential workshops addressing
    - Introduction to data science and entrepreneurship.
    - MIT Global Startup Labs PRO (a technology incubator course focused on developing a model for a product or a company using entrepreneurship, machine learning, and data science).
    - A project presentation focused on raising seed funds.

The Micromasters and entrepreneurship courses are pre-existing courses previously developed for a broader audience. Courses developed by the Uruguayan universities are either adapted or newly developed courses, and the workshops are particularly tailored to the program.

2.2 Delivery

This novel framework employs the *blended learning* and *mentoring* learning theories as the main delivery mechanisms, as it combines asynchronous online classes with synchronous online mentoring sessions and complements these with residential workshops that will take place in Uruguay. In all cases content delivery is guided by the MIT motto "*Mens et Manus*", ("mind and hand" in English), making hands-on learning the driving teaching approach [11]. Furthermore, to support delivery, the framework integrates physical and digital learning environments based on the content covered. In greater detail:

- MicroMasters® and entrepreneurship courses are offered on the edX platform.
- Online elective courses offered by Uruguayan universities use the edX, open.edX and Moodle platforms.
- Residential workshops include hands-on and face-to-face activities in Uruguay, and synchronous video conferences using Adobe connect.
- Synchronous mentoring sessions use Moodle and Adobe connect.
- Live discussion forums, led by faculty from Uruguayan universities, will be available on the Moodle platform.

The different delivery mechanisms are presented in Fig. 1, while Fig. 2 presents integration of the various learning environments in greater detail.

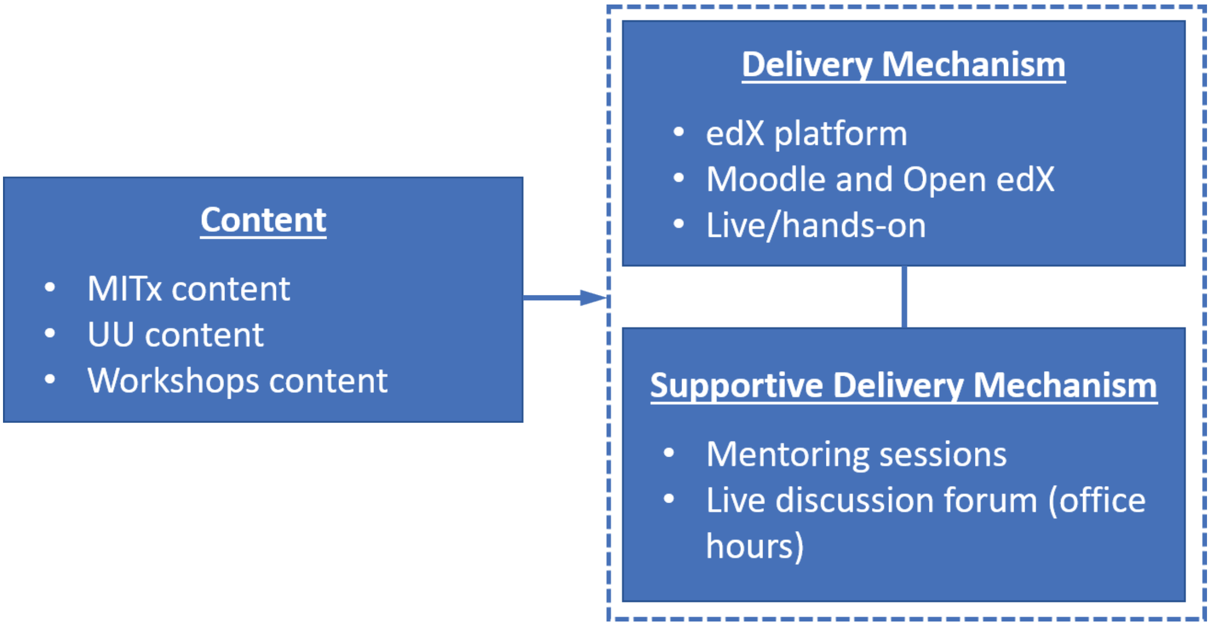

Fig 1. Delivery mechanisms

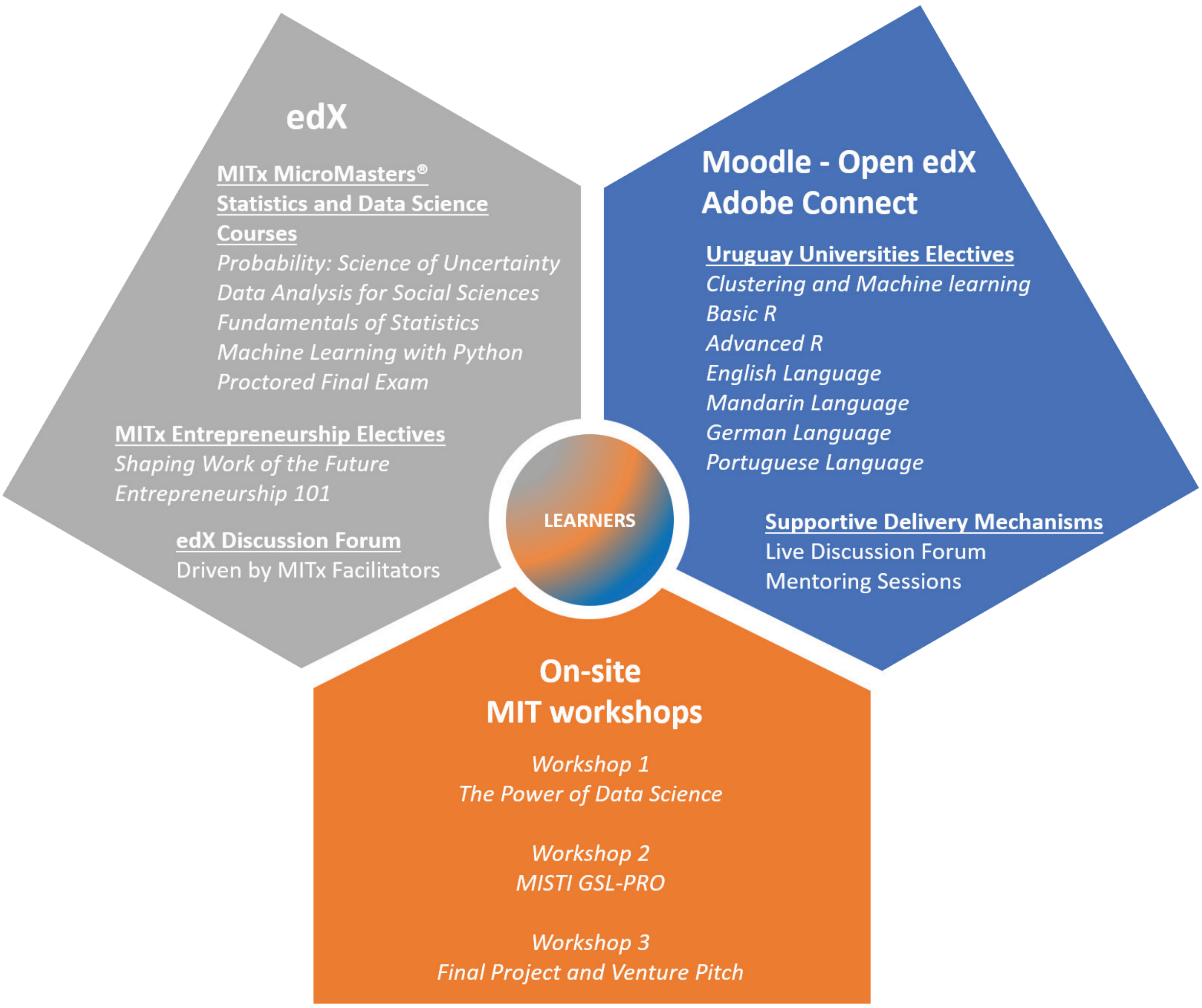

Fig 2. Learning environments

2.3 Faculty development and knowledge transfer

The driving force for the development of this framework has been the need to train local Uruguayan faculty in innovative blended learning models, adequately incorporating and using technology during instruction. In order to expedite offering this graduate program, while in parallel ensuring appropriate faculty training, program developers from MIT and local universities have particularly designed a Faculty Development Program (FDP) where local faculty will be receiving training on data science as well as on the appropriate didactical methods throughout the program. The same training will be attended by MIT personnel who will serve as mentors to the program. "Learning through teaching" is the main learning theory employed for the faculty development program. However, active participation in classes and mentorship sessions will also introduce them to all appropriate active learning pedagogies suggested by MIT to deliver the data science related content.

The current FDP starts one month before the beginning of the designated courses, as presented in Fig. 3, and continues throughout the life span of three student cohorts. During the first cohort, faculty from Uruguayan universities will be actively enrolled in the MITx MicroMasters® courses, while they will be trained by MIT to support the MIT-led mentoring sessions. During the second cohort, both MIT and UU mentors will share equal responsibilities during mentoring sessions. For the third cohort, the UU mentors will take the leading role during mentoring sessions. Fig. 4 Introduces how the leadership role transitions from MIT to UU mentors across cohorts.

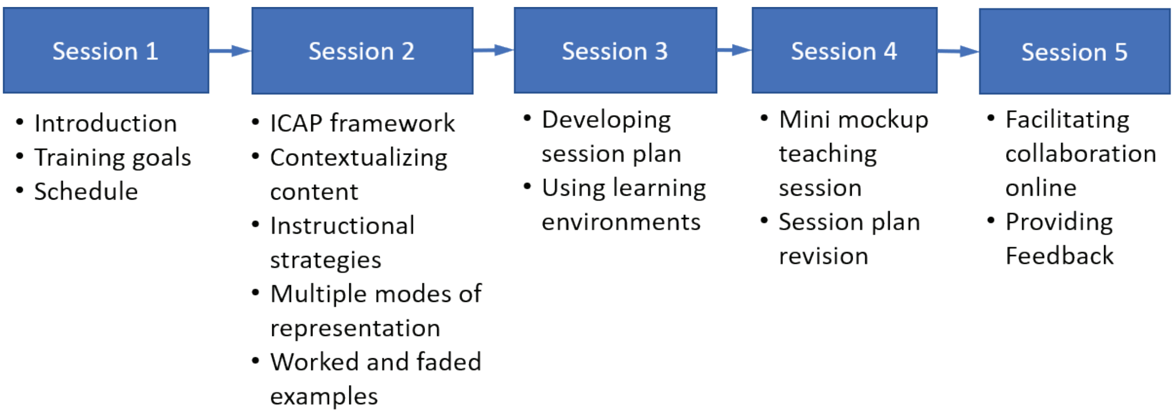

Fig 3. Mentor training process

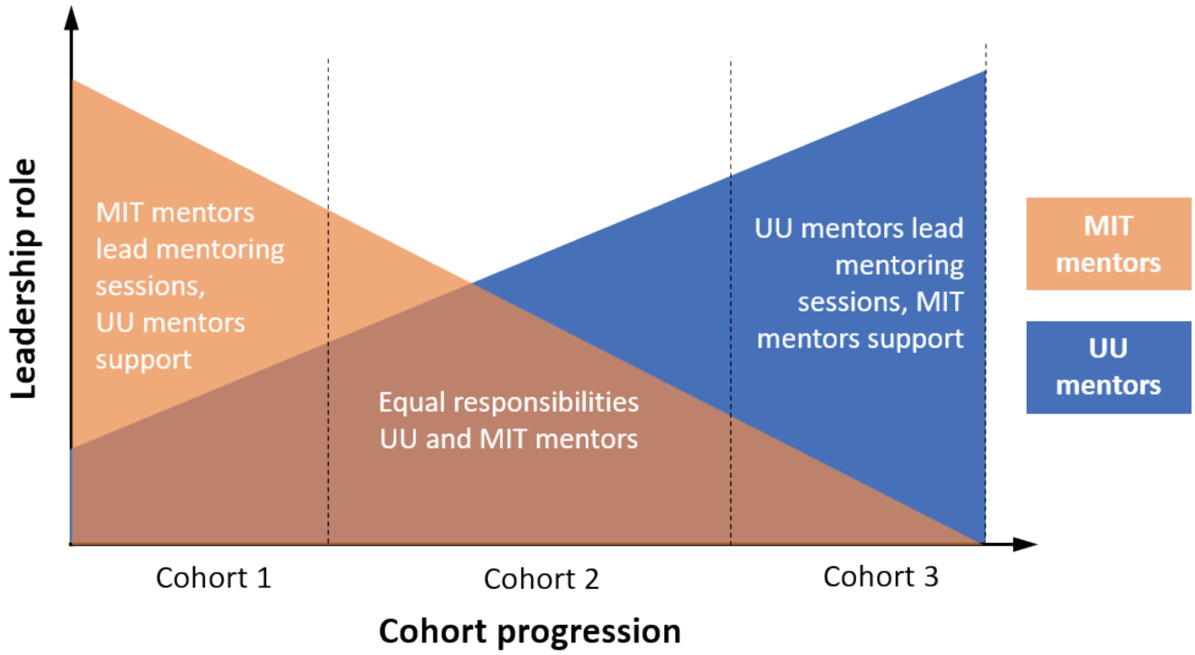

Fig 4. Leadership role transition for MIT to UU mentors across cohorts

3 CONCLUSIONS AND FUTURE WORK

In this paper we have presented a novel framework that is designed to accelerate development of an academic program in Data Science by synchronizing launching of the academic program together with the FDP, taking full advantage of this parallel process. Although this framework has been developed with this particular program in mind, it can easily be adapted to supporting other emerging fields.

The inaugural cohort for this program started in May 2019, and attendees represent an international population, mainly stemming from Latin American countries, with diverse professional backgrounds. The Program aspires not only to educate the learners but also to move beyond formal education by promoting formation of a long-lasting community, as well as creation of a knowledge base for the future data scientist of the region, while still fostering MIT engagement with the future scientists of the world. Finally, we are also planning a careful evaluation of teaching, learning, and online mentoring processes as well as the content developed to address the Latin American context, with intent to guide future development both of the academic and faculty development program.

4 ACKNOWLEDGMENTS

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Smartphones: a new approach to the parallel-axis theorem

L. M. Sánchez Ruiz[1]
Centro de Investigación en Tecnologías Gráficas, Universitat Politècnica de València
Valencia, Spain

I. Salinas
Centro de Tecnologías Físicas, Universitat Politècnica de València
Valencia, Spain

M.H. Giménez
Centro de Tecnologías Físicas, Universitat Politècnica de València
Valencia, Spain

J.A. Monsoriu
Centro de Tecnologías Físicas, Universitat Politècnica de València
Valencia, Spain

J.A. Sans
Instituto de Diseño para la Fabricación y Producción Automatizada,
Universitat Politècnica de València
Valencia, Spain

Conference Key Areas: Fundaments of engineering education: mathematics and physics; Integrated learning environments for the digital native learners

Keywords: Smartphones; parallel-axis theorem; torsion pendulum.

ABSTRACT

The use of new technologies is a useful tool to approach the students to fundamental Physics problems. In particular, smartphones are the most common devices among the young people and may be suitable in multitude of basic Physics experiments.

Here, we report the use of the accelerometer sensor of a smartphone to visualize and demonstrate the parallel-axis theorem in a torsion pendulum. The study of the moment of inertia using a torsion pendulum is a typical example in the first courses of fundamentals of Physics. Several works have exposed different simple approaches to this system in order to make it attractive to the students. On the other hand, a recent trend to use the Smartphone's sensors has arisen in basic Physics lab practices, so the students work with instruments that are familiar to them. We attached a smartphone to a torsion pendulum in order to collect the acceleration time series and thus, i) to determine the stiffness of the spring, ii) to demonstrate the parallel-axis theorem and iii) to describe the Harmonic oscillations produced.

[1] Corresponding Author
L.M. Sánchez-Ruiz
lmsr@mat.upv.es

1 INTRODUCTION

The use of new technologies to approach the students to fundamental Physics problems has stimulated several works along the last years. In particular, smartphones are the most common device among the young people. Here, we report the use of the accelerometer sensor of a smartphone to visualize and demonstrate the parallel-axis theorem [1] in a torsion pendulum.

The study of the inertia momentum by the use of the torsion pendulum is a typical example in the first courses of fundamentals of Physics. This example allows to explore the inertia momentum theory, the 2nd Newton's law, the Harmonic motion and the parallel-axis theorem all-in-one. Several works have exposed different simple approaches to this system [2-4] in order to make it attractive to the students. On the other hand, new learning strategies try to exploit the use of common devices in Physics lab practices. This way, the students work with familiar instruments to them. Thus, a recent trend to use the Smartphone's sensors has arisen, exploiting the possibilities of its accelerometer [5-6], ambient light [7] or microphone [8] sensors to describe Physics phenomena. Our experience by using the students' smartphones in class has always enthusiastically well perceived by them who have eagerly taken an active role.

Here, we present a study of the motion of a torsion pendulum coupled to a Smartphone in order to collect the dependence of the acceleration with respect of the time and thus, i) determine the stiffness of the spring, ii) demonstrate the parallel-axis theorem and iii) describe the Harmonic oscillations produced in this system.

2 THE TORSION PENDULUM

2.1 Theory

The torsion pendulum is an invaluable example of several fundamentals Physics laws. A torsion pendulum is composed with a rod, which rotates around its centre subjected to the force of a spring (stiffness k) and two known masses (m_1, m_2) that may be placed at several distances from the centre of rotation.

Applying the Newton's second law to this system, we know that the force momentum or torque is related to the angular acceleration (α) and the inertia momentum (I). Therefore, the movement is dominated by the stiffness of the spring and the angle shifted (θ) with the following relation:

$$M_T = I\alpha = -k\theta \qquad (1).$$

As the angular acceleration (α) derives from the rotated angle (θ), the equation that must be solved is:

$$\ddot{\theta} + \frac{k}{I}\theta = 0 \qquad (2).$$

In a simple harmonic motion, the angular frequency (Ω) is related to the period (T), thus the solution of the previous equation is:

$$\Omega = \sqrt{\frac{k}{I}} = \frac{2\pi}{T} \quad (3).$$

The inertia momentum (I) of the system is the addition of the components and it can be calculated as:

$$I = I_{rod} + I_{m_1} + I_{m_2} \quad (4).$$

The parallel-axis (or Huygens-Steiner) theorem says that the inertia momentum around any axis (I_{m_2}), can be obtained from the inertia momentum, of a parallel-axis passing through the mass centre of the object (I_{m_0}), and the distance (d) between the two axis:

$$I_{m_2} = I_{m_0} + m_2 d^2 \quad (5).$$

This way, equation 4 can be rewritten as:

$$I = I_{rod} + I_{m_1} + I_{m_0} + m_2 d^2 = I_0 + m_2 d^2 \quad (6).$$

Where (I_0) is the inertia momentum of the system, around the rotation axis, except the corresponding to the mass m_2. From *Eq.* (3) and *Eq.* (6), the period squared of the oscillation is:

$$T^2 = \frac{4\pi^2 I}{k} = \frac{4\pi^2 I_0}{k} + \frac{4\pi^2 m_2}{k} d^2 \quad (7).$$

Thus *Eq.* (7) indicates that there is a linear relationship between the period squared of the oscillation and the distance of the mass to the rotation axis.

2.2 Experimental setup

In the experimental setup we replace the mass m_1, of a torsion pendulum, with a smartphone, located at one end of the rod (*Fig.* 1). We use the accelerometer sensor in order to measure the accelerations, caused in the extreme of the rod, while a known-mass (m_2) is placed at several distances from the centre rotation. By means of a slight shift of the rod in the spring, the system starts to oscillate.

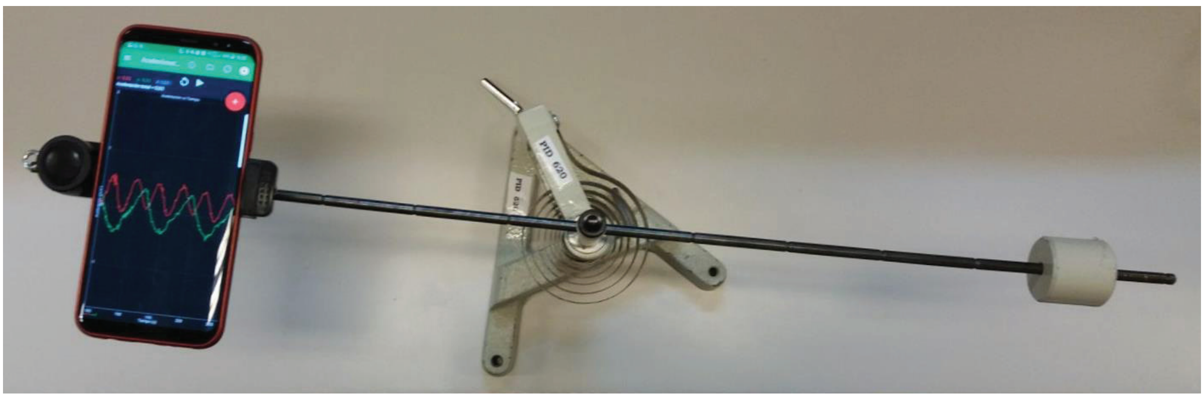

Fig. 1. Experimental setup developed to demonstrate the parallel axis theorem with a torsion pendulum coupled to a Smartphone.

a) b)

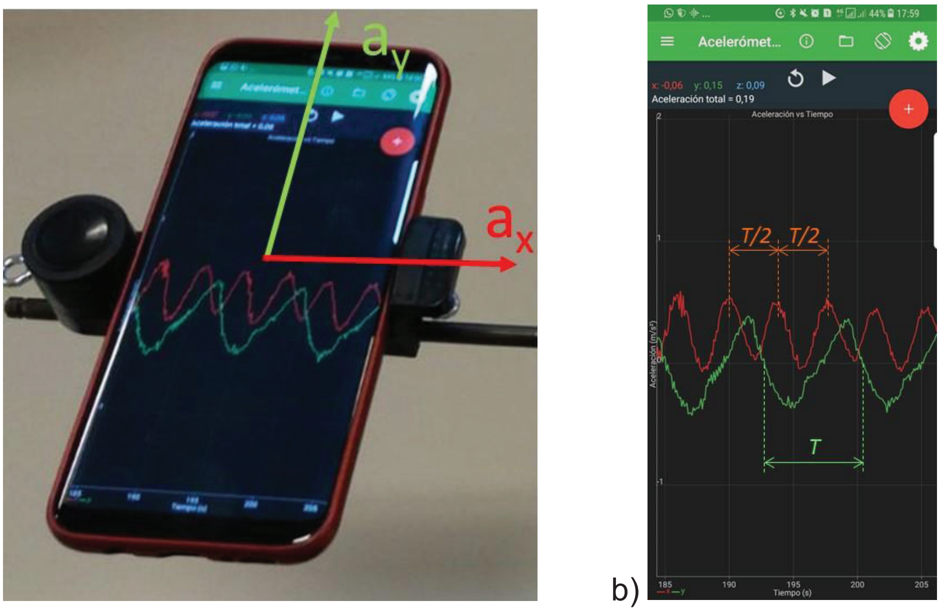

Fig. 2. a) Smartphone in the extreme of the rod plotting the accelerations normal (a_x) and tangential (a_y). b) Snapshot of the application Physics Toolbox Suite [9]. The oscillation period (*T*) is overprinted.

The normal and tangential component, of the acceleration of the system (*Fig.* 2), are collected by the Android application Physics Toolbox Suite [8] taking advantage of the Smartphone's accelerometer sensor. The snapshot in *Fig.* 2 shows the oscillations and the period (*T*) is overprinted. Students see the harmonic nature of oscillations directly on the screen of their smartphones.

2.3 Results

The data gathered with the smartphone is exported to an Excel by means of csv files. For each position, *d*, of the mass m_2 of 0.236 kg, we calculate the period (*T*) of each oscillation and the average period ($T_{average}$). In our experiment we studied the oscillations of the tangential component of the acceleration. The experimental values, T^2 versus d^2, are displayed in *Fig*. 3. A linear trend can be observed, according to the tendency expected by *Eq.* (7).

Thus, from the fit to a linear dependence through minimum squares and comparing with *Eq.* (7), we can obtain that the slope (a) is related to the stiffness of the spring as follows:

$$a = \frac{4\pi^2 m_2}{k} \quad (8).$$

And we calculate:

$$k_{measured} = \frac{4\pi^2 m_2}{a} \quad (9).$$

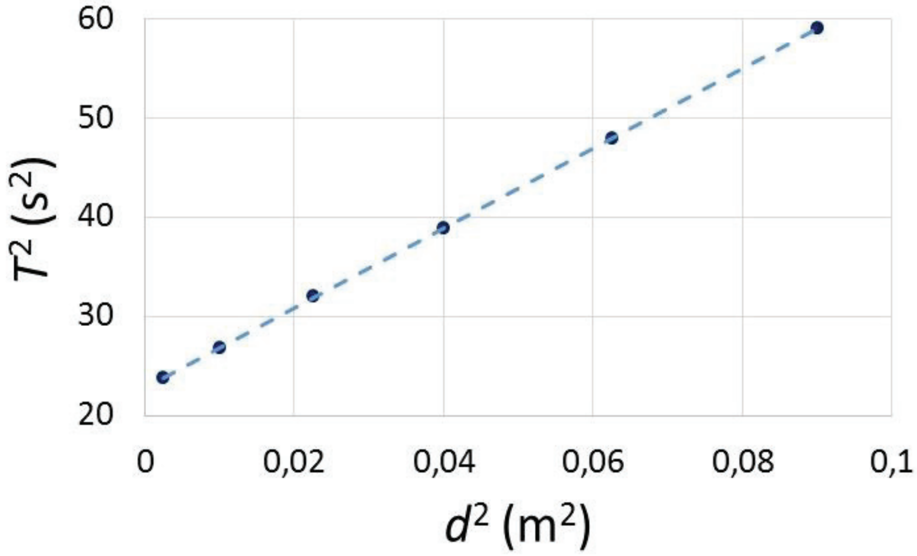

Fig. 3. Representation of the evolution T^2 vs d^2. Linear fit is shown as dashed line.

Applying the *Eq.* (1), the value of the stiffness of the spring can be obtained:

$$k_{calculated} = \frac{|M_T|}{\theta} = \frac{F\,d_F}{\theta} \quad (10).$$

by the application of a force (F) at a determined distance (d_F) the rod rotates the angle (θ). We applied 0.25 N at a distance of 0.3 m and we observed that the rod rotated π radians.

In *Table 1* we gather the essay parameters and the results calculated. The quality of the fit (r^2 = 0.9999) offered a large reliability of the parameters obtained. Also noteworthy is the fact, that the discrepancy in the calculation of the stiffness of the spring, by these both methods of is less than 4%.

Table 1. Essay parameters and results.

	Parameter	*Value*
	m_2 (kg)	0.236
Linear fit: $T^2 = a\,d^2 + b$	a (s^2/m^2)	402.9
	b (s^2)	27.79
	r^2	0.9999
	$k_{calculated}$ (Nm)	0.0240
	$k_{measured}$ (Nm)	0.0231

3 SUMMARY

In summary, we present a new way to calculate the stiffness of a spring applying previously acquired knowledge about inertia momentum and parallel-axis theorem thanks to the use of the accelerometer sensor of a Smartphone. This new method has been proved as an invaluable tool to make the experiments closer to the students and discover the potential possibilities of this common device as sensor in multitude of basic Physics experiments. In addition to the attractiveness for the students of using in a lab session a device of their own that they use constantly it is the fact that helps sorting out a problem we have with big groups at lab sessions as it may be the experimental costs. In this case it is extremely economical as smartphones are provided by the very students.

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Umbrella Courses at the BEng programme in Civil Engineering at the Technical University of Denmark

H.P. Christensen,
J. Molin,
A.H. Schelling[1]

DTU Center for Bachelor of Engineering Studies
Building, Environmental and Civil Engineering
Technical University of Denmark

Conference Key Areas: Integrated learning environments for the digital native learners, New Notions of Interdisciplinarity in Engineering Education

Keywords: CDIO project course, complexity, interdisciplinarity, motivation.

ABSTRACT

Based on solid principles for learning, a curriculum for our BEng programme in Civil Engineering has been built around large interdisciplinary so-called umbrella courses. Within a digital framework, the courses – in a novel way – combine motivating project work on authentic cases with embedded theory modules to generalise the learning, giving the students coherent, sustainable and applicable competences including important generic competences. The students find the umbrella courses very challenging, so a firm structure with a high level of information and rigorous planning has been necessary. Developing the umbrella concept has been a long and challenging, yet qualifying process for the teaching teams made up of engaged professors from several departments, and the rewards are now beginning to show. The students feel they get good learning, which is seen in the high grades, and older students, who first experienced the umbrella course, now see the value of the interdisciplinary approach and praise the courses for laying the foundation for a good education.

1 INTRODUCTION

Based on the CDIO standards (CDIO, 2004), a new curriculum for the Bachelor of Engineering programme in Civil Engineering was implemented from autumn 2014. The hallmark of the new curriculum is the large umbrella course, which collects all the necessary topics to complete a project as in an umbrella organisation. The umbrella course is the core of the first and second semesters. The inspiration for the umbrella course came from a merge of two existing programmes, the civil engineering design process, basic principles for learning, and the CDIO teaching concept. Designing buildings and infrastructures is getting more and more computerized, so it is important to give the students the coherent viewpoint necessary to build multidimensional all-embracing computer models.

CDIO was developed to get practice back into engineering education; Conceive-Design-Implement-Operate emulates the way engineers are working, and this is fully

[1] Corresponding author:
A.H. Schelling, Associate professor
adsc@dtu.dk

implemented in the umbrella course, as it fits with the phases in the way buildings and infrastructures are designed and constructed.

One of the requirements of a CDIO programme is that it should include two Design-Build projects. This is implemented in surplus, since the four first semesters are all built around Design-Build projects. CDIO also specifies a syllabus with an emphasis on generic competences – i.e. collaboration, communication etc., which directly are in focus with the learning objectives in the umbrella courses.

The aim of the umbrella-based teaching is primarily that the students will achieve *a deeper, more useful and coherent understanding* of the topics in a civil engineering education. This should give a good starting point for the second year, where the student goes deeper into the theory.

Secondly, the umbrella courses aim at keeping a high retention rate. Not all students have been top performers in high school, so many have difficulties starting a demanding higher education like engineering. And not all students are clear about what civil engineering is, so the motivation may not be high from day one. Therefore, dropout rates should be kept low during the first year. However, at the same time, it is also important quickly to stop students, who clearly have chosen the wrong education. The umbrella course structure should, through respectively group work and the focus on individual learning, live up to both these somewhat contradicting goals. The independent work should also help to transform the student from school pupil to university student.

This paper aims to

- Describe the teaching method and structure of the two umbrella courses.
- Present a preliminary evaluation of the two courses, in terms of student dropout rates, grades, and student satisfaction

First, we outline the existing theoretical background for the design of the courses. Secondly, we describe the two courses: their teaching method and structure. Next, we outline the evaluation methodology. Finally, we present the evaluation results and discuss the findings and limitations of the evaluation.

2 EXISTING LEARNING THEORETICAL BACKGROUND

Learning is an active emotional process that fuelled by sensory and cognitive input takes place in the growth layer between the known and the unknown (Christensen, 2008)

The umbrella courses are based on empirically well-documented principles for learning – e.g. described in *How People Learn* (Bransford *et al.,* 2005). Two of the main conclusions are that learning is an emotional psychological process and that learning requires activity – we can only learn, if we need to and are interested and actively engaged: *Need-based active learning* (Kurki-Suonio & Hakola, 2007). It is all about motivation. Deep learning requires internal motivation; external motivation like passing an exam doesn't give sustainable learning (Bruner, 1977). Students must be put in a situation, where they must learn in order to carry out an activity they want to do. And designing buildings and infrastructures must be interesting and motivating for civil engineering students.

Another learning theoretical point is that to develop competences within an area, you need to have a solid factual knowledge base understood in a relevant conceptual framework (Bransford *et al.,* 2005). Learning is contextual – that is why it is so difficult to apply math learned in a pure math environment. The context bound case-related learning must be generalised. This is the reason for the unique way the umbrella courses are designed with embedded theory modules. And the delivery of these modules must be closely aligned with the progress of the project, so the students have them, when they need them; the difficult *just-in-time* planning and coordination.

We learn on basis of what we already know: Our horizon of understanding. The big picture does not make sense, if we don't know any details, but we are not motivated to learn the details, if we cannot use them and see them in the big perspective. This is the hermeneutic circle (Gadamer, 1960). So, neither a top-down nor a bottom-up approach is useful. We need to have all the information from the start which is, of course, not possible. Therefore, we must start with a few details and a simplified overview, and then add more and more details and create a better and better total view: The rationale behind *spiral learning* (Bruner, 1977).This is the theoretical reason for the phase structuring of the umbrella course with clear learning objectives for each phase. There is also a practical engineering reason for this, as the civil engineering design process is standardised in phases from idea generation to operation and removal. A spiral process where more and more information is added to the model.

3 TEACHING METHOD AND STRUCTURE

The main part of semester 1 and 2 of the BEng programme in Civil Engineering consists of two umbrella courses. An umbrella course is 15 weeks long and takes up 2/3 of a semester. It is built around a project with an authentic case with embedded theory modules including relevant math and physics providing the necessary knowledge and skills to complete the project. Most modules are given at the beginning of the course, and then more and more time is allocated to the project. In the final three weeks there is only project work. In addition to the theory modules, the umbrella courses include hands-on activities like construction, field surveys, and lab work.

The students work in fixed groups throughout the entire course. All groups have a process facilitator to help them with the difficult teamwork. As a counterweight to the group work, the students must participate in individual learning checks throughout the course. The purpose of these is primarily to give the student feedback on her/his learning, which is essential to learning (Argyris, 1992), but also to ensure that all students have obtained the necessary basic understanding of all topics in the course for their continuing studies. A student cannot participate in the final exam unless she/he has passed all the learning checks. Most checks are one-hour online multiple-choice tests with questions that check the student's understanding; not the ability to remember knowledge or do calculations.

The students are graded on the final project documentation including a process document and an oral presentation with individual questions in order to give individual grades. The students are expected to be able to explain every aspect of the case and the corresponding theories.

3.1 Semester 1: Building Construction

The case is designing a one-family house – see Figure 1 for an example of a student project. Digital construction is the framework for the course, which has the following theory modules:

- Building Design, BIM
- Building Design, Construction
- Load-bearing Structures, Statics
- Load-bearing Structures, Applications
- Mechanical Installations
- Building Energy

The course aims to introduce basic building knowledge through the design of a single-family house, with the involvement of the industry's forms of communication and forms of collaboration. The building design deals with building technology, the building's load

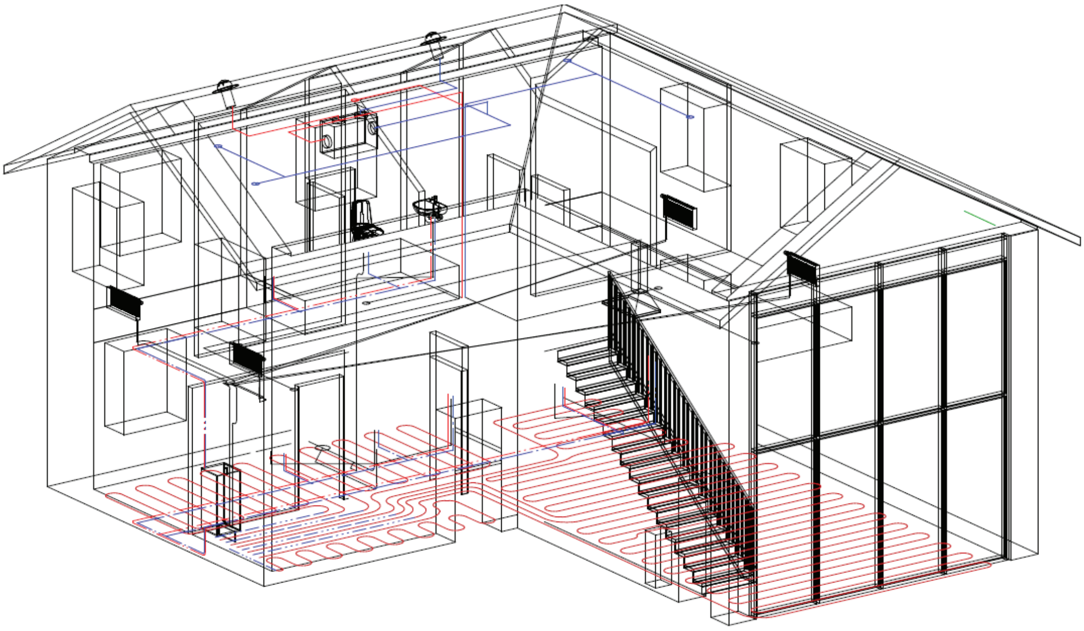


Figure 1: Digital model of a one-family house with mechanical installations.

bearing construction, energy calculations and the building's installations. The students must acquire knowledge of the building design's prerequisites through insight into building regulations and local plan, as well as applicable norms, standards and building practices.

The aim of the course is that the students acquire tools for constructively entering into and contributing to the group's collaboration, and that the students are introduced to the industry's digital communication forms with special emphasis on BIM, Building Information Modelling.

The course and the course assignments will be divided into the following phases:

- Appraisal
- Project proposal
- Regulatory project and tender design

During the course the students do presentations of the progress with the case after each phase, but this is not part of the grading.

Figure 2 shows the learning outcomes for the Building Construction course. In addition to the technical disciplinary knowledge, the CDIO Syllabus specifies the learning outcomes as personal and interpersonal skills, as well as skills in product, process, and system building skills. The figure shows which of the individual learning outcomes will contribute to the students' learning in each of these four sections.

3.2 Semester 1: Training in Process and Collaboration

Together with the teaching in engineering subjects, it is an important learning objective to acquire skills in team working and collaboration through the first year. The idea is to support the students' transition from school pupils to students of engineering.

From the beginning, each group is required to write a Collaboration Contract, and we train the groups to carry out conducted group discussions where they reflect on the working process. As a result of the reflections, each individual student will state what he or she will do to contribute to targeted improvements of the team's working process.

During the first semester, there are regularly scheduled sessions where the focus is on the process, not the technical content of their work. At the end of the semester,

A student who has met the objectives of the course will be able to:

•	*Apply digital forms of communication with emphasis on (BIM) Building Information Modelling.*
•	*Explain the phases of construction including construction management, financial estimates, scheduling.*
•	*Design a small residential building with a focus on the whole, building construction and building materials.*
•	*Dimension a simple structural design, including conducting a preliminary static analysis.*
•	*Perform basic design of the building envelope and the building's heating and ventilation systems.*
•	*Calculate and simulate the expected energy use of the building.*
•	*Document the suggested solutions and communicate and argue the solution in writing and orally.*
•	*Explain the learning group process cooperation.*

1	Technical knowledge and reasoning
2	Personal and professional skills and attributes
3	Interpersonal skills: Teamwork and communication
4	Conceiving, designing, implementing and operating systems in the enterprise and societal context

Figure 2: Learning outcomes for Building Construction. Colour code according to the four sections of the CDIO Syllabus.

each group prepares a Process Document. Furthermore, two times during the first semester, a personal conversation of 15 minutes length between each individual student and a professor is scheduled. The first round of conversations takes place in the middle of the term, and the second at the end, closely to the final examination. In this second conversation, the Process Document is commented.

These individual conversations are held in an atmosphere of respect and personal interest, and the professors conducting these conversations are not a part of the teaching team of the first semester – thus eliminating the potential fear of telling something that might influence negatively on the student's examination.

3.3 Semester 2: Civil Infrastructure Engineering

The 20 ECTS Umbrella Course for the second semester aims to enable the students to plan, design and renovate municipal infrastructure facilities, based on municipal planning, traffic conditions, and supply conditions. The course is project organized and includes six theory modules as well as a continuous project.

The requirements for our cities change over time; this also applies to roads and paths, drainage and water supply. They must be renovated so that they meet today's and tomorrow's requirements for road safety, accessibility and climate protection.

The learning outcomes – displayed in Figure 3 - describe the knowledge, skills and competences the students will acquire.

The various subject areas are gathered in a continuous project, dealing with an existing, older industrial area in suburban greater Copenhagen. In the Municipal Urban Area Development Plan, the area has been designated as an urban conversion area. The transformation has begun in the area's north-eastern corner. Here, a high-rise residential development has been erected on an old industrial site. This gives rise to new requirements for the traffic system - including the need to identify a need for a better school route that must overcome the barrier that the railway constitutes.

A student who has met the objectives of the course will be able to:

• *Describe and analyse a project organization for an infrastructure project.*
• *Identify and locate traffic problems.*
• *Develop and assess the implications of solutions to traffic problems.*
• *Design roads in urban areas.*
• *Plan and design distinct systems for water supply.*
• *Plan and design distinct facilities for drainage, including renovation of drainage systems.*
• *Acquire knowledge and implement hydraulics for pipes and canals systems.*
• *Analyse geological conditions, perform basic geotechnical calculations and plan and interpret typical geotechnical studies.*
• *Design minor civil structures such as retaining walls.*
• *Develop schedule and economic estimate for the design and construction.*
• *Communicate and argue for the assignment in writing and orally, with focus on digital tools such as GIS, Geographic Information Systems.*
• *Explain team cooperation and development and reflect on the use of personal and interpersonal skills.*

1	Technical knowledge and reasoning
2	Personal and professional skills and attributes
3	Interpersonal skills: Teamwork and communication
4	Conceiving, designing, implementing and operating systems in the enterprise and societal context

Figure 3: Learning outcomes for Civil Infrastructure Engineering. Colour code according to the four sections of the CDIO Syllabus.

Along the area's eastern border an upcoming light rail line will further boost the development. There are many large commercial buildings and a large part of the area is paved. The southern part of the area includes allotment gardens.

The six theory modules are:

- Geotechnics and Structures (4 ECTS)
- Climate, Water and Environmental Engineering (5 ECTS)
- Roads and traffic (5 ECTS)

- Planning and Process Management (3 ECTS)
- Geoinformatics (1 ECTS)
- Hydraulics (2 ECTS)

In the spring semester of 2018, the 107 students were organized in 18 groups of generally 6 students. Before the term begins, the students are invited to form pairs of two or three students, and to indicate with which other students they would like to form a group. These pairs were then combined to groups of 6 students by the course supervisor. The students respond very positively to this invitation: 90 per cent of the students have indicated preferred teammates.

The teaching team included 11 professors from 3 different Technical University institutes and from the industry, as well as seven teaching assistants – older students, helping the groups understand the matters and getting started.

Each group is assigned a process supervisor. The process supervisor must guide the group in relation to

- manage their time and resource plans so that milestones are not moved
- follow-up on the collaboration contract
- facilitate collaboration problems

Six of the professors are also process supervisors. The meetings are scheduled every two weeks in the beginning of the course, and later there is a meeting once a week.

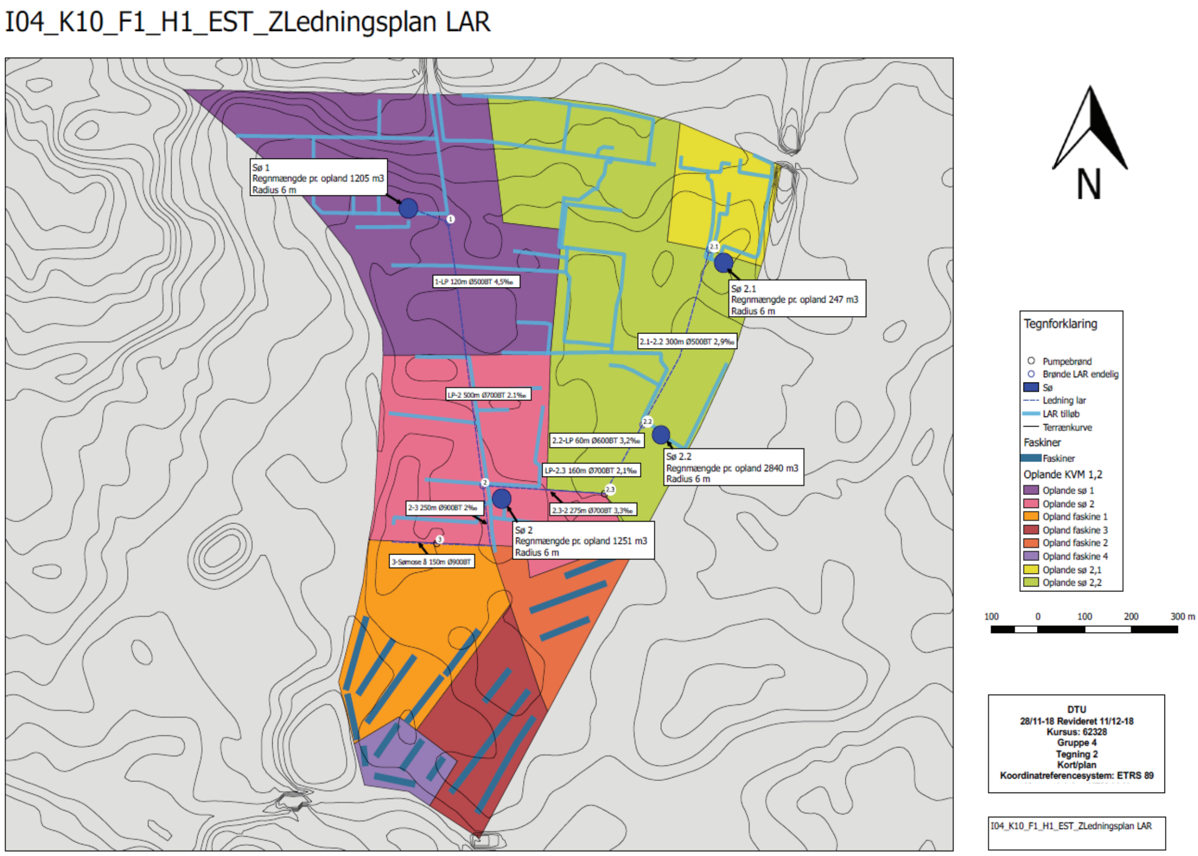


Figure 4: Example of a project drawing from the Infrastructure Engineering course: A WSUD (Water Sensitive Urban Design) solution for the Herlev Business District.

All faculty can provide professional guidance. If students need specialist guidance outside the scheduled teaching sessions, they send an email with a request for a meeting, including an agenda. At the end of the course, each group prepares a Process Document. It is included in the final assessment.

3.4 Semester 2: Considering Assessment

The goal is that the assessment is aligned with the teaching method and the learning outcomes. The course is evaluated by an oral group examination based on the project report and the process document. During the course 6 tests are held, and to be able to take the examination 5 out of 6 tests must be accepted. Everyone is assessed individually. In the spring semester of 2018, the project examination included 107 students, 20 groups, 2 days, 3 rooms, 3 external examiners, and 7 professors.

Hand In. The groups handed in their project electronic on the university's teaching platform one week before the examination. The groups are requested to deliver their material in a predefined file structure, according to the Danish Building Information's Standard.

Marking. The individual subject professors review, comment and evaluate the material of all groups as regards their own subject area. This is done on commentary sheets. The process documentation is evaluated and commented by the group's process supervisor. This process can take maximum four days.

Preparation. The examiners (process supervisors) receive all comments and all printed drawings from the subject professors and provide an overall impression of the individual group's performance. This process can take maximum one day.

Examination. The process supervisors carry out the oral examination, together with one colleague who has another professional profile. The groups hand over a printed agenda for the presentation to the examiners. The students are instructed to leave enough time for questions and discussions (one third of the total time)

Examination Time

• Group presentation Geotechnics and Structures	18 minutes
• Group presentation Climate, Water and Environment	18 minutes
• Group presentation Roads and Traffic	18 minutes
• Group presentation Planning and Process Management	18 minutes
• Group presentation Process	10 minutes
• Voting	10 minutes
• Buffer/pause	10 minutes
• Total	102 minutes
• Rounded up to (1 hour and 45 minutes)	105 minutes

4 EVALUATION METHODOLOGY

This preliminary evaluation study is based on the two umbrella courses on semester 1 and 2 of the BEng programme in Civil Engineering. The earlier versions of the courses, which ran from 2014/15 to 2016/17, were included.

The data are all routine information, collected from the grade statistics and from the standard university course evaluation system. In this system, the students are invited to answer 9 questions about the course, and in addition, there are several questions about each professor. The students may also write text-comments.

Three of the 9 questions were selected for this study, as they were – in this connection – the most relevant ones. The other questions deal with the students' active participation, the teaching material, their own performance and the course description's prerequisites. The three selected questions are shown in section 5.2.

As pointed out earlier, a deeper understanding of the topics in a civil engineering education was expected, and a low dropout rate.

5 DOCUMENTATION AND DISCUSSION

5.1 Dropout Rates and Grades

Both umbrella courses have, as expected and intended, a very low dropout rate, with approximately 90 % passing.

The average grades for the courses are, as shown in Figure 5 and 6, around the average grade of 7 – for the first semester course, grades tend to be lowest in the spring semesters which include more students who have been away from school for some years. However, after the study plan adjustment spring 2017 there is a significant increase in the average grade for the first semester course reaching 9.3 in spring 2018.

It should be noted that it is the same core of professors and external examiners, who have run the exam all the years, so the grade increase must be assumed to be a real expression of a higher learning outcome. For the second semester course, a similar increase is not seen.

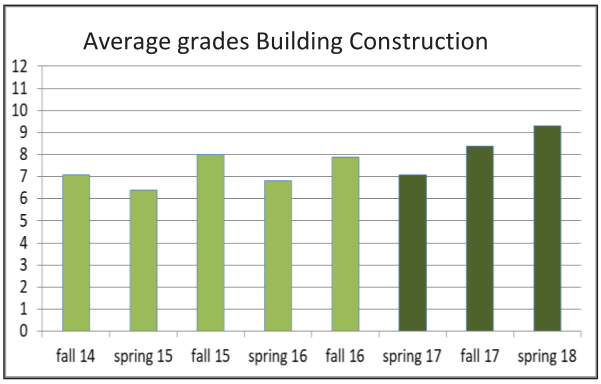


Figure 5: Average grade for the first semester umbrella course on a scale from 0 to 12. The results from autumn 14 to autumn 16 are for the original course, the results from spring 17 to spring 18 are for the revised course.

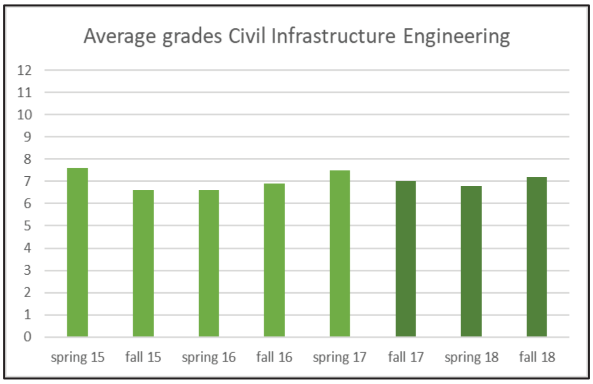
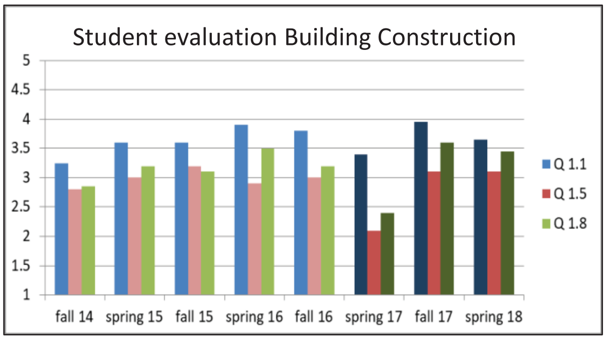


Figure 6: Average grade for the second semester umbrella course on a scale from 0 to 12. The results from spring 15 to spring 17 are for the original course, the results from autumn 17 to autumn 18 are for the revised course.

5.2 Standard Course Evaluation

Figure 7 and 8 show the answers to the selected questions from the standard university student evaluation since the introduction of the umbrella courses autumn 2014 and spring 2015 respectively. The three selected questions are:

- Q 1.1: I think I am learning a lot in this course
- Q 1.5: I think the teacher/s create a good continuity between the different teaching activities
- Q 1.8: In general, I think this is a good course



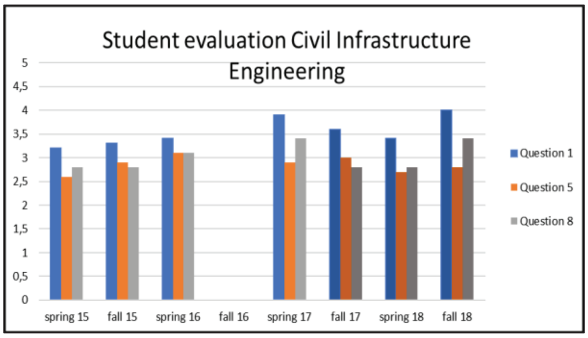


Figure 7 (left) and 8 (right): Average answers for 3 questions on the standard university student course evaluation for the two umbrella courses on a Likert scale from 0 completely disagree to 5 completely agree (data for autumn 16 are not available for the second semester course).

For the first semester course, the results are slowly getting better until the curriculum adjustment spring 2017, where there were problems with the introduction of the learning checks. After that, the results have increased. For the second semester course, the results are slightly better, and more stable.

5.3 Further studies

This preliminary study has already caused implementation of several changes in the teaching concept but leaves a few interesting questions which deserve further investigation:

1. What is the value of the learning checks, and how to improve them?
2. What are the reasons and solutions to the students' feeling of confusion?
3. How can the complex topics be made more understandable to new students?

5.4 Dissemination

The umbrella concept has been presented at a CDIO conference (Winther, 2016), and recently, the umbrella course has received the Technical University's teaching Award 2018.

5.5 Conclusions

The innovation described here is not just about a promising new way to teach – it is about changing the philosophy behind traditional curriculum design: From The Technical University norm with independent 5 ECTS courses to a fully aligned curriculum with large interdisciplinary courses based on proved learning principles and in accordance with the CDIO concept and industrial standards. The core umbrella courses have a novel architecture designed to create motivation and assure deep applicable learning. To implement this has been a challenge to both students and professors, so this has been a long developing process with necessary adjustments along the way.

If you give the students demanding challenges, they will find it hard and at first be frustrated, but the learning will be deep and sustainable, and the benefit to the students will be great in the long run. But students don't see the long run, so you must make courses motivating and relevant with transparent methods and objectives. That's why and how we made the umbrella courses. When talking to older students and graduates, they express that the umbrella courses they were exposed to at the beginning of their study now make a lot of sense to them. They can see that the interdisciplinary approach gives them a good basis for further learning and strong job competences.

This is, in the end, what the umbrella course curriculum is all about.

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Case Study: Visualizing Computer System Programming Concepts for Education

Florian Schmidt[1]
Technische Universität Berlin
Berlin, Germany

Johannes Ohlemacher
Technische Universität Berlin
Berlin, Germany

Vincent Hennig
Technische Universität Berlin
Berlin, Germany

Odej Kao
Technische Universität Berlin
Berlin, Germany

Jan Nordholz
Technische Universität Berlin
Berlin, Germany

Conference Key Areas: Open and online teaching and learning, New Complexity quest in engineering sciences

Keywords: interactive visualization, large scale courses, complex animations, system programming

ABSTRACT

In the area of computer system programming, theoretical concepts between hardware and software solutions need to be explained. Even though this topic is highly practical, as it covers the theoretical concepts of any modern machine like computers and smartphones, it is still difficult to provide easy access to any practical experience as the gap between current hardware solutions and basic implementation of operating system processes is too large for undergraduate students. As it is not possible to test those concepts in an applied way, we aim to provide an interactive web simulation framework called SysprogInteract. SysprogInteract provides modern animations of the behaviour of single computer components as well as more complex ones that show the relationship between components. The goal is to provide high quality media content, accessible any time to any student, providing

[1] Corresponding Author
F. Schmidt
Florian.schmidt@tu-berlin.de

individual feedback and fostering exchange between students through the overall platform. This paper presents the first animated hardware component (CPU) of SysprogInteract, visualizing the concept of scheduling processes. Based on this tool, we show how it can be integrated within a lecture with more than 800 students at the TU Berlin, Germany. Furthermore, we present a case study with 59 students, showing a high usability through the System Usability Scale with a score of 79.5; more than 86% of students responded they would use this application for exam preparations. Additionally, we present the overall concept of the platform, which is ongoing work.

1 INTRODUCTION

Computer system programming describes theoretical concepts between hardware and software solutions, which are present in operating systems. Even though this topic is highly practical, as it covers the concepts of any modern machine like computers and smartphones, it is still difficult to provide access to any practical experience as the gap between current hardware solutions and basic implementation of operating system processes is too large for undergraduate students in the first year of their studies.

Furthermore, in recent years the number of students in our course Systemprogrammierung at the Technische Universität Berlin (TU Berlin) was constantly growing, such that currently more than 800 students attend our lectures, making it almost impossible to provide individual feedback.

Due to this lack of individual feedback and due to the difficulties of teaching these concepts in an applied way, we have decided to create an interactive web simulation framework called SysprogInteract. With this framework we provide a set of modern animations, some of them rendering the behaviour of a single computer component, others simulating several components together with the relationships between them. The goal is to create high quality media content, accessible any time to any student, providing individual feedback and fostering exchange between students, while at the same time integrating seamlessly into the educational process within the course.

Thus, this paper presents the following core contributions:

- Description of the open source, interactive web application SysprogInteract, showing in detail the different simulations for the hardware components of CPU scheduling, memory placement and resource management.
- Integration possibilities of the application into the educational process within the undergraduate course with more than 800 students at TU Berlin, Germany.
- Showing preliminary results of a user study with 59 students in order to verify the acceptance, interactivity and motivation to use this tool.

Outline: The rest of the paper is structured as followed. The next section describes the state of the art of thematically and methodically related applications and animations for computer system programming education. Afterwards, we continue with the description of our current web application SysprogInteract and our vision of the final architecture in section 3. We continue with information on how SysprogInteract can be integrated within a large scale course in section 4. Section 5 presents the user study we conducted to evaluate the interactivity and motivation for students using SysprogInteract. Lastly, we conclude this work in section 6.

2 RELATED WORK

Discussing the effectiveness of animation in educational environments, Rieber [1] has shown how animation can be integrated beneficiently. While he gave general recommendations for educational animations in different disciplines from geography to physics, Lawrence et al. [2] have focused on the effectiveness of algorithm animation in particular. English and Rainwater [3] studied the use of animations in an operating systems course and concluded that they proved to be more effective for teaching procedural topics than basic concepts. To make use of these benefits Jones and Newman [4] developed a simulated operating system. Like SysprogInteract, their tool simulates essential operating system parts, however, it was last updated in 2003 and is therefore outdated.

More recent developments of educational simulation software are rather similar approaches, mostly focusing on CPU scheduling. The tool developed by Suranauwarat [5] visualizes various process scheduling algorithms like FCFS, RR, SJF, SRTF and MLFQ. It also features a practice mode in which students can check their predictions on the algorithms or test alternative scheduling decisions. Although the visualization is quite detailed, it lacks a user-friendly evaluation part, e.g. time-based graphs. A short evaluation may be sufficient as the process queue is limited to a size of four. Unlike SysprogInteract, this tool does not allow its users to study the behaviour of the supported algorithms in larger test setups.

A similar approach was proposed by Kotalny and Spinczyk [6]. Their tool AnimOS features the same algorithms (apart from MLFQ), however, it does not include a practice mode. Still, it is more flexible as it allows the user to define custom algorithms and to simulate an unlimited amount of processes. But especially that makes the lack of proper presentation for the collected performance data quite severe.

With OSLAB, Zareie and Najaf-Zadeh [7] are combining two essential parts of operating systems' lectures: in addition to CPU scheduling algorithms they also simulate memory management. OSLAB comes with only two predefined algorithms (FCFS, RR) for both parts but allows, like AnimOS, to add further ones. Due to the layout, it is not possible to observe memory and CPU behavior simultaneously. Like the tools discussed above, OSLAB also lacks appealing metric presentation.

None of these tools are aiming to simulate multiple components of an operating system at the same time, so it is impossible to observe interdependencies between components and selected algorithms and giving intuitive possibilities to monitor the performance of different configurations. Thus, we will now introduce our tool SysprogInteract which provides the possibility of visualizing such dynamic interdependencies between different components.

3 SYSPROG-INTERACT

The course of Systemprogrammierung focuses on selected algorithmic approaches employed by operating systems to handle the computation on conventional computer hardware. Thus, the course concentrates on the following main hardware components: Central Processor Unit (CPU), Random Access Memory (RAM) and Hard Disk Memory (HDD). Additionally, the concept of a process is introduced, which embodies a certain computational workload. The operating system faces the task of allocating the available hardware resources to each process, such as "scheduling", i.e. distributing the CPU time among the processes, and partitioning memory in order to load the code and data of each process. Furthermore, processes might make use of the same resource, which may eventually result in a conflict when these accesses coincide. Those need to be resolved by deadlock handling mechanisms.

SysprogInteract provides configurable animations for each of these individual tasks, illustrating several different algorithmic solutions. The application allows to choose between visualizing individual components or a complete system, showing all the relations between its components. In order to meet the expectations of a modern user interface, we use the Javascript library D3 [8] which gives us the opportunity to create several different aesthetic visualizations.

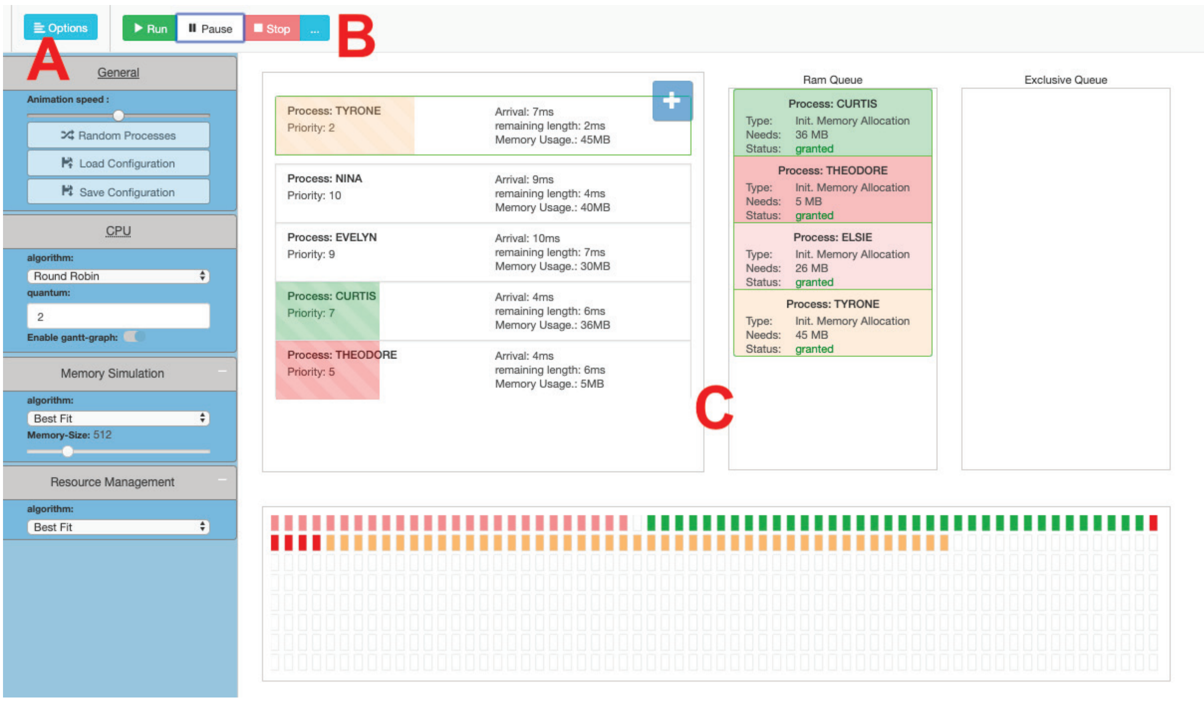
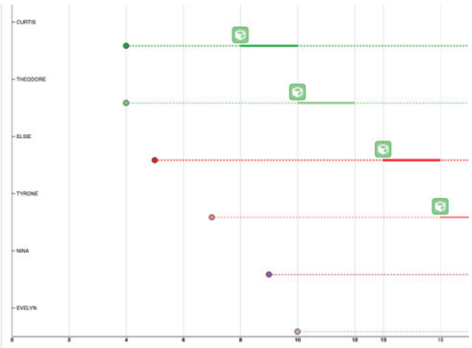


Fig. 1. SysprogInteract user interface structure

Fig. 1 shows the overall structure of the user interface. Part A shows the option bar (blue), which contains the configuration settings for all of the algorithms. Furthermore, the user can decide to use the overall visualization of all components or select parts of the components, which is useful while some components have not yet been introduced to the students. Part B of the image shows the stepwise control bar. Like a music player, users can start, stop, and pause the animation and go stepwise forward and backward in order to closely inspect crucial parts of algorithms. Part C shows the animations and advanced diagrams.

Currently we support the following components and features:

- CPU scheduling algorithms: First the user has to specify the set of processes whose execution shall be simulated. The scheduling methods FCFS, RR, SJF, SRTF and MLFQ are supported and animated. Fig. 3 shows the resulting diagram, which is also used when introducing these algorithms in the lecture. Fig. 4 shows process information containing average waiting time, longest waiting time, etc.
- Memory placement strategies: First-, best-, worst-, rotating first fit are integrated. Running processes can be configured to use memory resources, which are illustrated in the bottom part of Fig. 1. Average memory usage and further metrics are presented as an additional diagram (see Fig. 5).
- Resource management strategies: For resource management, on the upper right part of C animations are presented, but additionally a diagram as shown in Fig. 2 is animated to illustrate the complete history of resource usage for each process. Again, this diagram can be used within the lecture.
- Saving and loading of configuration files: It is possible through the option bar to save and load configurations of processes and algorithms. This enables the possibility to prepare showcases and tasks.



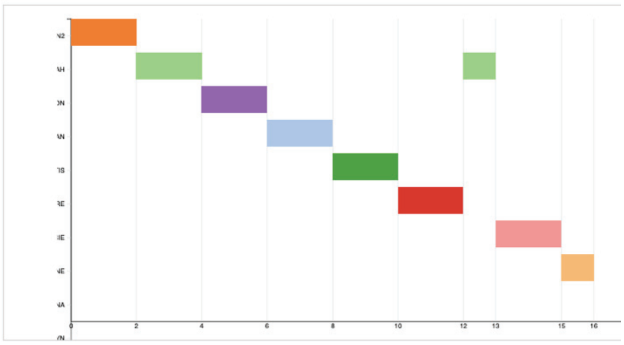
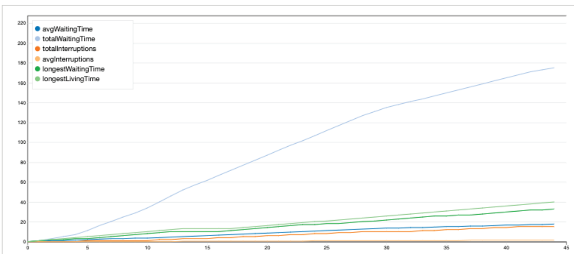


Fig. 2. Resource management

Fig. 3. CPU scheduling



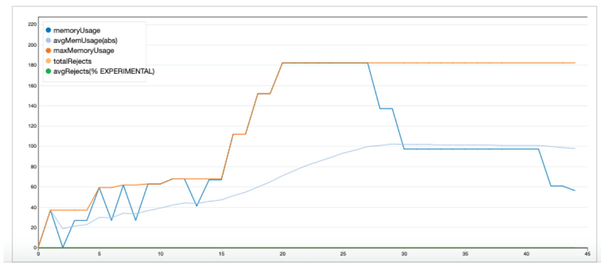


Fig. 4. Process metrics

Fig. 5. Memory metrics

Another feature worth considering is the integration to edit algorithms by students themselves, in order to provide more practical usage of simulation by creating or adapting algorithms. This is already possible by directly editing the publicly available code of our application, but the usability of such a feature may be increased in the future by providing an editor inside the web application.

We hope that SysprogInteract will be used in further education facilities to gain an impact in the computer science. Thus, we published SysprogInteract under the open source Apache 2.0 license on the Github[2] with a demo page[3]. For students as well as teachers, videos have been produced to show the usage of the tool and the setup on own servers. The videos are collected on a Youtube playlist[4].

4 INTEGRATION INTO EDUCATIONAL PROCESS

The application can be used within the educational process in various ways. We will now describe different scenarios of how the tool has already been used or how it could be used within the course.

Within the lecture, SysprogInteract is used for demonstrating the different algorithms during the presentation. While running the animations, the lecturer can pause and go steps back at any time in order to showcase key phases of the illustrated approaches. As the solution provides visualizations for interdependencies of system components, different chapters of the course are visually connected and may give further motivation why specific algorithms are selected for demonstration.

Additionally, SysprogInteract provides the possibility to save and load configurations (for process definition and algorithm configurations for the individual components). This enables the creation of tasks where results can be analyzed through the simulation. Such exercises can be used for exams or interactive sessions within small group exercises. In addition, the tool is used for group discussions, where students explain certain concepts to each other or give predictions on the overall outcome for certain statistics.

The code of the application is available as open source, such that students could be also asked to add further algorithms. This has not been tested within our course yet, but we plan to give this option to students who think they are capable of doing so.

As the tool is developed as web application, students can also use it at home for individual learning. This is useful, as it can be used for homework and preparation for the final exam. Besides the video material of the usage of SysprogInteract, we also aim to publish open access material for teachers such as slides or exercises to improve the overall usability and to facilitate the integration into further courses at other universities.

[2] https://github.com/citlab/SysprogInteract
[3] https://citlab.github.io/SysprogInteract/
[4] https://www.youtube.com/watch?v=CzDeF80RYHs&list=PL2wkohQ2DA3vtUHH2F6yO2iwwX5O_QOTl

5 USER STUDY

Within the course, we conducted a user study with 59 students in order to evaluate the usability of the tool and motivational aspects for education. For those interviews, we gave students access to the application without any instructions and a paper-based questionnaire. Students were allowed to decline to answer any questions.

The participants were enrolled in computer science (39), computer engineering (10) or other major (9). 55 persons pursue a Bachelor degree and 1 person a Diploma degree. One of them is in the 1st, 46 in the 2nd, 1 in the 3rd, 5 in the 4th, 3 in the 6th and 1 in the 7th or higher semester. 11 participants identified as female and 45 as male.

For the usability study, we used the questionnaire developed by Brooke [9]. It consists of 10 questions in order to evaluate the usability of applied applications in the industry. We added further questions at the end in order to evaluate the motivation of using the application within the educational context. We integrated the possibility for open answers in order to give our students the opportunity to submit additional feedback. All questions and results are shown in the following diagrams (Fig. 6).

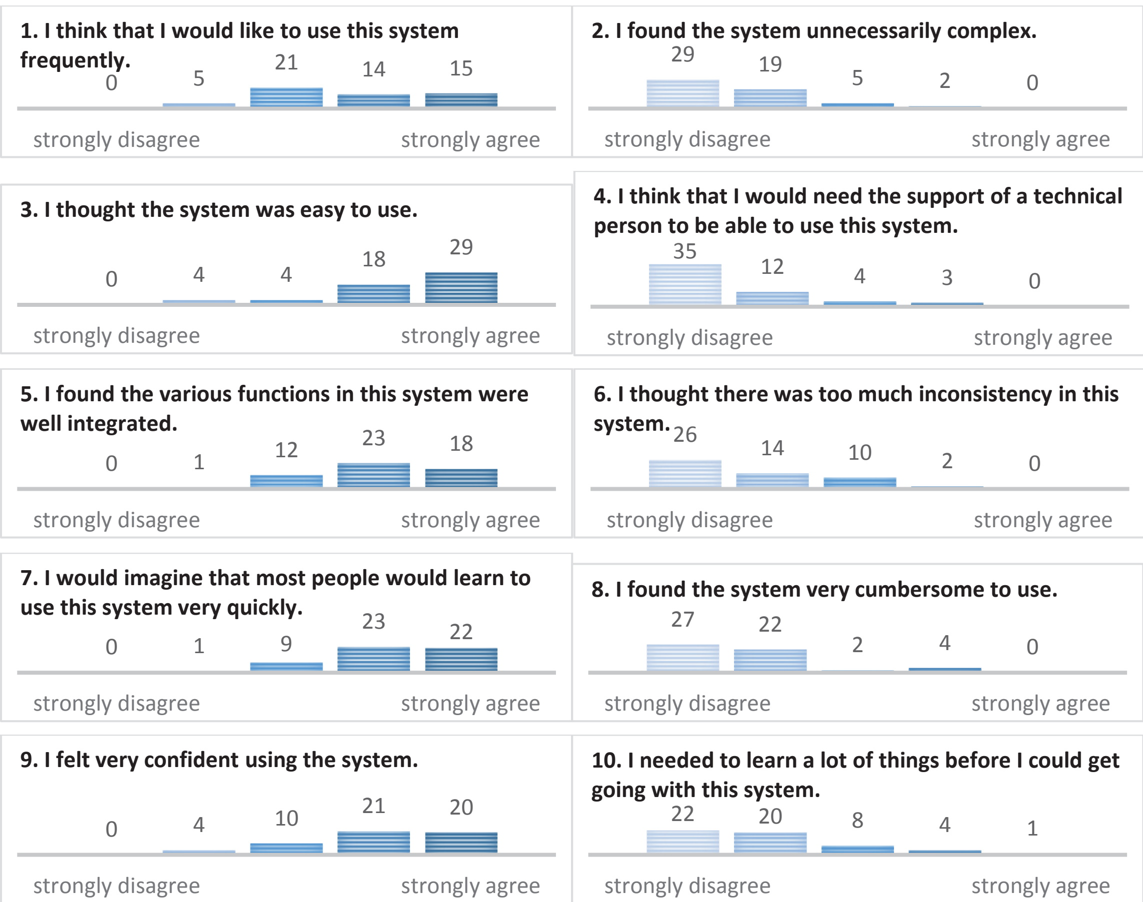


Fig. 6. Main ten usability questions from Brooke [9].

Diagrams 1 to 10 provide the results of the questionnaire by Brooke [9]. They all use a linear scale from 1 to 5, where 1 denotes a strong disagreement and 5 a strong agreement to the provided statement. Brooke [9] developed the System Usability Scale (SUS), which serves as a standardized test to evaluate applications, thus making them comparable. The scale ranges from 0 to 100 points. Even though the scale is linear within its range of 0-100 possible points, a large number of studies has shown that it cannot be inferred from the linearity of the scale that an average application gets a scale of 50 points for usability. Thus, Brooke presented in [10] further classifications to map the SUS to other scales.

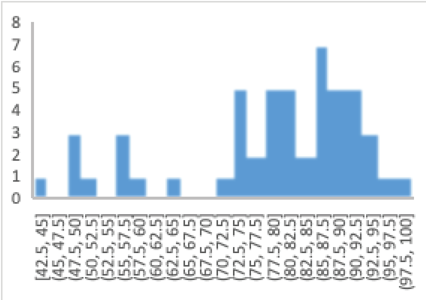


Fig. 7. Histogram of SUS scores

The usability questionnaire shows that for all statements the tendencies lean towards the positive side, such that most declared that e.g. the system is easy to use. Looking at the individual SUS, we see 9 people giving scores between 50 and 60 points, while the rest gave higher SUS, up to the maximum of 100. Fig. 7 shows the distribution of all individual SUS. The average SUS is 79.52 points, with a standard deviation of 14.23 points. The confidence interval is [75.81, 83.23] with confidence of 0.95. Lewis and Sauro [11] showed in their study that the average is between 70.1 and 62.1, standard deviation is 21.7 and 22.2 for more than 2,300 and 300 individual SUS, respectively for two different data sets. Thus, our average is higher and standard deviation smaller than the shown study. Using the further classifications of the given scale by Brooke [10], the average lies within the adjective rating for a good usability. Next, we show the results of the additional interview questions (Fig. 8).

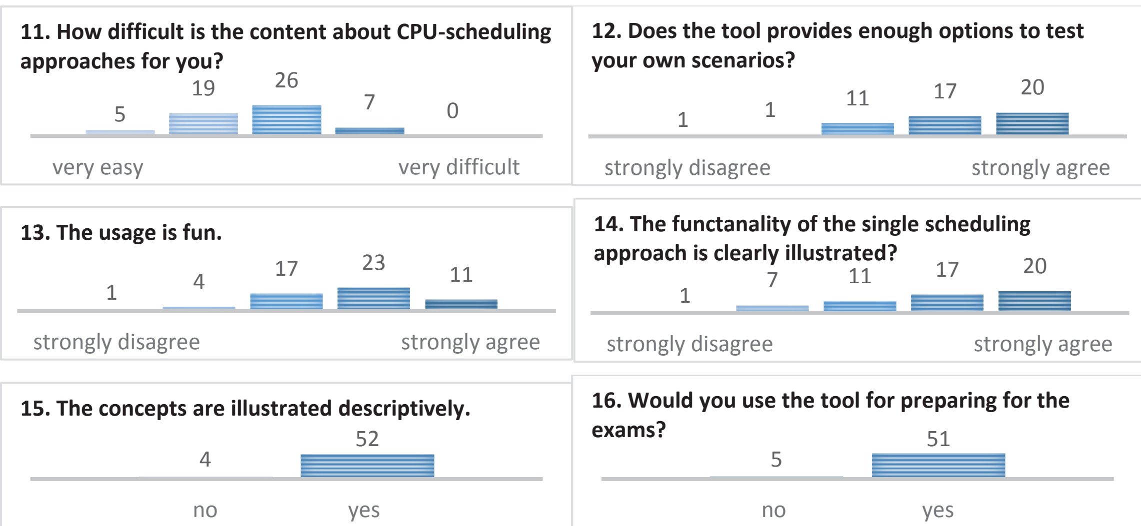


Fig. 8. Further questions of the user study questionnaire.

Question 11 shows that the overall topic of scheduling algorithms is perceived as moderately difficult. Questions 12, 14 and 15 show the tendencies that the application functions positively for learning purposes. Furthermore, question 16 shows that 86.44% of students would use this tool as additional material for exam preparation. Question 13 evaluates whether the application is fun to use, to which more than 57% of students responded favorably, i.e. agreed or agreed strongly. For the open questions, we got suggestions for improvements such as adding further scheduling algorithms and making the processes configurable in order to select your own process name, which is currently randomly assigned. Furthermore, one participant stated that the presentation of the scheduling algorithms as Gantt chart (cf. Fig. 3) is great as it shows the connection to the lecture.

Summarizing, the SUS evaluation indicates that our application has a good usability. Also, the students emphasized that they are going to use this tool for exam preparation. Further improvements will be done in the future, e.g. by extending the visualization, and we plan to conduct follow-up evaluations to continuously monitor the usability of our application.

6 CONCLUSION

This paper introduced SysprogInteract, a web application for animating complex concepts of low-level programming and operating system design in an educational context. We have described the details of our application and presented possible integrations into the educational process. Furthermore, a user study shows promising results as students are motivated to interact with this application and think the tool will help them to gain deeper understanding of the algorithms. We plan to continuously evaluate while developing further animations. We also hope that other universities will integrate this tool into their courses, so we can learn from their integration and adapt our application to fulfill the needs of all its users.

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How students and companies learned sustainability in mutual Problem Based Learning loops

K Schmidt[1]
Aalborg University
Copenhagen, Denmark

MA Mosgaard
Aalborg University
Aalborg, Denmark

Conference Key Areas: Sustainability reflecting the complexity of modern society; Lifelong learning

Keywords: PBL, Student-company cooperation, Sustainability

ABSTRACT

Problem Based Learning at Aalborg University is centered around projects and group work to enhance the students' learning. In this paper we present two cases where a problem based, real world context was applied in undergraduate environmental management courses at two different campuses, and involving two case companies. The learning of the students and the capacity building at company level were supported as parallel goals. The students learned to handle environmental management at a company level and the companies developed their capacities within these fields. The course started with a visit at the case-company, followed by five lectures where the students did assignments based on the challenges of the case company. At the end, the students presented and discussed their work with the companies. As appropriate case companies, we identified smaller companies who had relevant challenges for the students to work on, and who were interested in environmental management but did not yet have a system. The outcomes of the first two iterations of the course showed that the students got a deep understanding of sustainability issues in theory and in practice, while one company ended up changing their actual practices by e.g. implementing new sustainable business models, and they continued to develop their sustainability efforts after the students' input. In the other company, the collaboration also enhanced learning, but not as successfully due to the type of company and the timing of the interaction between company and students.

[1] Corresponding Author
K. Schmidt
kirstens@plan.aau.dk

1 INTRODUCTION

Problem Based Learning at Aalborg University (AAU) is part of the tradition of experiential learning, where students learn by applying theory and knowledge to solve problems in complex contexts, also outside academia, and reflect on their experiences [1]. Taking departure in understanding and solving an authentic problem may also lead to enhanced motivation among the students and influence their satisfaction and confidence [2], [3]. At AAU, Problem and Project Based Learned is the foundation for students' learning, and the model encompasses both extensive project work and more subject based courses each semester to support the students' construction of theory and knowledge of relevance for the semester theme. The project work for many students involves cooperation with external partners. Companies and other organizations are also encouraged to contribute with problems or issues, they would like to have students to work on.

As illustrated by Holgaard and Kolmos [4], there are different types of project collaboration between AAU students and companies, from the latter acting as informants, through more case or client based collaboration to shared practices and co-construction of processes and solutions. Their study looked into how the different types of collaboration could inspire the design of educations for employability [4]. This is in line with PBL related research on the impacts of the collaboration, focusing on how working with real problems in a given company can enhance students' learning. Not much PBL research, though, has looked into how the project collaboration may have an impact in the case companies [5]. However, research exists on the impacts of academic research on society, including private companies, and even if they may be differences in perceptions, values, etc., there are mutual benefits from cooperation between academia and the private sector. Not least, in the cases of co-construction of knowledge [5], [6], [7]. Consulting, or client-based projects, in the sense of students solving a given problem for a specific company, is also a recognized learning strategy that may potentially deliver valuable input to the company [3], [8], [9].

Most discussions of academic-practitioner relationships highlight differences in perspectives and intended outcomes, but such relationships may also be considered from a more encompassing standpoint that includes how they may jointly contribute to the creation of common knowledge and understanding on larger social issues like for example climate changes or sustainability [7]. Since PBL based student projects, according to Henriksen et al. [5] have important parallels to academic research practice, it is also relevant to look into the impacts of such projects on a company level.

Phillips [3] argue that the client-based projects may stimulate students' self-directed learning, enable students to learn a specific and practical skill, and facilitate the transfer of skills from the classroom into personal skills for life. However, the lack of structure and instructions that characterizes the self-directed projects may also create frustration and ambiguity among some students. More formalized structure and guidance in the research process could not only reduce the students' negative feelings but also reinforce the positive ones [3].

In an evaluation of a series of client-based projects carried out by students, Grossmann [9] mentions that benefits for the industry depend on the selection of projects, the maturity of students, and the degree of faculty involvement, and range from stimulus to actionable advice. A small fraction of student projects can even go on to become case studies or applied research. Moreover, industry clients stated that the process of explaining their business and responding to students' questions stimulated valuable new thinking, even if the student deliveries were not of direct use for the company [9]. In a recent, still unpublished, study, Henriksen et al. [5] analysed if and how PBL based student projects with case companies stimulated the creation of mutual values and impact. They distinguished between a potential for impact and a realized impact. The potential impact was affected by the quality of the project including among other things the mutual engagement, coordination, and alignment of expectations, while the realized impact was affected by activities at the company, including what the company invested in the project, how the students' reported their findings and related to the companies, and how, or if, the company decided to continue working with the results [5].

At the AAU bachelor program Urban, Energy and Environmental Planning, sustainability is a major issue for the students to work on. The fifth semester is dedicated to how companies can work systematically to improve their sustainability performance, and students are working with companies during their semester project. Two parallel courses deal with the environmental impacts caused by companies and with the organization of the environmental effort, among other things based on the ISO 14001 Environmental Management Systems standard to familiarize the students with a management system standard approach [10]. The courses are examined on their own, but they also support the students' learning of relevant aspects of potential use in their semester projects. Faculty on one of the courses decided to test if a small scale project together with a case company could facilitate the students' learning of the basics of environmental management in the course, and at the same stimulate the company in advancing its environmental practices. The interaction was also thought to have a positive impact on how the students organized their self-directed semester project.

The purpose of this paper is to reflect on the testing by discussing the following questions:

- What are the outcomes for the students and for the companies of a mutual, PBL based learning loop on how to organize systematic environmental management in the company?

- What to consider when planning and organizing a mutual learning process for students and companies as a part of a course to optimize the learning outcomes?

2 METHODOLOGY

The paper uses a case study approach to analyze how the interaction between students attending a course on environmental management, and selected companies influenced the students' learning outcomes and the companies' environmental practices. The course and the semester projects took place at two campuses in parallel, but were organized and conducted in different ways. This opened for reflections on what may influence the learning outcomes when it comes to planning and implementing, within a PBL framework, the use of small scale projects on course level in combination with larger, student directed semester projects.

Two parallel semesters and courses ran in two different campuses at the university. The analysis took a point of departure in the Aalborg case, since it has run for 2 consecutive years, 2017 and 2018, with the same case company, but with different environmental focus areas determined by the interests of the company. This provided two years of empirical data for the analysis. The Copenhagen case, following the same structure as in Aalborg, but only in 2018, contributed with reflections on lessons learned when working with another type of company and another group of students. The companies were chosen by faculty from these criteria: willingness to cooperate with the students, having relevant environmental challenges for the students to consider, having a physical site for the students to visit not too far from campus.

Case studies often involves numerous sources of evidence [11], and Table 1 presents an overview of the sources of evidence used to evaluate the outcomes of the small scale project in Aalborg.

Table 1. Sources of evidence used for evaluation of outcomes in Aalborg

Source of evidence	**Purpose**
Learning objectives, curriculum and program of lectures and activities	Understanding the course set-up and purpose
Feedback on steering group meetings	Evaluation of outcomes for the students
Ongoing evaluation on the course and evaluation at the end of the semester	Evaluation of outcomes for the students
Interview with 4 students in 2018 and 4 students in 2019	Evaluating the outcome for students and understanding how motivation is influenced by the “real world” case
Meeting with company before semester start in fall 2018 and fall 2019	Understanding the motivation of the company and preparing the case
Interview with company representatives after the course has ended	Understanding the impacts from the students on the practices etc. of the company

The outcomes for the students in Copenhagen were evaluated from feedback on steering group meetings and from ongoing evaluation during the course and at the end of the semester. Company outcomes were evaluated from oral feedback given by the technical director to the students, by e-mail correspondence between company and faculty after the project, and by statements made by the company in an article published in public media after the project [12].

3 CASES

The following part presents the “Organization of Corporate Environmental Management” course as it was structured in 2017 and 2018 on 5th semester at the bachelor program Urban, Energy and Environmental Planning at Aalborg University. Initially, the course is described from a content perspective. Then follows an analysis of how the course structure resulted in learning outcomes for both the students and the involved case companies (section 4). Finally, there is a discussion (section 5) of success factors for creating mutual learning students and companies, and how this motivates both students and company, including also aspects that might demotivate students.

3.1 The content of the course

During the course, the students learn how companies over the last approximately 50 years have developed their approach to handling the environmental impacts from production and products, and how this is regulated by the authorities. The first part of the course addresses a systematic approach to environmental management related to both strategic, tactic and practical approaches. The learning objectives focus on understanding how standards for corporate environmental management are implemented in organisations. The students learn, among other things, how to formulate environmental policies and implement these in procedures, goals, targets and action plans in a company. It is in this part of the course, a case company is involved, as illustrated in Table 2:

Table 2. Overview of the small scale project in the course

	Theme/Lecture	Assignment	Interaction with company
Lecture 1	**The historic development in corporate environmental management**	**Different wiews on corporate environmental management**	**Site visit and presentation**
Lecture 2	**Strategic environmental management**	**Environmental policy**	**Limited to written information**
Lecture 3	**Tactic environmental management**	**Environmental procedures**	**Limited to written information**
Lecture 4	**Operational environmental management**	**Environmental goals and action plan**	**Limited to written information**
Lecture 5	**Environmental management – the system**	**Strategic environmental initiatives**	**Assignments are presented to the company**

During the course, students and companies interacted through a site visit at the first lecture, for students to have a presentation of the company and a real-life experience of the ongoing activities. Written materials of relevance were provided to the students during the following lectures as a part of their working with the requirements in the ISO 14001 standard. At the last lecture, the company visited the university to hear students presenting their analyses and recommendations, followed by a discussion among students, faculty and the company.

The lectures were designed to create a learning loop for both students and companies by having both the site visit in the beginning and the presentation of assignments in the end, where the students needed to reflect on their assignments in order to make a coherent presentation for the company.

As part of the preparation for the oral exam, each student prepared a few slides per lecture as a starting point for explaining the main issues and challenges of implementing environmental management on the different levels, from strategic to operational, in the case company – including their recommendations to the company. Thus, examination was closely linked to all five steps in the small scale project, and the students had an interest in getting the most out of working with the company case.

3.2 Organization of the interaction with the companies

The preparation of the case is essential for a positive outcome of the case collaboration. It is important to choose a company that faces exactly the kind of challenges that the students' need to work with to meet the learning objectives of the course. In this case, a company interested in a systematic environmental management system, without having implemented one yet. Also it is important to make it clear to the company that they will not receive "expert solutions and ideas" but need to collaborate with the students to their mutual benefit and learning for both partners. The level of environmental awareness and experiences in the company presents different learning potentials for the students as well as for the companies as shown in Table 3:

Table 3. Overview of learning opportunities

Type of company	Learning opportunities for students	Learning opportunities for company
Proactive on environmental management	Understanding a "best practice" approach. Analysing existing practices and suggest changes	Limited, but may get some new ideas and perspectives on existing practices or potential improvements
Interested in environmental management	Learning how a company operates and suggest how to implement environmental management	Big learning opportunity as they have limited experience but would like to learn
Reactive on environmental management	Learning the importance of (lack of) organisational support. Developing suggestions for how to change priorities and implement a new approach	Potentially the learning opportunities are big but in reality it is hard to implement the ideas

In the Aalborg campus, students worked with a recycling company that were motivated to implement an environmental management system certifiable according to ISO14001. The company had not started implementing a system yet, but the director and the operations manager of the company had both worked in ISO14001 certified organisations before, and had an idea of the potential benefits and obstacles of such a system.

In Copenhagen, students worked with a company leasing equipment to craftsmen and to construction sites. The company had no production of its own, but handled and maintained products from suppliers. The company had a certified Quality, Health & Safety and Environmental Management System, according to DRA (Danish Rental Association), and the company was interested in knowing how they could proceed to a more advanced environmental management as required in the ISO 14001 standard. For practical reasons, the site visit to the company took place only two weeks before the last lecture, not in the beginning.

4 OUTCOMES OF THE MUTUAL LEARNING PROCESS

This section shows the learning outcomes of the students and what the companies gained through the collaboration.

4.1 Outcomes from a student perspective

Based on feedback from students on semester steering group meetings, through interviews and from the students' reactions after presenting for the case company, the main outcomes, the students gained from cooperating with a specific case company were related to better understanding of real life challenges and opportunities for working systematically with environmental management. Moreover, getting immediate feedback from a potential "customer", the company, helped them understand and assess the relevance and potentials of their ideas and suggestions. This is very important since working with environmental management only from the requirements in a standard may lead to rather hypothetic proposals.

Another positive outcome mentioned was a higher motivation, not the least from realizing that the companies de facto implemented student-based ideas. This was especially important in the second year in Aalborg where examples from the previous year were available. The students in Aalborg also expressed very clearly both years that the fact that they had to present their results to the company, and get their feed-back was very motivating. One of the students said:

"All of a sudden we found out that even at the 5. Semester with a new topic at hand, we can actually develop materials that a company finds valuable." (5. Semester student, 2018)

From a teacher and examiner point of view, another type of outcomes also became clear. Presenting analyses and recommendations in a way that made sense for a company, and at the same time being able to bring their learnings and discussions to the academic table during the examination, helped the students bridging practical experiences and academic learning. Moreover, the small scale project with a case company served as a good preparation for the exam, which the students on average passed with high-end grades (*Statistics on grades provided by examiner).*

In Copenhagen, students were also happy to have the chance to work directly with a case company. However, they struggled to find what they thought of as something useful for the company, since the company already did a lot of things. Some students also found the company uninteresting, since it apparently had no major environmental issues to improve. Finally, the rather late site visit meant that the students lacked the on-site experiences when they worked with the strategic and tactical aspects of environmental management.

4.2 Outcomes from a company perspective

The outcomes from the company perspective ranged from ideas and inspiration to specific proposals that could be, and in some cases were, implemented.

In Aalborg 2017, the students focused on how the company could make their business models more proactive in a sustainability context, and they suggested a new model for renting the products to costumers instead of selling them. This secures an increased use of the single product and hence reduced the need to produce more products. A year later, this was implemented as a leading business model for the sale of this product category. In a broader understanding, one can say that the company expands its focus from resource reduction to circular economy as a part of the business model. As another outcome of the collaboration, the company initiated an ongoing collaboration with both Aalborg University and Network for

Business Sustainability in Northern Jutland, to keep focus on strategic environmental management.

In 2018, the students had a focus on how the company managed the machinery and addressed this by suggesting how to involve the employees in the environmental efforts. This lead to a change of practices in the company where the employees are now involved in reducing the environmental impacts from production and operation of the company.

Another type of outcome was a discussion of how the products (non-permanent sound reduction walls) could have an added value by using the “back side” of the wall for interaction with the local community in the area. E.g. by being equipped with “climbing walls”.

Thus, the case company in Aalborg was satisfied with the outcomes, as stated by the production manager:

“We find the interaction very enriching. The students come with suggestions that we never considered before, but they do it with respect of who we are” (Manager of the company, 2018).

In Copenhagen, focus for the students was to prepare a new version of the company’s environmental policy, to select a relevant environmental issue (most of them chose waste handling) and to prepare an action plan and procedures that could be incorporated in the existing DRA certified management system. The company did not express any specific areas for the students to look at. Since the intended outcomes was quite open ended for the company, students and faculty prepared a brainstorming list with around 30 suggestions for the company on how to improve their environmental performance. The technical manager responded to the ideas and were especially happy for the suggestions to improve waste handling, to realize market potentials in becoming an ambassador for environmental improvements in the construction sector, and to start co-working with the suppliers, even if it may become challenging. After the project, the company continued working with environmental aspects on a strategic level with a point of departure in the UN’s Sustainable Development Goals. The company contacted the university later to ask if students would like to continue working with them.

“*Having 30 people looking into your business is truly a gift. With a larger number of people, we can have many more and new nuances on the way, we run our business”* (Quote from the technical manager of the company in the article published on the cooperation) [12]

5 DISCUSSION

For the small scale project to become a successful learning experience for the students, apart from the motivation in itself of providing valuable and useful input to the companies, some aspects are important to consider, even if this case is very small and one should be careful in generalizing. The small scale project took up half the lectures in the course, and one has to be sure that it can cover adequate parts of the learning objectives and provide sufficient understanding for the students on the environmental challenges of companies, both in theory and in practice. Four significant lessons were learned through planning and conducting the small scale projects:

Careful selection of case company. Students attending the course had no previous experiences on companies and how they deal with environmental aspects. They need to establish a basic understanding. As a teacher, it may be tempting to choose companies with best practices to inspire the students. However, the students learned more from challenging themselves to come up with suggestions to the company, than from being informed on what the company was already doing. From a company learning perspective, the optimal situation seemed to be a situation with high interest in environmental management, but not having a system implemented yet.

When constructing the basic understanding of the company's environmental impacts, and how to handle the impacts, students favoured direct impacts that were recognizable when visiting the company. For example, students in Copenhagen found very little direct impacts in their case company, since most of the impacts were indirect and related to either the suppliers/manufacturers of the equipment, or to the phase where the craftsmen used the equipment leased at the case company. The indirect impacts are also relevant in environmental management, but from a learning perspective, they may not be the best way to start.

The mutual learning process co-constructed a common understanding of the formal requirements of the ISO 14001 standard for environmental management, and the challenges a SME faces in implementing a systematic approach as required by the standard. Since small companies struggle with having time to search for background knowledge, the students' digested and adapted knowledge on the standard made it more useful, which may have stimulated the companies to continue working with the issues.

Alignment of expectations on process and outcomes to make sure that the company can and will provide information and constructive feedback to the students. This means that the company in advance has agreed to spend time and resources on providing data and information for the students, but also that the students will share their documents with the companies afterwards. As for the outcomes, students need information on what expected deliveries are, since they may be afraid of making a fool of themselves in front of the company.

Timing of meetings between students and company to support that mutual learning can take place. It is important that the students visit the company early in the process, as this creates the foundation for working with assignments related to the case. In addition, an early visit creates an opportunity for the company to influence the relevance of the work made by the students.

Structure of the project. A clear and determined structure of the small scale project is needed to secure the fulfilment of learning objectives. Relating each lecture with a requirement for the exam proved to be effective in having all students' focus on active participation, even if they may not be very interested in the topic of environmental management on the mandatory course. Moreover, the clear structure in the small scale project served as a stepping stone for the students to transfer the learnings into their self-organized semester projects that were started up in parallel to the course, but with a longer time frame. This may help overcome the ambiguity and frustrations, some students face especially in the beginning of the self-directed projects.

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‘Quo Vadis’ Engineering Education?

K Schrey-Niemenmaa[1]
Senior consultant, Quality of Education and LLL
Espoo, Finland

M Jones
Imperial College London
London, UK

Conference Key Areas: 4th Industrial Revolution, How to detect and attract talents with new generations of learning technologies and networks?

Keywords: Engineering education attractiveness, future needs, diversity, competences

ABSTRACT

During the 46 years of SEFI’s existence things have changed both in engineering practice, e.g. CAD/M and simulation, and in education, e.g. blended learning and MOOCs. However, there are some things that continue to be of concern, such as the expanding curriculum, engineering status in society, engineers’ knowledge of the wider constraints affecting engineering decisions and the ability to communicate effectively to non-specialists. This has been brought into focus by the recently announced decision in the UK to establish a new university – the London Interdisciplinary School - with the expressed intention of providing a much broader curriculum of science, arts and design technology while at the same time receiving endorsement from several organisations that state they want ‘a new style of graduate, who is more rounded and able to solve problems’. Knowing how much effort engineering academics make to produce a balanced curriculum, matching an understanding of basic principles with learning to address contemporary challenges, one wonders where the shortfalls exist. At the same time engineering educators are being asked to address sustainability and climate change issues, ethical dimensions, attractiveness whilst encouraging entrepreneurship. Where should we put our goals and ambitions? What is the role of lifelong learning? In this paper we try to inject clarity into the discussion by suggesting that the admission requirements of the students, the nature of the education, and the possible ongoing opportunities should be made more explicit. It is examined both from societal needs and issues bothering the profession.

[1] K Schrey-Niemenmaa
katriina.schrey@gmail.com

1 INTRODUCTION

1.1 Starting point

The complexity of challenges facing engineers today has risen exponentially during the years of industrial revolutions. In the beginning scientists needed all the available information and they were creating new theories and inventions based on that. However, today no one can manage all the information available and the inventions are expected to tackle much wider aspects. How can engineering education not just follow - but enable students to acquire the skills to meet the requirements of future needs?

No degree can any more give enough competences for the whole career. The role of lifelong learning in engineering has become inevitable.

1.2 Future needs

But from where are the future needs coming? What is the role of engineering education when building the future? How can the cooperation between different disciplines be made free of boundaries? Furthermore, what is the role of Universities in the future - what and how much should be included in the different degrees - bachelor/master/doctor of engineering or technology; and what is the role of continuing education. How much does an individual need to carry responsibility and costs for acquiring and maintaining his/her on skills, what about the employers and society?

1.3 Growing and declining skills

Based on its report the ”Future of Jobs Report 2018” the World Economic Forum has listed those skills, which are required to perform most jobs and has highlighted that these will have shifted remarkably by 2022. Still according to that report the amount of core skills that remain the same is expected to be about 58%. [1]

When taking a more detailed look at the skills listed in the figure 1 one can wonder how such skills are best developed. What kind of subjects need to be included directly in the curricula. Furthermore an important issue is the role of different pedagogical methods to be used. One example of this is how you teach or learn, perhaps broadly called “Emotional intelligence”?

However, an important issue is how one can learn “analytical thinking and innovation” or “technology design and programming” if “reading, writing, math and active listening” are not managed appropriately?

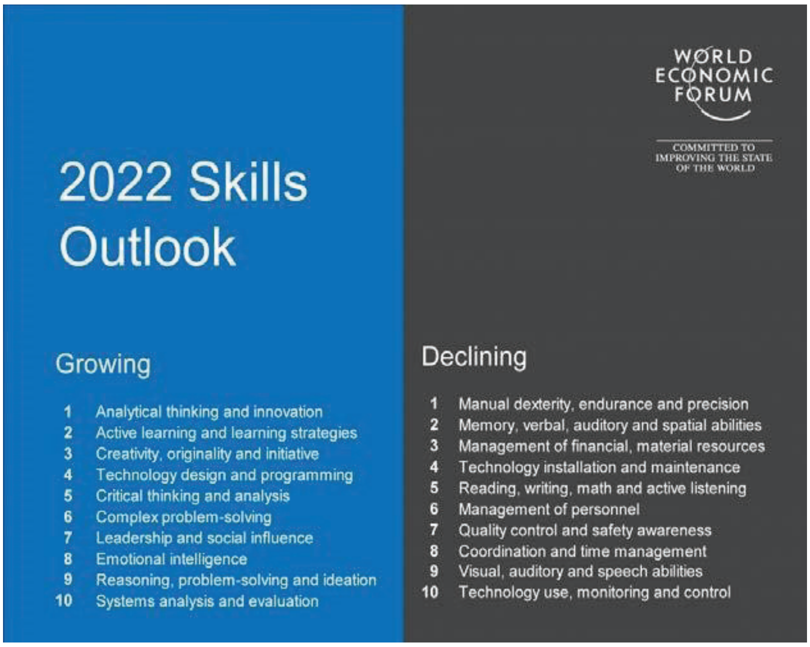

Fig. 1. Growing and declining skills from World Economic Forum; Future of Jobs report 2018 [1]

2 CHANGING WORLD

2.1 Challenges of the planet

Climate change and the problems that are caused by it can no longer be ignored. Facts and figures related to climate change are collected by The Intergovernmental Panel on Climate Change which is the United Nations body for assessing the science related to climate change [2]. All future decisions need to take into account a wide range of aspects that are not directly technical. Additionally the earlier constructions need rethinking and transformed to the use of sustainable solutions. Less polluting energy production, less energy consumption in the processes etc. This means that there needs to be a deep understanding and a willingness of engineers to evaluate their designs with these aspects in mind.

2.2 Challenges of the industrial work

The 4th industrial revolution is highlighting the role of artificial intelligence, internet of things and other consequences of digitalisation. These aspects are changing the way of working. As has been written by Professor Klaus Schwab, Founder and Executive Chairman of the World Economic Forum, “Ubiquitous, mobile supercomputing. Intelligent robots. Self-driving cars, neuro-technological brain enhancements and genetic editing. The evidence of dramatic change is all around us and it’s happening at exponential speed.” [3].

2.3 Challenges of globalisation

Everything seems to have a global impact. The 4th industrial revolution leads to Globalisation 4.0, combining the major shifts underway in technology geopolitics and society [4]. The financial crises and trade war, population movements, relationships between countries and continents are all part of the environment where the future engineers work. Still, what is the role of an individual engineer? Does each engineer need a holistic view of all the impacts of their work to the global situation? Or will the needs of education lead to skills in layers where each layer needs to understand the requirements of the input of the lower level and output to the higher level. However the “layers” are not hierarchic or appreciation rankings - but all equally important.

2.4 Challenges of the pedagogical formats and the role of University

The students of today are used to flexibly combine many formats of learning. Huge amount of information is available from the internet, additionally to the organised packages of learning offered by different institutions. In many cases the need for face to face contact, tutoring, mentoring and learning physically together is considered time consuming and inefficient. However, many inventions, finding right information, ensuring the balanced consideration of the issues require “old style of guidance” additionally to the new pedagogical setups.

3 REACTIONS OF THE UNIVERSITIES

How can Universities react to these rapidly changing requirements and demands? The answers are additional to the global trends and very much dependent on cultural traditions [5]. It seems that there are several main streams to the competence development of the students:

- Deep theory with tools of STEM in a limited area of disciplines - competences of scientific work in that area
- Basic understanding of science from multiple areas (generalists), competence of defining the problem and gathering together specialists to solve it
- Pedagogical solutions might arise from theory based learning versus practise based learning. Furthermore, digital technology can be used in multidimensional online ways - materials for learning, lectures, interactive courses and even simulations of demanding technical processes.

3.1 Example from UK

Imperial College London and New Interdisciplinary School of London [6] are based on fundamentally different approaches. In both cases the most talented students are wanted. In Imperial College the accumulation of a reputation over many years attracts high quality applicants and the institution can select “the best of the best” for their programmes. Also the students are expected to work hard and learn the theories so that they can use and further develop their own in the future. In that curricula the demand for new elements to be added is ever growing - although one could think it is a narrow area. Currently however the institution is undertaking a complete review of its curricula in all departments.

On the other hand the New Interdisciplinary School of London is attracting students by promising “the needed core knowledge from each of the disciplines defined by the most successful industrialists and scientists”. Such students need to have an extraordinary talent for combining the essential knowledge without going-in too deeply on details. One can wonder, what is the real profession from this programme? How the highly intelligent graduates of these two different lines can work together, appreciate each other and create our future academic will have to be seen! **3.2 Example from Finland**

A similar type of diversity in the programmes can be recognised in Finland as well, although such extremes do not exist. In Finland the “normal” talent can enter the university and the theoretical programmes are slightly more general and the general programmes slightly more focused than in these examples from London.

The master’s programmes of Electrical Engineering are very deeply based on understanding of the calculations of electromagnetic fields and such knowledge of mathematics and physics. On the other hand there are several master’s programmes in engineering such as “Information networks” that for instance concentrate on building bridges between the machine designers and different users or customers. Analysing the challenges, creating solutions and understanding the possibilities of coding as a tool is very important. Still both of these programmes are strictly engineering programmes.

3.3 Role of continuing education

On the job learning is considered to be the most effective way of developing competences in working life. Recognising the learning and collecting a portfolio of development could help engineers to make visible the level of knowhow attained. However, additionally different kind of courses are needed. Especially in the cases when the jobs are changing, or engineers have been away from the working life for a while.

The International Association for Continuing Engineering Education IACEE is supporting and enhancing Lifelong Engineering Education around the globe for instance by promoting the use of online webinars, MOOCs and different options for learning more about sustainable development with the programme SERINA [7]

4 WHAT ATTRACTS STUDENTS

According to the authors’ experience, different types of engineers are needed. Important to all of them is to understand the role of their expertise. The usefulness of deep knowledge from narrow area needs to be introduced to colleagues who might not understand the details but who could be able to use the results.

The ones who might understand the need for a medical device might not understand how to create it - and the one to create it needs to get the information about the human interface to produce an appropriately adaptable design. And perhaps the programmer needs only some of the information to be able to create the algorithms and coding.

The jointly needed competence is communication, appreciation of each other's orientation to contribute to the overall solution.

4.1 TEK annual survey of new graduates

Academic Engineers and Architects in Finland TEK is executing an annual feedback survey for M.Sc.(Tech) graduates [8]. The survey covers the whole country and the response rate at over 80% is amazingly high. In the year 2018 at the time of graduation 76% were already employed, and thus had some understanding of the realities of working life and competences needed. Almost 90% of the graduates answered that if they needed to choose now the area of studies they would choose engineering again.[8]

In the survey, among other things, it was asked about the different competences - how important the engineers found them, how much the competences were developed during the studies and how much they were developed while working during the study time. In the figure 2 is illustrated the results of these questions. Replies were received from a total of 1783 graduates.

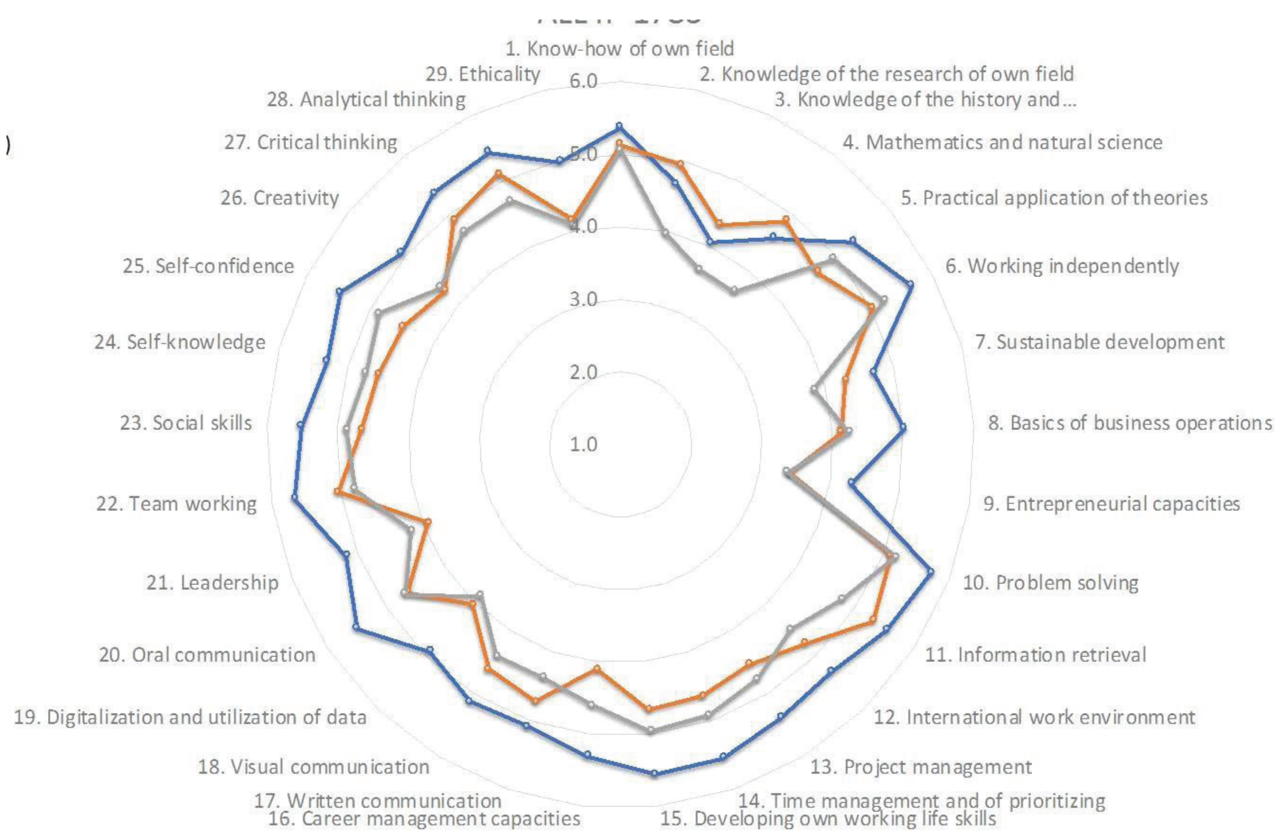

Fig. 2. The evaluated importance of competences (blue line) versus the gained competences from studies (red line) and work experience (grey line), the scale of importance is: 1=Not at all (important), 2=Very little, 3=Little, 4=Somewhat, 5=Much,

6=Very much. The illustration by Arttu Piri from the 2018 survey undertaken by TEK, in Finland [8]

Of interest is that the “knowhow of own field” was evaluated very important and the competency in that was gained very well both in studies and work-experience. That confirms the need to have a deep understanding of “hard skills” and then to support those with “soft skills”. As a surprise “entrepreneurial capacities”, “basics of business operations” and “sustainable development” were ranked about as low as “knowledge of the history and development of own field”. However, in these competences even the low needed level was not reached.

Quite large gaps between the required competences and gained competences were in ethics, creativity, leadership and “digitalisation and utilisation of data” were found. The last one might be a problem for the future career if the World Economic Forum outcomes are to be believed.

4.2 ASTEP2030

An ERASMUS+ project “Attracting diverSe Talent to Engineering Profession 2030” is aiming to increase awareness of Engineering in Europe, highlighting the critical part that Engineers will play in solving global challenges and encouraging more diverse students to engage with engineering studies. That project is created by the SEFI working group of Attractiveness of Engineering Education [9].

Already the first results show that the big questions, problems and global challenges need engineering knowledge to be adapted to all developments and solutions. More cross disciplinary cooperation and diversity in all possible meanings (gender, nation, religion, region, age etc) need to be involved to build the future of human kind.

The challenge to Universities is to introduce engineering programmes as ways to become problem solvers. This means also the development on learning methods. Learning needs to be fun. Connection to real life projects, problem based learning, CDIO, use of offerings from internet like MOOC’s could enable individual learning baths.

Engineers, as a profession need to manage the “hard skills” and fundaments to development them - furthermore communication and cooperation with other professions with honest appreciation is crucial.

5 SUMMARY

The answer to the question: ‘To where engineering education is going?’ is very much giving directions where the whole globe is going to. How well we can educate narrow deep specialist and wide generalists who can work together benefitting the competences of each other of them. Communicating and appreciating the different views. Finding solutions which are good for the sustainable development of the future.

These are not easy demands for engineering education of the future - but if engineering schools are able to manage the diversity they will attract much wider population to the profession.

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Enhancing group work learning with the Individual Peer Assessed Contribution (IPAC)

Alan Seatwo,

Learning Technologist,

University College London, United Kingdom

ABSTRACT

In 'Are Universities Redundant', Arvanitakis and Hornsby (2015) suggest that global, technological and scientific changes are driving change of curriculum design in University that curriculum design needs to embed the concept of the 'Citizen Scholar' which promote scholarship and *inculcate a set of skills and cultural practices that educate students beyond their disciplinary knowledge*. How to Change the World is a two-week scenario for second year engineering undergraduates that emphasises engineering's potential as a vehicle for positive change. This paper attempts to explore the effectiveness of embedding peer assessment in the Programme to assist graduates reflecting on across a range of proficiencies and attributes that are essential for the challenges of tomorrow. IPAC (Individual Peer Assessed Contribution) is developed and led by Dr Pilaras Garcia Souto as a pedagogical tool and a digital tool to train graduates to give constructive criticism, meaningful and professional feedback to each other in group work assessment. This peer assessment was also designed to improve the fairness and transparency of group work assessment across these proficiency clusters.

The quantitative data confirmed that overall student engagement was improved. It suggested that students within their group seem to understand better about their roles and responsibilities; the proficiency to deliver the expected assessment outcomes; and the value of their individual contribution to group work. Although the overall assessment grades were not comparable to suggest whether graduates achieve higher learning levels, this paper suggested that graduates were motivated to learn in a group work with peer assessment format.

INTRODUCTION

Our world is now much better connected than ever before. Technological enhancements in computing science enable people to work seamlessly regardless of geographic, time and language barriers. Complex challenges, such as climate change, global health, sustainable energy and rapid urbanisation, have significant global impacts on social, economic, educational and cultural levels. The global, technological and scientific changes are driving structural change at a global level affecting the way we live, learn and work. University graduates not only require having the knowledge competencies, but they are also expected to equip a range proficiency to enable them to deal with complex global challenges in fast changing environment. This paper aims to use a two-weeks intensive inter-engineering programme entitled “How to Change the World” delivered by the Department of Science, Technology, Engineering and Public Policy in the University College of London (UCL) for a cohort of six hundred and sixty- seven students as a case study to explore the effectiveness of using an online peers' assessment within a problem-based learning approach to enhance student engagement and tackle issues associated with group work. The paper will draw qualitative data from two separate evaluations and the programme teaching log to inform the impacts and further development.

1 THE PADAGOGY

1.1 The concept of “Citizen Scholar”

Arvanitakis and Hornsby (2015) argue that universities simply offer education around disciplinary content alone is no longer adequate to address the needs of the 21st century graduate. Universities need to future-proof themselves by focus on a new set of ‘Graduate Proficiencies’. Particularly important to this is the concept of the ‘Citizen Scholar’ in which it is the role of a university to promote scholarship and inculcate a set of skills and cultural practices that educate students beyond their disciplinary knowledge.

As a part of the Citizen Scholar concept, the writers identify distinct groups of ‘proficiency clusters’ as a broader categorisation of proficiencies and attributes that are essential for preparing students for the challenges of tomorrow.

These proficiency clusters are as follows;

Cluster 1: Creativity and Innovation	· Critical Thinking · Problem Solving · Reflexivity · Entrepreneurship · Being Process Driven · Systems thinking
Cluster 2: Resilience	· Adaptability · Mistakability/ Perseverance
Cluster 3: Working Across Teams and Across Experiences	· Interdisciplinary · Cross-cultural understanding · Developing new literacies · Internationalisation · Inclusivity
Cluster 4: Design Thinking	· People-centred thinking · Aesthetics · Ethical Leadership

These proficiency and attributes are especially important in the case of engineering programmes in UCL. We ask our graduates constantly to transcend their own particular disciplines and identify in particular how they can mobilise science, technologies and engineering through the use of diplomacy and leadership to practically navigate stakeholder concerns, lead interdisciplinary teams, and can communicate and engage with wide range of audiences through a variety of media. Two teaching and learning approaches are adopted to enable graduates to learn and apply these proficiencies: problem-based learning and peer assessment.

1.2 Choosing the right teaching and learning approaches

Problem-Based Learning (PBL) is an approach that put student as the centre of learning in which a problem needs to be solved. Students learn both new knowledge about the subject domain as well as problem-solving skills when they learn individually. But when they work in groups with their peers and use their prerequisite knowledge to define the problems, acquire new knowledge to design innovative solutions; this process fosters further development of communication, collaboration, and self-directed learning skills (Hmelo-Silver, 2004). These anticipated learning outcomes match the concept of ‘Citizen Scholar’ and the PBL is also proven approach that works well with peer assessment.

Peer assessment is defined as an arrangement in which individuals consider the amount, level, value, worth, qaulity, or success of the products or outcomes of learning of peers of similar status (Topp, 2009). Studies have informed that peer assessment is an effective learning approach to promote the development of teamwork and other professional skills in undergraduate students. It fosters the ability to critically evaluate their own learning and in helping students to develop a sense of ownership of their learning (Boud, 2007; Sivan, 2000). Although PBL and peer assessment offer great benefits to student’s learning, there are challenges in deploying them in group work learning.

The most common issue within group work is that some students present in the learning activities and pretend to be active but let others do the actual work. Group work assessment tend to give a collective mark equally to each group member. For student, these so-called “free riders” quite often affect the group dynamic: they demotivate others who would feel unfair as these “free rider” would receive the same mark as them. Other common issues within group work are absence of team leadership, poor communication, lack of participation and inability to resolve conflict etc. For teacher: it is difficult to intervene without any substantial evidence. Peer assessment is recognized as a good approach to tackle some of these student group work issues: students understand the marking criteria and in return understand better of how to achieve meeting the learning the objectives as a group by recognizing their individual roles and responsibilities. The feedback from the peers also provide teacher an insight of how well each group work. Still students can co-op themselves by agreeing on giving each other the same mark or game-on individual(s) within the group. There is also an administrative burden when conducting peer assessment manually. What it shows is that peer assessment method does not eliminate every issue associated with group work but the benefits to student’s learning are outweigh the potential drawbacks. Provided Together with an online peer assessment tool, teachers could administrate the process more effectively.

2 METHODOLOGY

This paper uses UCL How to Change the World with a cohort of 676 second-year engineering students as a case study to examine the effectiveness of using peer assessment to enhance student engagement and address group work associated issues when it is deployed in problem-based learning. Evidence will be drawn from feedback from two separate evaluations and the programme teaching log.

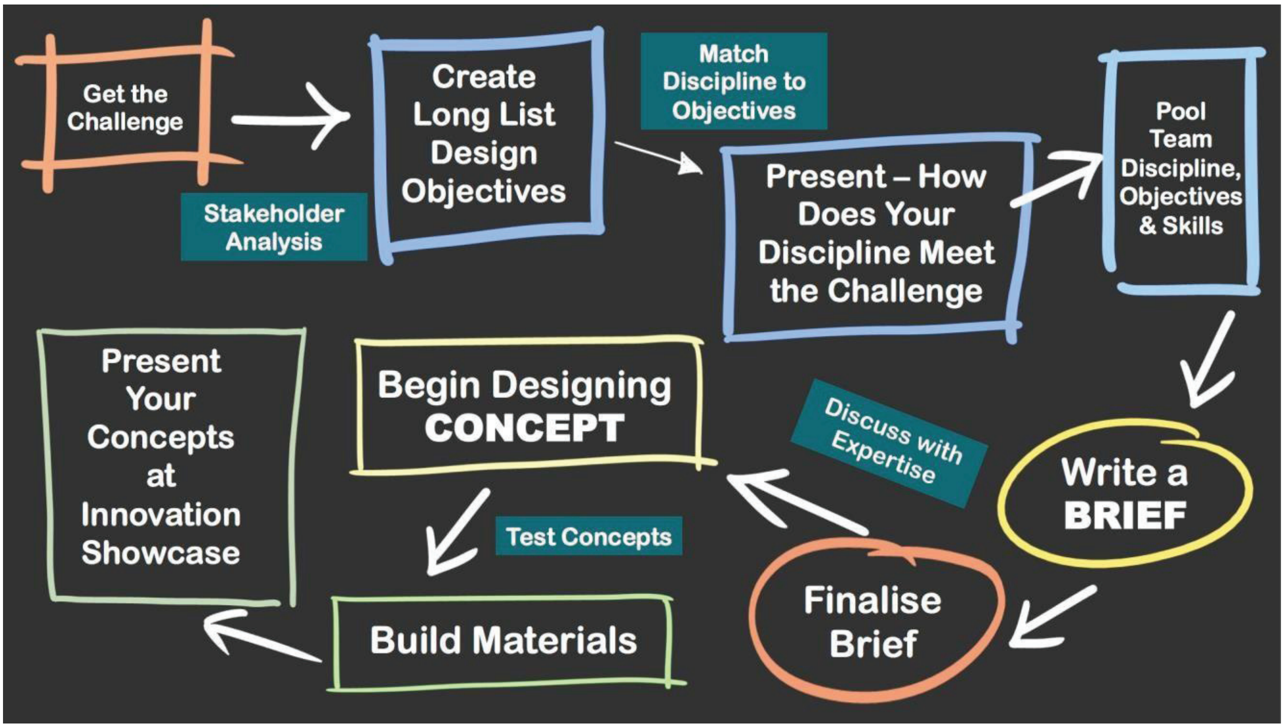
2.1 How to Change the World

The ‘How to Change the World’ (HtCTW) is designed with the concepts of ‘Citizen Scholar’ and a pedagogy that shift away from contents to a more problem-based learning approach. Throughout the UCL engineering degrees, students are taught the key technical skills they need to be leaders in their field. HtCtW aims to teach students the skills they need to apply this knowledge to specific real-world problems in a meaningful way.

In this two-weeks intensive programme (9 days teaching/ workshop facilitation), students are grouped in teams and work on open-ended problems, considering social and cultural contexts, and the different ways business and governments are motivated to engage with these changes. Students work in their teams and they are required to provide a design solution to a specific challenge. These challenge briefs are created in partnership with external experts, from policy, industry and the third sector and they are based on the United Nations (UN) Sustainable Development Goals (SDG) that relate to poverty, inequality, climate, environmental degradation, prosperity and peace and justice.

One of the primary objectives of this programme is to promote an interdisciplinary approach to some of these world’s big challenges. Each team is designed to consist of students from 7 different departments in UCL Engineering, ranging from Mechanical Engineering to Chemical Engineering and School of Management. The aim of this is to get students from several disciplines to create unique solutions to challenging issues. Students are encouraged to allocate team roles. For example, students from the School of Management may want to take on business and implementation plans, whereas engineers may want to take on technical aspects of design, and computer scientists equip the project with smart additions.

The programme is delivered through facilitated workshops in which students explore the social, political, and economic dimensions relating to their designated challenge. They were guided to use frameworks that enabled them to narrow the scope and produce innovative design concepts, whilst benefiting from feedback and input from external partners. On the final day, each team displayed their work at an Innovation Showcase and pitch their concepts to a panel of experts.



On Day One after the initial plenary session, students join their Challenge Cohort, meet the other students in their team and dive in the process to develop their design. From Day Two to Three, students have to complete their draft design brief (before the end of Week 1). On Day Five student will finalise their design brief after discussion with expertise; develop the design concept and produce presentation materials on Day Six and Seven; and Day Eight to pitch the concept to a panel of experts and Day Nine students showcase their works to their peers.

The programme is designed to be intensive with a level of uncertainty to reflect on the real-world environment: the programme consists of nine days in total; students are put in an interdisciplinary team that they never work with each other before; and the challenge briefs are complex to address.

To meet the learning outcomes successfully, students need to communicate across interdisciplinary; work in teams to gain an understanding of the complexity and challenges of the interconnected world; gain a strong sense of social, ethical and political responsibility. Students need to apply skills like teamwork, leadership and problem solving through innovation and entrepreneurship. Within their teams, students need to make every effort to include the expertise of all team members in the final design solution.

In previous years HtCtW experienced problems of student's engagement that some students did not turn up after the first week and some groups were dismantled due to team dysfunction. Programme evaluation revealed that they were partly caused by the timing of the programme but mainly issues of working in a team. All students were required to attend the programme right after they finished their final examinations and students generally felt fatigue at this point. To address the issues of student working in a team such as "free rider", a probation method was used when teams find that a member was not contributing: they could put this person on probation, which gave them 24 hours to re-engage with the group work. The team members would take a vote again on whether this person had shown that they are willing to contribute. If the team voted that this person was still disengaged, then steps would be taken by staff to get to the root of the problem. If the person on probation was found not to have engaged, then they would be awarded zero for the current assignment that the team were working towards and the team would continue without them.

Our experience showed that this probation process worked well on student complete disengagement, but it was less effective for those who intended to contribute to the minimal. The process did not allow staff to give students a fairer grade on the individual: it penalised the members who did not contribute but it did not reward those who contribute more than the others. It was perceived by students as a threat to trigger negative criticisms from team members towards the individual(s) rather than a motivational factor to encourage every team member to make positive contributions.

It was not easy for any team or staff to determine who contribute proportionally less than others during the programme as each member could not contribute equally at every single stage due to the nature of tasks and their subject disciplines.

The stake was high for any team who triggered the probation process because it would certainly create an uncomfortable atmosphere afterwards regardless of the actual outcome and such team might also loose such member(s) for the rest of the design process.

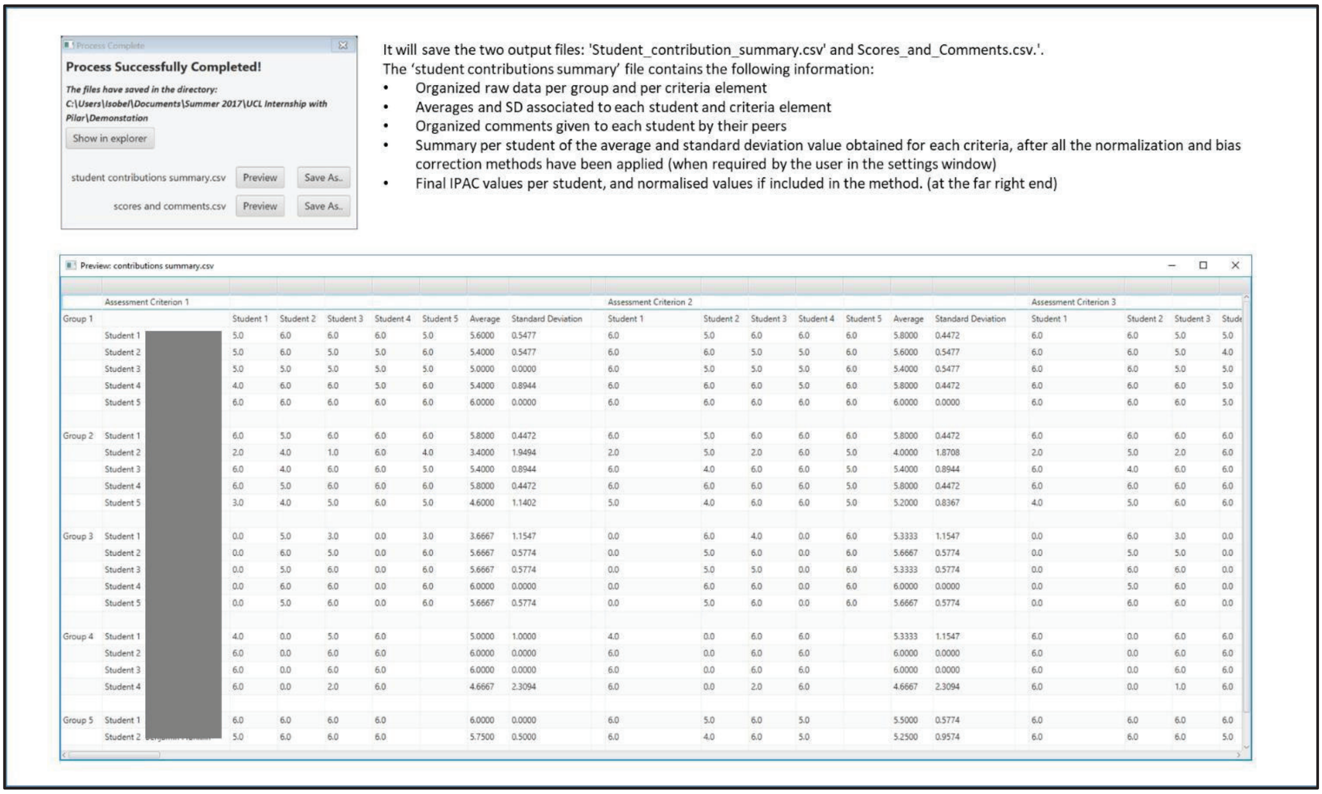
The programme needs to adopt an approach to work for both students and staff. It would allow students to make positive feedback to motivate their peers for good contribution and equally to make constructive feedback to reflect their peers who should make more contribution. Such approach would also allow staff to understand the group dynamic during the course of the team work; provide them scopes to try to address the issues; and to provide student grades that reflect on their contribution to the group work.

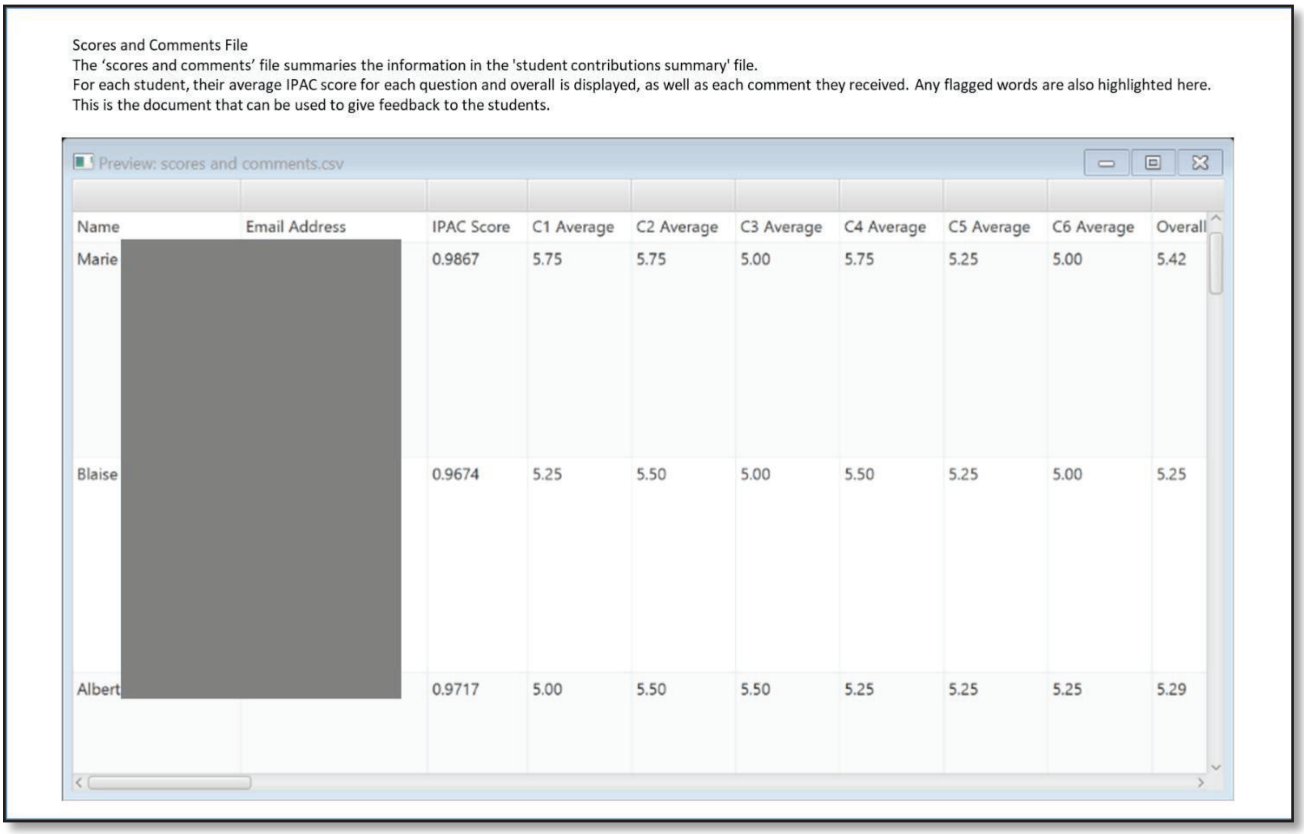
2.2 IPAC

To address this problem, IPAC (Individual Peer Assessed Contribution of group work) is adopted. This peer assessment method has been developed by Pilar Garcia Souto, Omer Mirza and Arjun Khurana to assess group work where an element of 'individual peer assessed contribution' is combined with the group mark to provide individual marks. It is used to address concern about the fairness of group assessment, which can consequently damage the student's experience during learning. The aim of this methodology is to provide student's with an individual mark that is based on their contribution, rather than all members getting the same group mark.

The group complete the project as designed and receive a mark for this work. An assessment of each member's contribution can be completed as many times as required, and these marks will be used to calculate scores by an online tool specifically developed for IPAC. These two marks will then be combined to give each member their own grade, reflecting not only the final piece of assessed work but also how she or he functioned in the group over the whole project.

This online IPAC tool collects the ratings and comments completed by the students via an online questionnaire within Moodle, the University's Virtual Learning Environment (VLE), and it generates scores through a variety of methods including normalisation and bias correction. This method first corrects the students' ratings by examining the degree of leniency of each student (the bias). If a student gives out more ratings than the average received rating in the group, then their outgoing ratings will be scaled down. The opposite is true for students who are overly generous; their outgoing ratings will be scaled up. Following this, the bias corrected ratings are then used to create individual contribution factors and from there calculate the final scores for students. Two files are generated by the tool to enable staff to see the individual scores and comments; and upload the file to VLE for students to view.




Scores and Comments File
The 'scores and comments' file summaries the information in the 'student contributions summary' file.
For each student, their average IPAC score for each question and overall is displayed, as well as each comment they received. Any flagged words are also highlighted here.
This is the document that can be used to give feedback to the students.

Preview: scores and comments.csv

Name	Email Address	IPAC Score	C1 Average	C2 Average	C3 Average	C4 Average	C5 Average	C6 Average	Overall
Marie	[redacted]	0.9867	5.75	5.75	5.00	5.75	5.25	5.00	5.42
Blaise	[redacted]	0.9674	5.25	5.50	5.00	5.50	5.25	5.00	5.25
Albert	[redacted]	0.9717	5.00	5.50	5.50	5.25	5.25	5.25	5.29

The IPAC tool also offer teachers to moderate the scores before they are released to students, for example a student is rated as absent or having contributed very little to the group, yet they have peer assessed the other members in their team. During the moderation process, teacher can use the ratings and feedback from the group and discuss specific issues with students before deciding the final grades.

In 2018 HtCtW, a cohort of 662 were grouped in 130 teams and all students were informed about IPAC both in writing in the programme handbook and at the very first taught session of the programme about this method.

The IPAC method was incorporated into the activity assessment which was used as formative tool in the first week – to identify problems – and as a summative tool in the second week – for the actual assessment marks. All students were required to take part these two rounds of the assessments. The first round of IPAC is designed to let students know how their peers rate their contributions to the team and adjust their efforts if necessary. The outcomes of it also inform teaching staff any signs of issue within the group and allow them to address such issues before they escalate further.

Students were informed that they would give and receive the scores and meaningful and individual feedback from and to their peers. They were guided on how they would rate and give feedback to their peers across five areas (**communication** and **sharing** of **disciplinary** knowledge; **team-working** skills; **quality** of research and application of technical and professional skills; **time** and

effort contributed throughout the project; **overall value** to the team's success) using 5 levels of marking criteria (Poor, Unsatisfactory, Satisfactory, Good, and Excellent). Although marks and feedback were anonymised, they were required to provide justification on their ratings and be constructive.

2.3 Impacts of introduced peer assessment

The completion rate for both IPAC assessments are as below:

Cohort	1st IPAC %	2nd IPAC %
C1	91	78
C2	93	78
E1	89	73
E2	88	55
M1	95	72
M2	89	59
T1	91	76
T2	94	72
W1	94	63
W2	88	74
Overall	91	70

The participation rate of the first IPAC formative assessment was 91%. Staff were very motivated by the high level of student's participation and they found the process was very useful because students provided them different insights about their group dynamic. Despite no report from staff about taking immediate action to any of the students who perceived to be less engage with the team, staff believed that the scores and feedback from their peers had informed these students what actions should be taken to address their shortfalls. Staff observed that overall student's engagement in the workshop continued to be positive.

In previous years the programme used the probation method to address students who either disengage or contribute to the minimal, administrator would need to move students from one group to another or sometimes dismantle groups because of not enough people left in the group. With the introduction of IPAC in 2018, the programme administrator reported that no such arrangement was required at all.

Although the completion rate of the second round of the IPAC summative assessment is lower at 70%, the scores and feedback on the individual who did not take part were consistent to the first round. The cause of the lower level of participation was due to the timing of the assessment: it was launched after the final assessment when students started their summer holiday break.

Due to the introduction of the IPAC as a form of peer assessment, it is not possible to compare the assessment grades between 2017 and 2018 whether students achieve better grades when the programme incorporates peer assessment method. For the purpose of this paper, data are drawn from the teaching log in 2017 and 2018 to compare the total number of staff report about student engagement. A sample of comments from students completed in the IPAC are also used to indicate the level of their team work experience and comments from two internal evaluation reports.

In 2017 (using probation method) a total of 81 entries were reported about student's disengagement or problems of student working in a team. In 2018 (using IPAC only) there were only 8 such reports filed to the teaching team.

Most of the students used the feedback to comment on their peers constructively and there were a high percentage of comments expressing satisfied with their group contributions, such as:

"Good teamwork and communication. Contributed a lot to the project. "

"Her point of view to the project was beneficial as she did not see it as an engineer like the rest of us. Looking at the project through a management point of view helped us find the best solution in terms of feasibility. She was a great team member to work with."

"Fantastic leadership and managerial skills. Contributed greatly to the team's success and was the driving force behind explaining our ideas to other people."

"Took leadership of the team and was able to provide a very good understanding from a chemical engineering background, punctual and on time to each session and meeting, often having to remind others to make it on time. Worked diligently to address any concerns the team might have had throughout the project and communicated well throughout."

"He played a key role to the group's success. His strong technical skills allowed us to come up with a solid engineering solution. He notably designed a 3D model for the presentation and inspected all technical specifications to answer questions efficiently. Even though he is reserved, he also demonstrated excellent team-working skills, in particular respect, careful listening and constructive attitude."

The positive use of IPAC is also confirmed by two internal evaluation reports.

HtCtW 2018 Report (2108) stated that staff believed the use of IPAC contributed to a very positive approach on the part of most students. When it was first explained at the very start of the programme, it seemed to add its motivational effectiveness.

How to Change the World 2018: Summary of evidence from stakeholder interviews (2018) pointed out that despite a progressively improving trajectory with each delivery of the activity, student engagement at the start of HtCtW continued to be low, driven by the timing of the activity, immediately after the end-of-year exams. During the initial few days of the activity –while participants were struggling to adjust to their new teams and grappling with the challenge of addressing unfamiliar open-ended problems –many continued to demonstrate low engagement levels. However, interview feedback consistently pointed to a significant increase in engagement as participants progressed towards the end of the first week of the activity, which then continued to rise throughout the second week. These improved levels of student engagement were often manifested in an increased likelihood of participants' citing the high-quality contributions of their teammates: *"our group worked well. They had the right mindset and put the hours in"*. Indeed, most participants consulted for this review reported that they were dedicating four–eight hours per day to unscheduled, independent work on their project, either individually or as a team. High levels of engagement were also evident in the observations of the supervised team sessions, where, in the words of one PGTA, "the students are focused on their problems, that's been the atmosphere [in the room], most of them are really thinking about the feedback from [the challenge partners]and getting on with it." The author of the report concluded that the introduction of IPAC peer assessment, providing reassurance that participants would *"get what they deserve rather than a group mark"* in the activity's assessment.

3 CONCLUSION

The introduction of the IPAC to HtCtW Programme has been very positive overall. Staff agreed that IPAC promotes a more positive approach to motivate student participate in team work than the probation method. While the probation method only threatens students to be penalised for disengagement with a zero mark, IPAC gives a fairer marks for individual contribution by rewarding good contribution and giving lower marks for less contribution. As a result, students use the IPAC to self-regulate their teams.

IPAC also allows staff to understand the group dynamic during the course of the team work and provides them scopes to try to address the issues.

A key concern of adopting IPAC is the ability of performing the technical tasks with the software. To generate the IPAC data, students need to complete the IPAC questionnaire in an identical order as their team list. The operator of the software is also required to prepare the group file consisting of student data from Moodle in a specific file format that matches the data file from the IPAC questionnaire. The software will fail to generate the data if any of the requirements are not met. The technical aspect of operating the software may put some staff off.

Despite some students gave their peers same score and same comment across each of the assessed areas, the software were not able adjust their IPAC score accordingly.

Although the feedback from both students and staff cannot conclusively confirm the introduction of the IPAC had assisted them to achieve higher learning level, the feedback from the peer assessment had shown that they better understood the required proficiency to achieve the expected learning outcomes. The significant reduction of reported incidents concerning student engagement from staff has shown the peer assessment method had an impact on the overall student engagement. To further explore the effectiveness of peer assessment in problem-based learning, more work is needed to minmise a cooperative and non-judgemental atmosphere within a group.

Some students also demonstrated poor quality of feedback to their peers and often very superficial. More support to equip students with the skills to provide feedback and more opportunities for them to practise can address this issue. Lastly a structured peer assessment evaluation will generate more data to better inform further practices.

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Dealing with Diversity

Co-designing a Game-based Learning Scenario in Engineering Studies

F Weidle,
A Seidel,
C Börner,
L Flagmeier,
J Vossler
Brandenburg University of Technology Cottbus-Senftenberg
Cottbus, Germany

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ABSTRACT

Lecturers are confronted with diversifying student bodies. Different admission restrictions allow students to enter institutions of higher education with varying educational backgrounds. Moreover, current internationalization strategies at German universities attract an increasing number of students from abroad. This results in varying knowledge levels and language skills that need to be addressed in the conceptualization of teaching formats and materials.

Engineering mechanics presents a challenge to a high number of students, as it is evidenced by weak examination performance. As a basic subject in most engineering programmes, learning and comprehension problems in this area, however, not only lead to failure in exams but could also create substantial knowledge gaps over the course of one's studies. One possibility to tackle these issues is the adoption of a game-based learning (GBL) approach. GBL presents a promising tool for mediating abstract content because of its motivating and cognitive effects. Moreover, adaptive elements can respond to the different needs, interests and habits of a diversifying student body.

The Learn&Play project presented here utilizes a participative user-centred design approach to develop a sustainable learning scenario for engineering mechanics that focuses on motivation, interest, learning strategies and comprehension as important factors for academic achievement. The concept paper will outline the results of the project's underlying problem analysis and illustrate the benefits of GBL in the context of the demands and challenges posed by engineering education in an increasingly digital, international and, thus, complex world.

1 INTRODUCTION

The tech industry is an interesting job market. This is evidenced by the high amount of enrolments in engineering courses each semester. However, the initial interest of students appears striking in the face of the high dropout rates in undergraduate courses at German universities and technical colleges (1). Problems are regarded to stem from the transition to the Bologna-system, insufficient prior knowledge, the abstract nature of the subject matter as well as differing educational backgrounds (2). At the Brandenburg University of Technology Cottbus-Senftenberg (BTU), the student body is especially diverse. Here, students can choose between an integrated, university and college degree program. Moreover, with up to 50% of students speaking German as a second language, various linguistic proficiencies, educational and cultural backgrounds as well as knowledge levels coalesce.

Weak exam results are indicative of the challenges posed by the basic subject of engineering mechanics (EM) (3). Due to its central role in engineering studies, learning and comprehension problems in this area can not only lead to failure in exams but also cause fundamental knowledge gaps over the course of the study programme. Sources for low academic achievement are seen in the high level of abstraction, the following of strictly specified rules and procedures, insufficient prior knowledge and a low level of self-regulation (3). Keeping the diverse student body in mind, these challenges need to be considered and directly addressed in the instructional design of learning content.

2 THEORY

2.1 Diversity

Under-representation of women and ethnic minorities is a general problem in engineering studies. Adelman (4) stressed already twenty years ago that universities should place more emphasis on minorities by mirroring a rather balanced workforce, which allows graduates to communicate with a heterogeneous clientele, and representing socio-cultural diversity. Moreover, the numbers of women in STEM-studies have been declining since 2006 despite the high demand for qualified graduates (5). However, studying STEM seems unattractive to women because of its traditional focus and portrayal as male study field, cultural discrimination against female students and different learning behaviour as well as an emphasis on rather male teaching methods in school and university (5).

2.2 Learning Strategies

To study at a university implies structuring the process of learning in a self-regulatory way. But which learning strategies (LS) do students apply in their study of EM and which of those are more efficient than others? LS are defined as sets of behaviour directed towards a learning task (6). Wild clusters LS in cognitive and meta-cognitive strategies as well as resources (7). Cognitive LS can be divided into deeply and superficially cognitive LS and are described as processes which are connected to information acquisition, processing and storing. Meta-cognitive LS direct the active and self-aware control and regulation of learning processes such as the planning, observing and adjusting of one's learning behaviour. Resources are linked to processes that structure learning as a whole such as concentration or cooperative learning. Although every LS is important in its own right, gathering and storing information is necessary for all of them which is why Wild suggests the use of cognitively deep LS for gaining a more in depth understanding of complex concepts (8).

2.3 Game-based Learning

Game-based learning (GBL) describes a learning environment in which learning processes are supported by narrative, immersive, adaptive, competitive, cooperative and other game elements (9). The aim is to transfer the principle of hard but satisfying labour, which leads to a sense of achievement and, ultimately, the experience of pleasure or fun, onto the learning experience. By carefully selecting and combining game elements such as digital storytelling and reward systems, affective, motivational, cognitive and socio-cultural factors can be stimulated (10), which has the potential to increase students' interest in the subject matter (11) and eventually steer them towards a greater engagement with the learning content (11).

According to Wouters and Van Oostendorp, GBL can take on different functions during the learning process: 1) It can prepare future learning, 2) teach new knowledge and skills, 3) train existing knowledge and skills and 4) convey skills of the 21st century (11). Nevertheless, the learning success associated with GBL, its respective purpose and design depends on a variety of factors and has become subject to critical debate (12). The increased time investment and unbalanced emphasis of game and educational objectives (13, 14) are often discussed as central problems. Since more situated analysis is needed to understand the interplay between gaming and learning, the project presented here makes a significant contribution to the current state of research in this area.

3 OBJECTIVES OF THIS STUDY

The aim of Learn&Play is to develop a GBL scenario that prepares engineering students for the challenges posed by EM during the first semesters. In the initial phase of the user research conducted in the context of this project, specific problem areas related to differing knowledge levels, learning processes and content were identified in order to devise concept ideas for a suitable scenario. The suitability of the scenario will be determined by and evaluated according to its capacity to positively affect the learning experience cognitively, motivationally, behaviourally and socio-culturally over the long term. To ensure the suitability, sustainability and integration of the scenario into established teaching and learning structures the developers seek to work closely with the respective target groups including a set of prospective students, beginners and lecturers as diverse as possible.

The following questions and objectives were vital in directing the user research:

1. How motivated are students to engage with EM? Do factors such as gender, language and educational background play a significant role in the extent to which students are motivated?
2. Which attitude towards EM do students display? Does the attitude differ regarding to gender, language and educational background?
3. Which types of LS do students use? Do the LS differ regarding to gender, language and educational backgrounds?
4. What kinds of problems do students face while learning EM? Do the learning problems differ regarding to gender, language and educational backgrounds?

4 METHOD

4.1 Participants, Materials and Procedure

Over the period of one month, an exploratory survey was conducted with 154 engineering students of universities and technical colleges in Brandenburg, Berlin and Saxony (16 women, 1 diverse, 13 not defined: $M = 21.61$ years, $SD = 3.34$). Students could participate via an online questionnaire that was mainly distributed via social media platforms including respective student groups on Facebook.

Additionally, a paper version was handed out at the end of three EM lectures at BTU and the University of Applied Sciences Dresden. As an incentive for their voluntary participation, students had the chance to win one of four 15€ gift vouchers.

The digital as well as the paper questionnaire contained twelve questions addressing aspects of motivation, attitude, learning strategies and learning problems in regard to EM. Furthermore, it gathered demographical variables including age, gender, educational background and first language.

4.2 Measures

Motivation was described by adapting six items of the *Expectancy-value-Form of Domain-Specific Learning Motivation Questionnaire* (EWF-LM) (15). The concept was divided into activity-based motivation including statements such as “I enjoy dealing with content related to engineering mechanics” and content-specific motivation including statements such as ”I think content related to engineering mechanics is boring”. Answers were given according to a five-point Likert scale between 1 (“not at all”) and 5 (“absolutely”). Negatively coded items have been recoded for analysis. In order to calculate the motivation average value the three sub-items of each motivation type were added together and then divided by three.

The attitude towards engineering content in general and EM in particular was measured via a five-point Likert scale. Participants were asked to rate the importance of EM in their daily life by assigning values between 1 (“Not important at all”) and 5 (“Very important”).

LS were assessed using an open question as well as a multiple choice format. First, students were asked to describe the preparation for their last EM exam. They could then choose among a given set of LS they preferably applied. The list of examples were devised according to the learning strategy classification by Schiefe and Wild (16) and, thus, included cognitive (“I learn content by heart”) and meta-cognitive LS (“I ask myself which is the best strategy in order to reach my objective”) as well as resources (“I make a timetable”). Answers to the open question were coded according to the LS cluster (8).

To measure personal learning problems in EM participants were asked to describe both, general as well as more specific problems they usually face during the study of EM. Answers were coded in a semi-open way following inductively devised categories and cross-checked by a second rater.

5 RESULTS

5.1 Motivation

To assess differences in motivation regarding gender, language and educational background, a one-way ANOVA was conducted. Because the assumption of a normal distribution was violated, a Kruskal-Wallis-Test was conducted.

Table 1. Means and standard deviations of motivation regarding gender, language and educational background

Variable	N	Content-specific motivation *M*	Content-specific motivation *SD*	Activity-based motivation *M*	Activity-based motivation *SD*
In total	152	3.84	1.03	3.19	0.86
Female	16	3.4	1.22	2.92	1.08
Male	124	3.93	0.95	3.24	0.81
German as first language	127	3.89	0.99	3.21	0.84
German not as first language	11	3.88	0.86	3.3	0.95
A-levels/high school diploma	101	3.82	1	3.16	0.86
Technical diploma, professional training	39	4.03	0.96	3.33	0.8

No differences were found regarding content-specific motivation in gender ($H(1) = 2.71$, $p = 1$), language ($H(1) = 0.01$, $p = .91$) or educational background ($H(1) = 1.39$, $p = .24$). Furthermore, no differences were found regarding activity-based motivation in gender ($H(1) = 0.96$, $p = .33$), language ($H(1) = 0$, $p = 1$) or educational background ($H(1) = 1.66$, $p = .19$).

5.2 Attitude

To assess differences in attitudes regarding gender, language and educational background, a one-way ANOVA was conducted. The variables do not mirror a normal distribution. Thus, a Kruskal-Wallis-Test was conducted instead.

Table 2. Means and standard deviations of attitudes regarding gender, language and educational background

Variable	N	Attitude engineering science *M*	Attitude engineering science *SD*	Attitude EM in studies *M*	Attitude EM in studies *SD*	Attitude EM in daily life *M*	Attitude EM in daily life *SD*
In total	152	4.19	1.1	3.97	1.12	3.44	1.14
Female	16	3.95	1.13	3.88	1.15	2.88	1.45
Male	124	4.3	0.99	4.05	1.06	3.56	1.04
German as first language	127	4.27	1.03	4.11	1.02	3.52	1.11
German not as first language	11	4.27	0.65	3.55	1.29	3.27	1.01

A-levels/high school diploma	101	4.21	1	3.94	1.05	3.43	1.13
Technical diploma, professional training	39	4.38	1.02	4.26	1.1	3.64	1.06

No difference in attitude towards engineering science was found in gender (*H*(1) = 2.05 , *p* = .15), language (*H*(1) = 0.5 , *p* = .48) or educational background (*H*(1) = 1.72 , *p* = .19). Neither were there differences in attitude towards EM in study programmes regarding gender (*H*(1) = 0.3 , *p* = .58) or language (*H*(1) = 2.61 , *p* = .11). However, a difference was identified related to educational background (*H*(1) = 4.68 , *p* = .03). Results concerning attitude towards EM in daily life show no difference related to gender (*H*(1) = 3.16 , p = .075), language (*H*(1) = 0.52 , *p* = .47) or educational background (*H*(1) = 1.03 , *p* = .31).

5.3 Learning Strategies

Differences in frequencies of LS adopted by students regarding gender, language and educational background were assessed via a chi-square test with two questions. Expected cell frequencies under five were assessed via Fisher's exact test. The open question "How did you prepare for your last EM exam?" showed differences in the use of cognitively deep LS in gender (Fisher's exact test, *p* = .01, *φ = .25*), language (Fisher's exact test, *p* = .02, *φ = -.25*) and educational background (Fisher's exact test, *p* = .01, *φ = .24*). Another difference was found in the use of meta-cognitive LS for gender (Fisher's exact test, *p* < .001, *φ = .32*). The most noted LS were of the cognitively superficial type (109 times), followed by cognitively deep LS (29 times), resources (18times) and meta-cognitive LS (18 times).

Table 3. Frequencies of LS according to gender, language and educational background (open)

	cognitively deep					cognitively superficial					meta-cognitive					resources				
	1	0	*x2*	*p*	*φ*	1	0	*x2*	*p*	*φ*	1	0	*x2*	*p*	*φ*	1	0	*x2*	*p*	*φ*
gender																				
male	21	90		.01	.25	14	2		.74	-07	11	103		0	.32	1	15		.69	-.07
female	8	8				90	14				7	9				16	98			
language																				
1.	24	96		.02	-.25	95	25		1	-.05	17	103		1	.01	16	104		1	.01
2.	5	3				7	1				1	7				1	7			
education																				
A-levels	27	68	7,61	.01	.24	76	19	0	1	.00	16	79		.15	.14	14	81		.78	.04
diploma	2	33				28	7				2	33				4	31			

Answers provided for the multiple choice question showed a different use of LS regarding language and resources (fisher's exact test, *p* = .01, *φ = .24).* Cognitively superficial (122 times) and cognitively deep LS (128 times) were indicated the most, followed by resources (84 times) and meta-cognitive LS (67 times).

Table 4. Frequencies of LS regarding gender, language and educational background (multiple choice)

	cognitively deep					cognitively superficial					meta-cognitive					resources				
	1	0	*x2*	*p*	*φ*	1	0	*x2*	*p*	*φ*	1	0	*x2*	*p*	*φ*	1	0	*x2*	*p*	*φ*
gender																				-
female	15	0		.22	.13	13			1	.03	7	8	0	1	0	8	8	0,56	.45	.45
male	106	16				102					57	65				73	49			
language					-															
1.	110	14		1	.02	107			.21	.10	57	67	0	.97	0	77	48		.01	.24
2.	10	1				8					5	6				2	9			
education										-					-					-
A-levels	89	9		.24	.12	82	16	0,02	.89	.01	41	57	3.29	.07	.16	55	44	1,43	.23	.10
diploma	32	7				33	6				23	16				26	13			

5.4 Learning Problems in Engineering Mechanics

A chi-square test was used to assess differences regarding the frequencies of gender, language and educational background. All expected cell frequencies were under five, which is why Fisher's exact test was conducted. No differences were found regarding to gender, language and educational background. Figure 1 shows the general frequencies of the answers provided by participants.

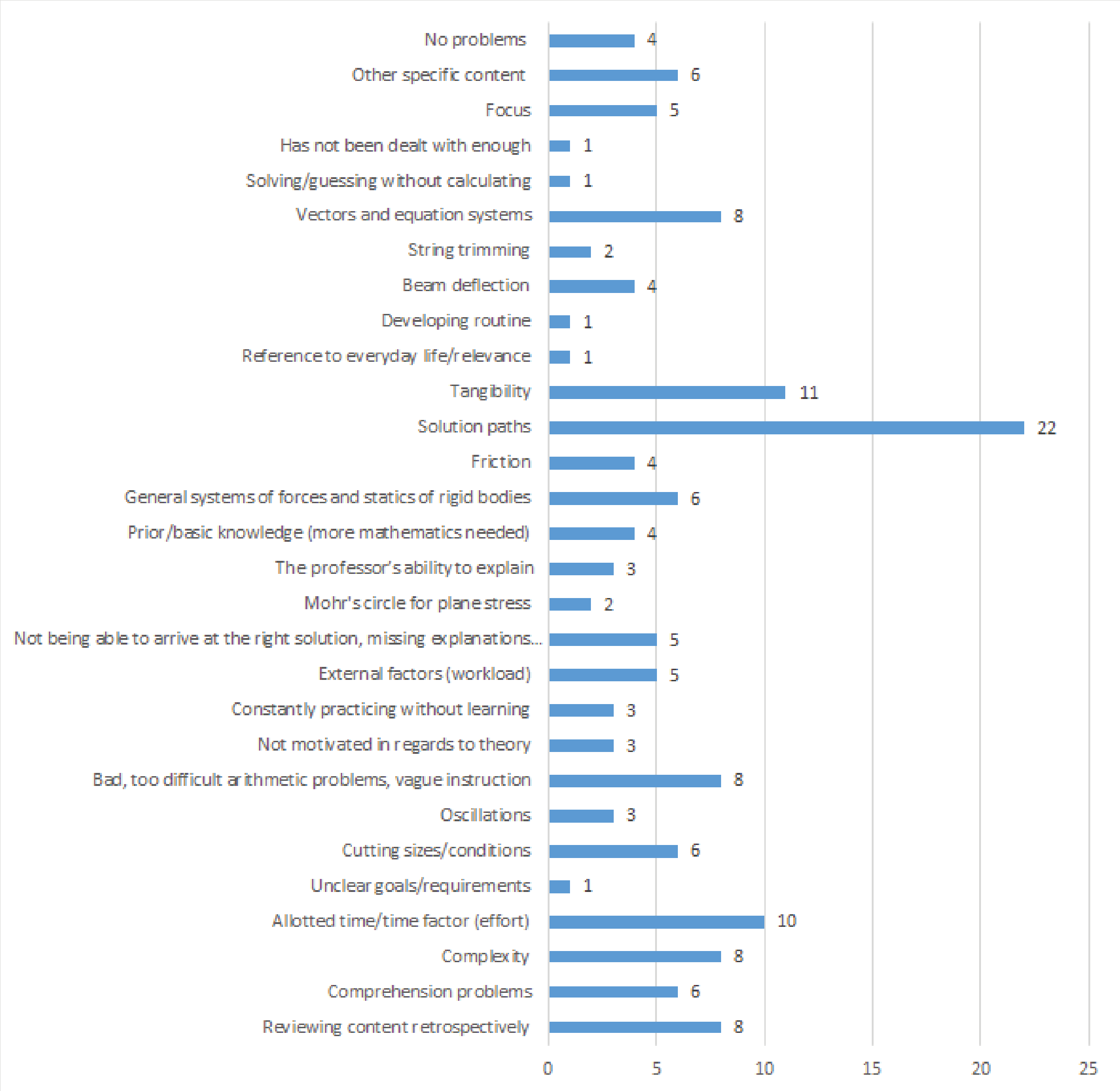

Fig. 1. Frequencies of learning problems in EM

Among the most frequent problems were the identification of appropriate solution procedures (22 times), the tangibility of the content (11times), the allotted time and workload (10 times), arithmetic operations including vectors and equation systems (8 times), too vague or incomprehensible instructions (8 times), the complexity of the content (8 times) and the retrospective reviewing of content (8 times).

6 SUMMARY AND IMPLICATIONS

The aim of the questionnaire was to gather initial information about engineering students' motivational levels, their attitudes towards EM and engineering sciences in general as well as their use of different LS and specific learning problems they face in EM. In addition, differences related to gender, language and educational backgrounds were assessed.

Content-specific and activity-based motivation are generally above average. Differences regarding gender, language and educational background were not found.

Overall, students appeared to be more interested in the content itself and less in actually engaging with it. This is not least due to the fact that the abstract and complex nature of the learning content often leads to comprehension and application problems. All students rated engineering in general and EM as part of engineering as important. Students with technical diplomas rated the importance of EM in the context of their studies as more important than students coming straight out of grammar school. There were no further differences found related to gender, language or educational background.

According to the answers given to the open question, cognitively superficial LS are applied the most, whereas cognitively deep LS, resources and meta-cognitive LS are less frequently used. Moreover, female students, students speaking German as a second (or third) language and students with a grammar school background use cognitively deep LS more often than others. Women also showed a higher usage of meta-cognitive LS. In contrast, ranking LS according to the provided list, cognitively superficial and deep LS are used the most, followed by resources and meta-cognitive LS. Students speaking German as a second (or third) language use less resources than native speakers. Since resources are usually provided in German, they may present a higher threshold for international students. Reasons for these results could thus lie in accessibility and language skills.

Learning problems frequently noted referred to solution procedures, the tangibility and complexity of the content, time and workload, basic arithmetic operations including vectors and equation systems, reviewing content retrospectively and the nature of the instructions provided. With its various functionalities, GBL offers different starting points for tackling these problems. According to the respective demands and objectives, GBL can be put to use at different points throughout the course of a study programme. In its orientation to support future learning it would be suitable as a tool to prepare students for an engineering study programme in general as well as a particular module or lecture by raising, for example, the activity-based motivation of prospective students. Furthermore, prior knowledge especially in mathematics, which was a noted problem in this study, could be trained in an interactive and playful way so that students are prepared better and feel more engaged. The content mediated and trained within a game-based learning scenario can be transferred onto the dissemination of knowledge in lectures and seminars as well as the practical engagement in exercise sessions, tutorials and studios. In the scope of this study, GBL should address the way students interact with the solution of tasks to better understand the process. Moreover, as the retrospective reviewing of content appears to be one of the major problems, the scenario to be developed should assist students in their entire learning process and, therefore, provide different levels of difficulty that can be useful throughout the first semesters.

Another objective pursued in the development of a suitable GBL scenario should rest on the enhancement of students' ability to choose adequate LS. As noted by Jonassen (17), one of the advantages of a game world is that it enables learners to immerse themselves in another reality and adopt its rules. It is via these rules that learning content can be mediated without directly addressing it as such (18). Thus, by embedding it in a coherent game world the abstract problem area could be rendered more tangible for students and comprehension could be increased. The personal experience and (embodied) actions of players can strengthen a sense of relevance that supports the learning behaviour (17, 10) – and may increase the use of cognitively deep LS. On the other hand, the world portrayed in a game is abstracted into a model and can thereby simplify the learning process similar to the teaching strategies already employed to convey the basics of EM (18). In this way, an interactive learning scenario would allow the link between idealised learning content and practical application. By drawing on both, effects of flow and immersion as well as direct feedback mechanisms, learners could be motivated to playfully solve problems in an experimental low risk environment. Once again, tangibility could be increased and complexity reduced.

Insights gained from engaging with a game world can also lead to a change in attitude, which is linked to tendencies of shifting one’s action and attention towards the subject matter. GBL can facilitate such a deep engagement on various levels and help automating specific solving patterns (10). In order to do so, content would need to be designed and structured in a way that supports the use of cognitively deep and meta-cognitive LS as well as resources. A special emphasis should be placed on students whose first language is not German and their use of resources such as cooperation with peers and additional support offered by the university. Among other things, this is can be achieved by evoking positive emotions via reward systems and adapting the scenario to different needs – an aspect that is of special importance in the face of the diverse student body in engineering courses. However, it is important to keep the transferability of gained knowledge and skills onto actual exam situations in mind (19).

6 OUTLOOK

Game-based learning environments have the potential to convey complex subject matters in a more tangible way. Given their various functionalities, they can support the entire learning process from activating prior knowledge to facilitating exam preparation. The empirical data gathered from the survey presented here will help to determine at what point in time the learning scenario will be put to use and how it needs to be designed. As of the data gathered and analysed up to this point the greatest demand appears to lie in the preparation of future learning as well as the training of existing skills and knowledge. Although differences in the learning process proved to be only minor in this study, it is still pertinent to design the scenario in an adaptive way so that it can respond to the increasing diversity of students’ backgrounds, interests and needs regardless of whether they are gender-, language- or education-specific. In the next project phase, design concepts and prototypes devised on the basis of the obtained data will be evaluated together with the target group. In this way, the Learn&Play project responds to Hoblitz’s postulation to investigate further the tension between gaming and learning experience by producing process-oriented results which can be seen as a basis for further developments in the field of technical knowledge and its forms of dissemination in academic contexts (12).

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Examining *Exemplarity* in Problem-Based Engineering Education for Sustainability

V Servant-Miklos
Aalborg University
Aalborg, Denmark

A Guerra
Aalborg University
Aalborg, Denmark

Conference Key Areas: Strong demand for democratic involvement in educational processes, Sustainability reflecting the complexity of modern society.

Keywords: exemplarity, project-based learning, problem-based learning, sustainability

ABSTRACT

Oskar Negt's critical educational concept of exemplarity was a core component of problem-oriented, project based education in Denmark at its inception in the 1970s. Nearly fifty years on, this model of project education has grown in popularity around the world, especially in the field of engineering education. In the practice of engineering education today, while these projects have retained an interdisciplinary, practice-oriented, and experiential learning approach, the specific socio-historical aspects of exemplarity in Negt's theory have fallen by the wayside. In this paper, we ask whether these aspects have a place in twenty-first century engineering education, with a specific focus on the issue of sustainability, and what could be learned from exemplarity for curriculum design. The paper critically examines Negt's concept of exemplarity and its early application in project-based higher education in Denmark, then looks at the way in which it translated into engineering education, starting at Aalborg University, before appraising its relevance in the light of the growing number of sustainability issues covered in many engineering curricula.

1 INTRODUCTION

Problem-oriented, project-organized learning, often shortened to "PBL", is an approach to engineering education pioneered in Denmark but now gaining popularity all over the world [1]. The essential characteristics of this approach are semester-long interdisciplinary group projects, complemented by disciplinary courses. Unlike the type of project work that is commonly found in secondary and vocational education, these projects are not designed as mere applications of protocols given by teachers, but as part of a problem-formulation process. One of the key requirements of problem-formulation is that it should be connected with real-life, or at least a realistic situation, rather than just abstract concepts.

The origins of this pedagogical approach is not to be found in engineering or technical education, but in the social sciences. Indeed, this model of education was developed in Germany and Denmark in the late 1970s as a response to traditional modes of higher education. It was implemented in several "radical" new universities with a strong left-wing brand of social sciences; most notably Bremen University and Roskilde University Centre [2]. The educational principles enunciated in these experiments were participant direction, problem-orientation, interdisciplinarity and exemplarity [3]. When the model was transferred to the newly opened Aalborg University in 1974, the managers were confronted with a challenge: unlike Bremen and Roskilde, Aalborg University (AAU) was dominated by a faculty of technical and natural sciences (TekNat), of which engineering was a big part. Suddenly, this pedagogical approach with a socialist analysis of the society had to be adapted to suit a study area mainly focused on technical and practical matters [4]. In practice, the engineering education programme retained the elements of participant-direction, loosely understood as student-centred learning within project groups, problem-orientation, in which the problems were practical problems, and interdisciplinarity, mostly within the technical field. The principle of exemplarity, as it was understood at Bremen and Roskilde, was not very much discussed at TekNat in the early years. There are several factors that account for this. Firstly, the principal author of the theory of exemplarity, Oskar Negt, was derided within some circles at AAU as an outdated Marxist, and those within the university (mainly social scientists) who followed him were criticised by sceptical colleagues [5]. Secondly, Negt wrote using 1970s Marxist jargon, and was therefore difficult to access for people without a background in philosophy or sociology, which the people running the engineering education programme did not have at that time [4]. Thirdly, the faculty of engineering at AAU was built on the merging of two pre-existing engineering education institutions in Aalborg, and many of the staff who were then transferred to Aalborg University were traditional teachers. Servant-Miklos and Spliid [4] have described how challenging the transition was for these teachers, in the light of which Negt's exemplarity may simply have been a bridge too far. Finally, the pragmatic nature of engineering education itself makes problematic the development and application of educational concepts steeped in particular (e.g. dialectic materialist) ontological and epistemological paradigms, such as Negt's exemplarity.

Nonetheless, the authors of this paper believe that there is a case to be made for a renewed understanding of the principle of exemplarity in engineering education today, adapted for the conditions and challenges of the 21st century, particularly the challenges brought about by climate change and the sustainability crisis. To begin, an explanation of what exemplarity is must be offered. Secondly, we must discuss whether exemplarity is still relevant in today's context. Finally, we focus on the concrete implications of exemplarity for engineering education, particularly when it comes to tackling issues of sustainability.

2 WHAT IS EXEMPLARITY?

There are historically two approaches to exemplarity, a purely pedagogical one, and a social-emancipatory one. The prime proponent of the former is Martin Wagenschein, and the latter Oskar Negt [6].

2.1. Pedagogical exemplarity: Wagenschein

For Wagenschein [7], exemplarity was a pedagogical method to reduce the contents overload in higher education curricula. By using good examples, through a process of analogy, students get an idea of the fundamental principles at stake (e.g. if I look at four or five different types of plants, I will have a good idea of how photosynthesis works). There is no requirement for this type of exemplarity to be either interdisciplinary or student-centred. In fact, teachers probably know better than the students which examples will be most conducive to understanding the principles required for the course learning objectives. Wagenschein expected that students would acquire learning habits that would make them more interested in their personal and cultural development. Therefore, from a disciplinary starting point, some form of interdisciplinary understanding would emerge.

2.2. Exemplarity as sociological imagination: Negt

Negt disagreed vehemently with Wagenschein [8]. Negt's starting point for exemplary learning was the sociological imagination. This is a concept developed by the American sociologist C. Wright Mills [9], to describe a situation where an individual is able to make sense of his or her personal circumstances in the light of global, historical, social, economic and political events. The sociological imagination is therefore what in technical terms would be called a *dialectic*. This means the opposition between two worldviews – the personal and the socio-historical – that reconcile into a viewpoint that understands the personal as social and the social as personal. To give a concrete example, the sociological imagination would provide farmers from the Mid-West of the USA who were subjected to historic flooding in early 2019 with the means to understand their personal losses within the broader context of human-induced climate change and its economic and social consequences, which would in turn spur them to take action, by protesting government inaction on climate change and voting out of office politicians who deny climate change, in the hope that this would in turn improve their circumstances. The sociological imagination has an explicit emancipatory element, meaning that it aims to empower people to take action for their personal and collective destinies within the socio-historical context. It is this emancipatory element that Negt latched onto in his conception of exemplarity. As a neo-Marxist, Negt's ambition was to free the working class from their oppressed condition through the power of exemplary education – that is, from the starting point of personal experience and practical examples issued from the everyday lives of workers, it must unveil the political economic conditions of society in its totality, and thereby provide a course to (political) action. It does this through the means of problem-orientation, participant direction, and interdisciplinarity, organized in the form of project work. Thus, exemplarity is a holistic project for Negt: it must be interdisciplinary to succeed, since social reality is not parceled into different disciplines. Negt's exemplarity is harder to pinpoint in precise terms than Wagenschein's, which is probably why exemplarity has often been reduced to its purely pedagogical form.

2.3. The application of exemplarity in Danish higher education

The journey of exemplarity from Negt's writings about working class emancipation to higher educational practice goes through the Danish Student Union, where a group of committed socialist students led by Henning Salling Olesen endeavoured to translate exemplary learning into an actual educational programme [10]. The result was the problem-oriented, project work method of Roskilde University, though the contextual difference between the alienated workers of Negt and the middle-class Danish students at Roskilde was duly noted by critics [11]. Initially, this method did not involve any traditional courses at all: the students did their projects, and called in professors if they needed help with theory. An exception was already made from the beginning for natural sciences, where professors felt that students had to have some scientific basis before they could start work on their projects, and a division of 50/50 between project work and courses was admitted. After some battles with the government, the 50/50 division spread to the entire university, and was exported as such to Aalborg University, including at the faculty of engineering education.

When it comes to interdisciplinarity, the Roskilde programme offered a two-year interdisciplinary basic education programme in natural sciences, social sciences or humanities using the problem-oriented, project-based approach. In AAU, this was reduced to one year. In effect, interdisciplinarity has been waning over the years in all Danish problem-oriented, project-based education, especially with the Bologna European education reform and the pressures to fit a full bachelor in three years, instead of a more comprehensive programme over the course of five years. A recent reform at AAU has formalized the separation of the courses from the projects at Aalborg, thus entrenching the disciplinary approach even further. With regards to problem-orientation, it was explicitly social at Roskilde but became very practical in the faculty of engineering at Aalborg. Whereas Roskilde's Faculty of Social Sciences dealt in its early days with problems such as "imperialism, the Asian mode of production" and "Danish capitalism in crisis", the problems at the Technical Faculty of AAU were much more local and pragmatic, such as "sports hall at a school in Aalborg", or "swimming pool in a school in a village outside Aalborg" [2]. In theory, exemplarity can be reconciled with such a practical starting point – the starting point should, according to Negt, be in the practical experience of workers. But in practice, AAU was keen to avoid political connotations, especially by comparison with Roskilde [12], and the engineering educators discovered in the meantime some much more easily-accessible education theory, such as Piaget, Kolb and Dewey [4]. And thus, exemplarity in PBL for engineering education has since been loosely understood in a Wagenscheinian sense (as an example from which an analogy can be made).

3 IS EXEMPLARITY STILL RELEVANT TODAY?

There are aspects of Negt's theory that are not significantly relevant to engineering education today. In particular, the distinction between the bourgeoisie and proletariat is a 19th century distinction that is unhelpful to engineering educators, especially given the collapse of the blue collar working class around the developed world. Even in the case of developing countries, there are more useful ways to understand the social dynamics at play in a globalized society than 19th century class dichotomies. As a result, the emphasis on class consciousness in Negt's exemplarity seems a bit unhelpful for contemporary educational challenges. However, we do believe that there is enough of relevance in Negt's theory, duly adapted to the conditions and problems of the 21st Century, to warrant promoting Negt's perspective on exemplarity as part of problem-based, project-organized engineering education, rather than using Wagenschein's restrictive conception of exemplarity.

Firstly, Negt is right to point out that examples treated merely as case-studies produce a fragmented, disciplinary view of reality, when true understanding comes from seeing the whole. In 2019, we live in a turbulent world that calls for broad, interdisciplinary analysis and action. The climate crisis, the staggering loss of biodiversity, the increase in ocean dead zones, the ongoing loss of massive swaths of rainforest, the plastic pollution crisis and other manifestations of the sustainability crisis cannot be treated as isolated problems, but must be seen as a part of the socio-economic system in which such a crisis was manufactured. Its impact on increasing inequalities, with the poorest on the planet being hit the hardest, must also be considered. Some of damage done by the crisis is already irreversible. We are on course to cross a threshold where it will be impossible to keep warming below 2 degrees Celsius in the coming two decades, according to the IPCC [13]. And yet, no technological "fixes" for the climate and sustainability crises are unproblematic. Take solar panels: where and how do we get the components to make them (and will this destabilize the places where we get them)? What do we do with them when they reach the end of their lifespans? How does building solar farms impact land use? How resilient are they to extreme weather events? What happens to people whose jobs and livelihoods depend on the fossil fuel industry? Another example is electric cars: where and how is the electricity produced? How are the batteries made and where are the components extracted? What happens to the enormous park of existing "dirty" vehicles? Is the effort to develop electric personal vehicles hampering the development of reliable, high speed public transportation? This doesn't even get into more difficult debates such as stratospheric aerosol injections and carbon capture and sequestration, which are nonetheless debates that our political paralysis on climate change will force us to have sooner rather than later. All students in all fields of study should be exposed to the systemic components of the crisis, but this is especially important for engineering students who will be working on many of the technological solutions.

Secondly, engineering students are also individuals embedded in a socio-historical fabric. Developing the sociological imagination should be a key responsibility of *all* higher education programmes in functioning democracies. In a technological world, this is especially important for engineering programmes. Our historical moment is one in which, as our dependence on technology reaches its zenith, the trust relationship between science and society has broken down and ordinary individuals increasingly believe and act on invalid propositions such as "climate change is a hoax" and "vaccines cause autism". Mills argued that for a democracy to function, a bridge had to be built between people's every day experiences and professional lives, and the political economy of the system. We would add that for a 21st century democracy to function, that bridge must also include a scientific and technological component, where technology is not just a thing you hold in your hand (a phone, a laptop) or a machine that will "solve" climate change, but is a network embedded in every level of our lives, from the mundane and personal to the professional and systemic. The sociological imagination today *is* technological and much as it is environmental. The historical moment we are living through is made up of people who use technology, and people who design and produce it. Technology's impact and relationship with society and the biosphere can be revealed, analyzed and understood through exemplary learning. We will now look at what this means concretely.

4 EXEMPLARITY AND ENGINEERING EDUCATION FOR SUSTAINABILITY

Sustainability is without a doubt a key issue for engineering education in the 21st century. The establishment of communities of practice (for example annual conferences, research centers, journals), elective courses and programs on sustainability, tools to assess curriculum opportunities for sustainability (see for example STAUNCH® [14]), student organizations and sustainability councils, are all evidence that stakeholders in engineering education seek to engage with the sustainability crisis. The current aims are to provide students with experience, knowledge and competences to solve current sustainability problems and prevent future ones. Yet even though there are some good examples of sustainability integration in engineering education around the world, for instance through using the PBL approach, these efforts are still behind the needs. It is a fact that even as PBL is gaining popularity in engineering education around the world, the problems addressed and curriculum goals are, primarily, designed to train competences required by employers and accreditation systems [15], neither of which are currently aligned with the scale of the sustainability challenge before us.

Education for sustainability is still fragmented across disciplines, not considered a priority and added to the curriculum through elective and standalone courses, thereby lacking a systemic approach [16]. What we are not seeing much of are curricula that explicitly challenge disciplinary boundaries, including between humanities and the technical sciences, treat the issue with the urgency it deserves, and involves students, staff and management in the possibility of a paradigm shift [17]. Partly, this is because higher education institutions, disciplinary areas and teaching cultures are notoriously resistant to change. Within engineering faculties, prejudices and misconceptions about sustainability abound, combined with bloated curricula that cannot accommodate any more contents, but which seem impossible to condense. Poor staff training, leading to a lack of practical knowledge on curriculum development is also a barrier, which contributes to slow institutional change and integration of sustainability [16].

4.1. Exemplary problems for a systemic understanding

While it's true that both Wagenschein and Negt's perspectives on exemplarity can contribute to the integration of sustainability in engineering education by helping to overcome some of the barriers previously stated, we believe that only Negt's perspective permits the possibility of a paradigm shift in the institutions and students' way of thinking about sustainability. Negt's concept of exemplarity goes beyond the purely pedagogical. Furthermore, there is a clear link here between the work of Sterling on sustainable education [18] and Negt, as Sterling calls for sustainable education to be transformative, interdisciplinary, contextual, action-and problem-oriented. As we have seen, sustainability is a complex and interdisciplinary problem by definition. Consequently, the type of problems that students confront in their projects, and the learning process they go through should reflect that complexity. In that sense, merely replacing existing disciplinary knowledge with "sustainability knowledge", or adding it, in the engineering curriculum, it perpetuates the so-called "technocratic approach". What is needed instead is a holistic and systems thinking approach when integrating sustainability in engineering, that does not compromise on technical excellence but embeds in within a relevant socio-historical context. The curriculum must be organized around "exemplary problems" with the following characteristics: grounded in the experience of students and "real life", requiring to involve different stakeholders, to be addressed from a multiplicity of angles, calls on high level technical knowledge and competences, able to provide an analysis that goes from the specific to the systemic, that takes into account the contingent, historical, social, economic and political context of technology. For example, taking a starting point as concrete as a project-problem that examines the planning of a cycle paths network, or the development of a new plastic recycling process can absolutely be exemplary in the Negtian sense, provided that students are guided in the problem-formulation process to consider the dialectic between the specific technical situation described by the problem and the systemic issues it raises. But students do seem to struggle to look at specific sustainability problems as systemic issues. For example, our experience in talking to students who study plastic recycling is that they have developed a keen interest in sorting their own waste and recycling in general, from an individual perspective, which is a good step, but hardly any of them question the scale of the production and consumption of plastic or the "throwaway" culture in which these are embedded, which is what the sociological imagination would require. Fixating on individual action and fragmented problems is precisely one of the issues that Negt raised against Wagenschein's exemplarity.

4.2 Building up problems from narrow to open and complex

It is fair to say, though, that throwing students at the deep end in their first year may be a big ask. It is possible to gradually build up to truly exemplary problem, though. As a model to progressively include the sociological imagination in the practice of PBL, we can look to Savin-Baden's five PBL models [19], which provide a holistic view of PBL environments and propose dimensions through which to organize learning around problems. The models move from narrow and well-defined with focus on the development of disciplinary knowledge (model I and II), to more ill-defined and complex problems with focus on metacognition and interdisciplinary knowledge (models III, IV, V) (*Fig. 1.*). Thus, one the one hand, a limited case scenario with sustainability components, written by content experts and tutored for a small group of students by teachers within a specific disciplinary field could fit within models I or II, and make use of Wagenscheinian exemplarity. This approach to PBL is popular in vocational technical education, for instance at polytechnic institutions. On the other hand, an open problem, defined across disciplines by students under the guidance of teachers from an array of specialties could correspond to model V, and is suited to using Negt's approach to exemplarity.

Model	Knowledge	Learning goals	Problem scenario	Students	Facilitator	Assessment	State of sustainability education
(I) PBL for epistemological competence	*Knowing-what*	Use and management of knowledge	Limited-solutions already known	Receivers and problem solvers	A guide to correct propositional knowledge	Test of epistemological competence	Education about sustainability
(II) PBL for professional action	*Know-how*	Outcome focused acquisition	Real life situations	Pragmatics induced by professional culture	Demonstrator of skills	Testing competencies for work place	
(III) PBL for interdisciplinary understanding	*Know-what & know how*	Synthesis of knowledge across disciplines	Knowledge to act and interact	Integrator of boundaries	Coordinator of knowledge and skills	Skills and contextual knowledge	Education for sustainability
(IV) PBL for trans-disciplinary learning	*Reconstruction*	Critical thought from subject positions	Resolving and managing dilemmas	Independent thinkers	Orchestrator of opportunities	Demonstrate an integrated understanding	
(V) PBL for critical contestability	*Contingent, contextual & constructed*	A hybrid imagination	Multidimensional and open	Explorers' of underlying assumptions	Commentator, a challenger and decoder	Open-ended and flexible	Education as sustainability

Fig. 1. Savin-Baden PBL models as framework for Education for Sustainability (according to [16]).

In this *PBL for critical contestability*, the knowledge is characterised as contingent (i.e. depends on or is conditioned by other factors), contextual and constructed by the learner for given situations. The problem scenario is open, multidimensional and ill-structured. In the literature on education for sustainability, these problems are referred as "wicked problems" and call for multidisciplinary collaboration, innovation and critical thinking [20]. In this context, a problem scenario is a point of departure for problem identification, analysis and formulation and not a mere case provided by academic staff (exemplarity in the Wagenscheinian sense). Furthermore, the variety of PBL models also provides engineering educators with a framework for progressively developing engineering curricula for towards a transformative study of sustainability, starting with narrow problems with younger and less experienced students, focus on disciplinary knowledge and competences (including sustainability as a discipline), and increasing the complexity and openness of the problems and the interdisciplinarity of the projects as the students gain experience.

4.3. Educating the educators

Even when they are working on open problems, students shouldn't be left entirely to their own devices. At Aalborg University for instance, in some engineering education programmes, the project-problems are guided by a semester theme, defined by the teachers [21]. Developing real, complex, ill-structured themes wherein "wicked" problem scenarios can be identified and interdisciplinary sustainability issues are central, calls on teachers to collaborate and share their knowledge across disciplinary areas whilst empowering students to take action. Teachers need to be trained not only to work together in such a way but also on sustainability and how to integrate it on their own teaching/ discipline. Working beyond disciplines is a skill that needs to be developed, especially when teachers have been themselves educated and working for years within disciplinary boundaries. For this to happen, resources needed to be allocated in order to develop staff training and development courses on education for sustainability, reward systems and curriculum flexibility to set-up, for example, sustainability projects across departments and faculties [16].

4.3. Addressing curriculum overload

The overload of the curriculum is a problem in contemporary engineering education, as in many other higher educational studies, and is often used as an “excuse” to exclude sustainability issues. And yet this is happening in an age where knowledge is constantly produced and changing the way humans understand and interact with both technology and the biosphere, shortening the half-life of facts learned in the classroom. Simply adding more facts to the curriculum, even facts about the sustainability crisis, will only make the issue worse if students are not given the means to process the overload of information. Wagenschein understood the power of examples and analogy in reducing cognitive overload for students, but what he did not see what that examples could function as more than mere analogies, and rather as entry points into systemic issues that could function as an organizing principle for knowledge. Modern curriculum designers must not be afraid to cut out large amounts of contents, and trust in students to acquire specific contents as and when then need it in their professional careers. Instead, engineering students at university must learn to understand the system in which technology operates, examine it from all angles, thereby providing what in constructivist language we would call a “cognitive schema” in which future knowledge can be processed by the mind. In essence, this picks up on the distinction between know-what, how (education about sustainability), know-why, when and where (education for/ as sustainability) [16].

5 CONCLUSION

In sum, using exemplary learning could support the integration of sustainability education in engineering studies. First, through an alignment of sustainability learning principles with Negt’s concept and type of problems used. Second, by organizing the curriculum around exemplary problem, where both technical expertise and an systemic understanding of sustainability can be developed dialectically to educate technically excellent engineers that have a holistic understanding of the sustainability crisis. There are, around the world, several examples of problem-oriented, project-organized cases where exemplary learning is explicit [16, p.81], see for example, the elective programme from Arizona State University (US), GlobalResolve [21].

The central issue with developing exemplarity on a larger scale in engineering education programmes is that engineering education is currently a reflection of ministerial mandates for specific contents and competences that are largely driven by a market logic and only have a technocratic view of sustainability. These mandates are then pushed through via accreditation board who would not look favourably on paradigm shifting approaches. However, the rise in new environmental movements around the world and the speed at which climate change and other environmental issues are taking a toll on the planet currently is starting to shift the discourse, and may mean that exemplarity’s time has come for engineering educators.

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Science Camp - Science first hand at BME

F. Simon
BME Faculty of Natural Sciences
Budapest, Hungary

M. Láng-Lázi
BME Faculty of Natural Sciences
Budapest, Hungary

G. Pokol
BME Faculty of Natural Sciences
Budapest, Hungary

D. Módos
BME Faculty of Natural Sciences
Budapest, Hungary

B. Schmidt
BME Faculty of Natural Sciences
Budapest, Hungary

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ABSTRACT

The STEM education is facing considerable global challenges. The gap between education and research keeps growing because of the rapid expansion of knowledge generated by scientific research. Smart products or services of nowadays are based on scientific achievements but can be used with decreasing knowledge. Preserving secondary school students with scientific or engineering interest on these fields is a challenge. Consequently firsthand knowledge acquisition and experience-based learning are getting more and more valued.

The aim of our camp is to show the amazing colorfulness of physics and mathematics and their connections to other fields.

Another objective is to familiarize the children with the way the university function and – through the involvement of the students of Budapest University of Technology and Economics (BME) - the everyday student life. BME students play a key role in transmitting knowledge. On the other hand, they have an opportunity to taste social responsibility.

We target students who are at the point of deciding on their future career. We put special emphasis to select groups who are currently under-represented in our study programs. During our scientific programs we pick and show them topics that are

currently not covered by the high school curriculum but are supposed to be essential throughout their career.

During the week students participate in lectures; work on exercises from different fields and visit technology intensive external sites.

We plan to present the experiences and feed-backs collected during the four editions of Science Camp.

1 INTRODUCTION

In recent years, many studies have reported an alarming decline in young people's interest for STEM (Science, Technology, Engineering, and Mathematics) subjects [1,2]. It is highly desired to reverse this trend since the lack of STEM-skilled labour would be one of the main obstacles for economic growth. Besides the increase of the number of youngsters choosing engineering and natural sciences for their higher education, improving STEM-skills of those, who already hold a degree, is also necessary. In fact, the main contemporary challenge for the higher education is not to select the best students among the many good applicants but to find enough students worth for admission.

Some reasons of the low attractiveness of STEM studies are as follows:

- Students often lack real information on STEM professions and careers, e.g. how they look like in the real-life. As this field is rapidly evolving, often even the teachers and the career orientation counsellors do not have enough up-to-date information to help the students choose.
- Often the curriculum does not keep up with the latest scientific achievements thus its relevance is unclear for the students: they do not see the relation between the curriculum and the current issues of society.
- Experiments and team work are missing, although they could harness such experiences in real-life situations.
- Education does not go further than the institutional limits, i.e. the amount of field practice, industrial internship possibilities are limited.

All over Europe, women are underrepresented among those who choose STEM education [3,4]. In Hungary, growing expatriation of skilled high school students is a considerable issue. Actually more than 13,000 Hungarian students are learning abroad [5]. It is also a challenge to keep those high school students who take interest in STEM on a continued track.

Consequently, according to our conviction, first-hand knowledge acquisition and experience-based learning are becoming more and more invaluable. To mention a few examples, it can inspire tenacity and motivate to humble and hard work to see how 50 % of the overall Hungarian energy consumption is generated in a few power plant halls, or to visit the cutting-edge production site of a company (Semilab), which is a successful actor of the international semiconductor industry. Another example is to visit the National Institute of Oncology, where bio-medical imaging instruments are used extensively, all which are the result of the STEM related developments in the past 20 years [5].

Another paradox of our age is that the extent of the knowledge base required for a successful career is expanding. Lifelong learning and training are no longer an attractive notion but it has become a daily requirement for industry professionals. Nevertheless, it is becoming increasingly difficult to maintain the attention of young people during knowledge transfer. A common and widespread surmise is that any information can be easily reached from the internet on the smartphone so conventional learning is of limited benefit. To mention a real-world example, when someone is interested in nuclear energy or financial mathematics, browsing Wikipedia in 10 minutes (s)he can absorb more knowledge than the average. However this superficial knowledge will leave just as fast as it came. Moreover, no links with other fields are created so it cannot become a deep, practically usable knowledge.

In many cases, Hungarian youngsters living in the countryside or abroad are apprehensive of living in a metropolis and do not dare to choose the institutions of the capital. In order to overcome these difficulties, our faculty launched the "Science Camp" summer camp focusing on natural sciences in 2016. During the one week long camp, free accommodation and full board is granted for all attending high school students.

Though summer schools for high school students are organised all over the world [6,7] but the concept and the financial conditions of the Science Camp are very different.

2. The summer school

2. 1. The aim of the camp

The objective of the camp is to show the amazing colourfulness of physics and mathematics and to give an idea about their connections to other fields (medicine, chemistry, IT, engineering, and economics). Another goal was to familiarize the students with the way of operation of the university and – through the involvement of BME students the everyday student life. We also aim to motivate students for open-minded thinking and innovation, to improve their financial and legal skills. Throughout the social and cultural activities and sport programs, we also promote the BME and the local environment, the XIth District of Budapest. We hope that these efforts could contribute to the choice of BME at first place, overtaking even foreign institutions, when these students decide about the continuation of their studies.

2.2. Target audience

The target group for the camp is composed of 10th or 11th grade high school students who are at the point of deciding on their future education. We put special emphasis to select groups who are currently under-represented in our study programs (e.g. girls, students coming from the countryside, less-favoured regions, and from the Hungarian speaking minorities outside Hungary). Following a comprehensive information campaign about our camp in numerous high schools, students were selected for admission based on the recommendation letter of their teachers and a letter of motivation. A 4 membered scientific jury, which represents physicists, mathematics, and the student organization, evaluates the applicants and selects the participants of the camp. We pay special attention to give the opportunity for as many applicants living in economically less developed regions or abroad (mainly students of Hungarian mother tongue living in the neighbour countries) as possible. It is much more difficult for this target group to get into or even to acquire information about an event organised in Budapest than for those who live in Budapest or in its agglomeration. As the camp is funded by social sponsors or companies, their donation contributes directly to the advance of these young people. The distribution of the applicants by region is shown in *Fig. 1.* The circle diameters are proportional to the number of accepted students.

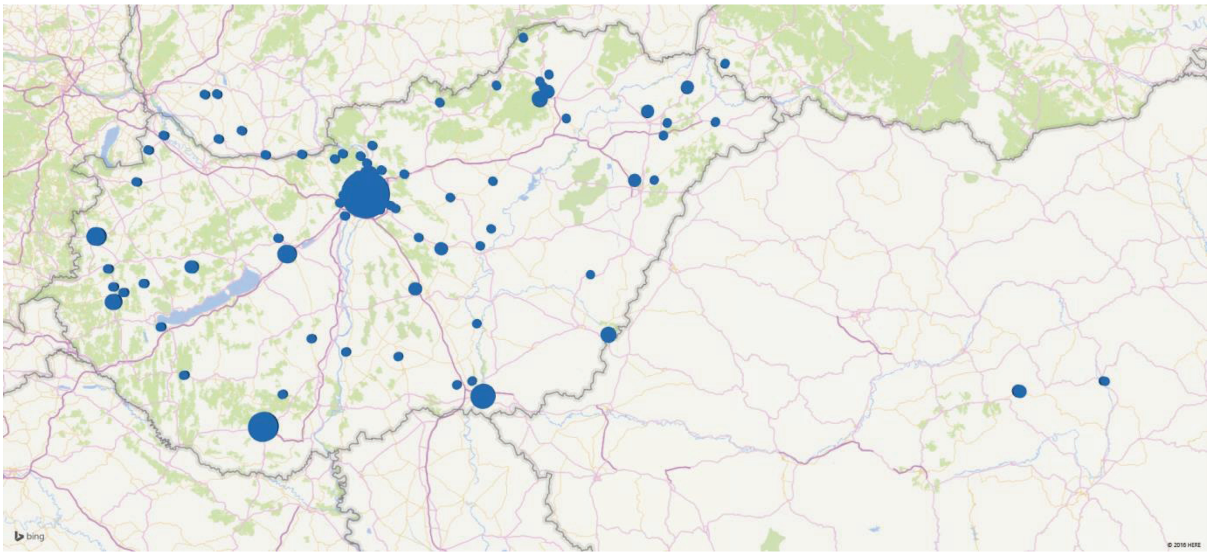

Fig. 1. The distribution of the applicants by region (2016).

We consider that the summer camp is successful if we can achieve that majority of our students choose a higher education, which focuses on natural sciences or engineering in Hungary.

2.3. Programs

During our scientific programs, we try to select and present them topics that are currently not covered by the high school curriculum but are supposed to be essential throughout their future career.

During the one-week long camp, students participate in scientific lectures, they work in teams on competition exercises from different fields (e.g. mathematics, physics, nuclear or medical physics, and financial mathematics). Thanks to the rich network of partnerships of the BME and the multifaceted experience on the labour market of our graduated former students, the high school students have the opportunity to visit technology intensive external sites (*Table 2.a*). With these external visits we wish to go beyond the traditional framework of the scholar education by showing real-life experiences, stories, and role models for the students. *Fig.* 2.

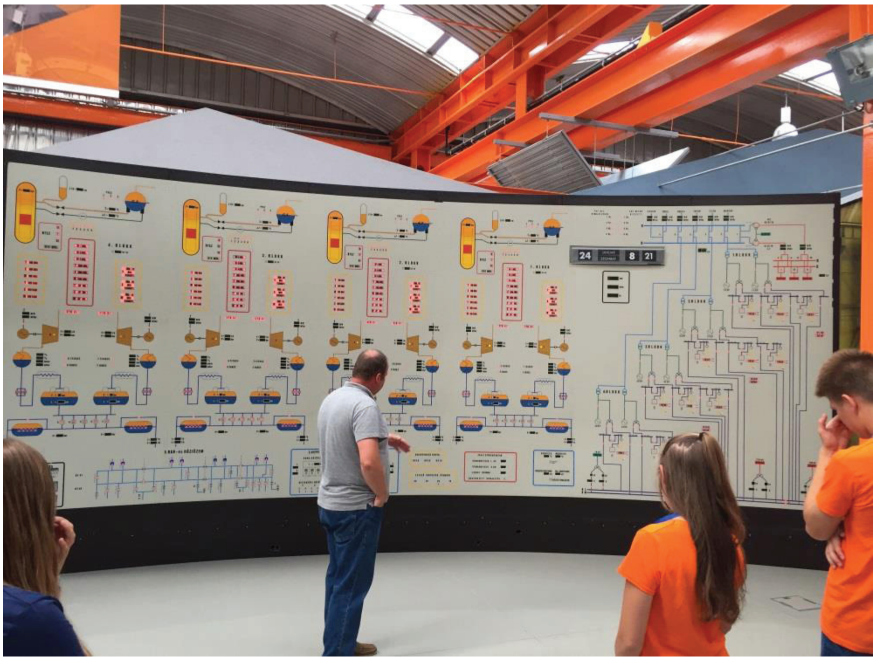

Fig. 2. Visit to Paks Nuclear Power Plant in 2018

Another important field, where we pay special attention to overcome the limitations of traditional education, is that we put great emphasis on solving problems together, in team. In contrast to the scholar education, where mostly the individual achievements are measured and evaluated, we encourage and promote teamwork. We believe that most of the scientific, financial or technological success stories are the results of coordinated teamwork. In a team, members having diversified skills and different personalities can complete each other and create results and solutions that go beyond their individual competence. To demonstrate the force of teamwork to the participants, we provide problems to the students to solve in small teams.

Fig. 3. Teamwork

As a result of our methodology of student selection, all pupils are highly-skilled and open-minded but their social background is very different just as their personalities, e.g. their self-confidence. Besides intellectual and cultural challenges, various social activities and sport programs play an important role in the program.

The most important programs of the camp of 2018 are summarised in *Tables 1-3.*

Table 1. Lectures

Lectures
From Fibonacci numbers to shift register
How reliable are numerical computations on computers?
Topological curiosities
Small evening physics

Table 2. Visits

a.) External visits
Paks Nuclear Power Plant. The Information and Visitors Centre and the Museum of Nuclear Energetics
Morgan Stanley
Centre for Budapest Transport: Central Trafic Management,Courier Center / Industry 4.0 (BME)
SEMILAB (semiconductor industry) / Oncological Institute
b.)BME Laboratories
Institute of Nuclear Techniques: training reactor, medical physics, plasma physics of fusion
Institute of Physics: nanoelectronics, high field electron spin resonance, molecular electronics magneto-optical

Table 3. Other programs

Other programs	*Leisure time programs*
Team-work problem solving	Sport, Sport Center BME
Competition	Escape Game (BME, HSZI)
Meeting with alumni	Get together party
Creative writing	Boat trip on the Danube
BME promenade with the eye of an architect	Closing Ceremony
	Gellért Hill

2.4. University student participants

From the very first moment, we paid great importance to the university students who helped in the realization of the dense programs located on multiple sites. They were mostly BSc and MSc students in physics, chemical engineering, and mathematics. They actively participate in guiding the students between sites, in the realization of the social events and competitions, and they help them adapt to the life in the college. There are 20-21 university students who participate in each summer camp. This may seem excessive compared to the number of student participants (between 45 and 60). However according to our experience, university students can be considered as rather active participants as compared to the persons who help in the arrangement and organisation of the camp. As an added benefit, the scientific programs have also a significant impact on the vision of the university students about natural sciences and their devotion to the speciality chosen. They play an important role in knowledge transfer through informal discussions with high school student. This also gives the university students a possibility to participate in social responsibility programmes as well.

3. Feed-back

From 2016, altogether 231 students participated in the four Science Camps. From the 135 students who graduated from high school , and could apply to higher education, 67 were admitted to one of the faculties at BME. It clearly satisfies the , above set criterion, which we consider as success for the camp.

On the last day of the camp, both high school and university students respond to an anonimous satisfaction survey. The results were always delighting to the organizers of the camp. The high school students gave high scores for both the overall camp and the participation and support of university students. Lots of useful observations are made which we try to consider in the following edition of the camp. Nevertheless, the different focus of interest and social background of the children is also reflected in their comments and observations.

3.1. Selective examples

-What do you recommend for the next Science camp?

A common suggestion was to make the timetable a little bit less crowded, leave more leisure time and to organize more sport program. Somebody wrote: “Maybe the schedule was crowded but so we had insight to more things”.

- **Do the things that you saw and heard in the camp influence your occupational choice?**

In many cases, according to the responses the things experienced and heard in the camp helped or influenced (strengthened) the choice. That is, these students would choose more confidently the BME after the camp than before. E.g*.: 1.* ‘I got a positive feedback on BME about which I had scarce information before. Now I have a more complete picture of it.” 2. “The camp showed me and made me consider new options which were unknown to me before”. 3. “No, but my choice of the BME university overtakes all other options.”

In some cases, the camp aroused the interest for the study programs of the Faculty of Natural Sciences. 1. “I saw that physics is better and less boring than I had thought before." 2. "I got convinced that the physics formation is not exclusively about physics. I saw that finding a job will be possible in several different fields. I feel like going to a college." 3. I got to know that physicists can work elsewhere than in research, this helps me choose the formation of physics". 4. Honestly, I took into consideration to choose physics and the Faculty of Natural Sciences, however I had been thinking about completely different directions before." 5. "Yes, I think the camp made me even more confused. I do not really know yet. But the spectrum became larger from what I can choose".

In some cases who replied yes, it was impossible to clearly identify what they were thinking about. E.g.: 1. "Yes, the camp confirmed that the profession I plan is nice and interesting." 2. "Yes, the presented formations attract me even more than before". 3. Yes, we heard honest opinion about the university, its faculties and about the life here." 4. "Yes. It was efficiently demonstrated what kind of work is to be done during an engineer or physicist career. Moreover we could participate in such programs and experiments. I see now more clearly the similarities and the differences. This will help me in choosing my career which is actual soon."

These citations illustrate that the camp made deep professional and/or human impression on the students. We consider that our goal to show them alternatives for their career choice was reached.

Fig. 4. After the closing ceremony (2019.)

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CROSS OVERS IN TECHNOLOGY-RELATED JOBS
21st century skills of a social media architect

Sjoer, Ellen[1]
The Hague University of Applied Sciences
The Hague, The Netherlands

Beelen-Slijper, Jeany van
Inholland
The Hague, The Netherlands

Biemans, Petra
Inholland
The Hague, The Netherlands

Jacobs, Frans
The Hague University of Applied Sciences
The Hague, The Netherlands

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ABSTRACT

A social media architect is an appealing new profession that entails crossovers between communication and IT & Design. There are no study programmes for this job. Important questions are how to interest secondary school pupils for such a new job, and how to prepare them for these jobs or jobs that do not even exist today? This research aims to set an example by presenting a realistic job profile of a social media architect by linking the '21st century skills' to the context in which he/she operates. In-depth interviews with social media architects that can take six different roles: strategist, designer, videographer, copywriter, content manager, and team head, revealed that 'creativity' and 'collaboration' are the most important skills clusters. By diving deeper into the subcategories, it became clear that they mean something different for each role. As a consequence, each role should be appealing for students with different profiles. Furthermore, we also look into what drives and motivates professionals to work as a social media architect. We should take a more holistic view if we want to attract and educate pupils about (new) professions. This research project serves as an example on how companies and secondary and

[1] Corresponding Author: Dr. E. Sjoer, e.sjoer@hhs.nl

higher education establishments can combine their efforts to innovate job profiles for the changing labour market.

1 INTRODUCTION

1.1 New Professions

Work is changing rapidly. Problems can no longer be solved from a single discipline because they are so multifaceted and complex that cross-overs between disciplines are needed. As a result, jobs are disappearing, or changing considerably, and new professions are created [1]. Job titles such as social media architect, neuro marketer, ethical hacker and drone pilot show that employers are looking for distinctive competences. These jobs often require technical expertise (which is constantly evolving), in addition to a greater need for so-called ‘21st century skills’.

Secondary and higher education establishments face difficulty in responding to these developments. In secondary education, it is important to be able to provide an up-to-date overview of study programmes and professions since pupils have to make a choice about their further education. Moreover, both secondary schools and higher education establishments would like to know how they should prepare their students for new professions or jobs that do not even exist today. For companies that want to hire these new employees, it is also important to gain insight into the profiles and the corresponding 21st century skills. Our education system has no suppliers for new professions, which makes it difficult for them to find the right staff.

To set an example, we decided to study one appealing new profession: a social media architect (SMA). An SMA helps companies to develop and execute a (media) strategy. It is a cross-over between communication and technology. We conducted three interviews with teachers of a secondary school. They indicated that they did not pay much attention to new professions during lessons in which they help pupils to select a study programme. Investigating an SMA as an example, seems a good choice to them, because it sounds good, but pupils have no idea what he or she does all day and what it takes to become one[2]. Furthermore, more pupils might choose a technical career. According to Endedijk et al., a technical career is now often chosen by ‘nerdies’ and ‘loners’ [2]. These students find it difficult to be confronted with the 21st century skill’s, such as collaboration skills. When we show the cross-overs in current jobs, students with different profiles might opt for a technical career.

1.2 Theoretical framework of the 21st century skills

To make clear that our future workforce requires different qualities than disciplinary knowledge and some soft skills, the term ‘21st century skills’ was introduced. A large number of frameworks were created primarily at schools and universities to describe

[2] This finding is confirmed in a small questionnaire with open questions among 112 high school students.

which qualities will become important [3]. We share the criticism that also arises about these 'lists' of 21st century skills. We, too, believe that they will not help sufficiently to educate students or employees. Moreover, 'skills' is probably not the right term. Nevertheless, it is helpful to use a framework in this paper to give an idea of the capabilities of our future workforce. We chose to use the 'Framework for 21st Century Learning' (P21 model), among other things, because this model is well documented. The model has been jointly developed in the United States by education, business and government [4]. This framework describes the skills, knowledge, and expertise students must master, represented by a rainbow, to succeed in work and life (see figure 1). It is a blend of content knowledge, specific skills, expertise, and literacies. In this P21 model, the 21st century skills are divided in three clusters, and several components. (see table 1).

Table 1. Clusters of 21st century student outcomes (P21)

Life and Career Skills	Learning and Innovation Skills	Information, Media and Technology Skills
Flexibility and adaptability Initiative and self-direction Productivity and accountability Leadership and responsibility Social and cross cultural skills	Creativity Critical Thinking Collaboration Communication	Information literacy Media literacy ICT literacy

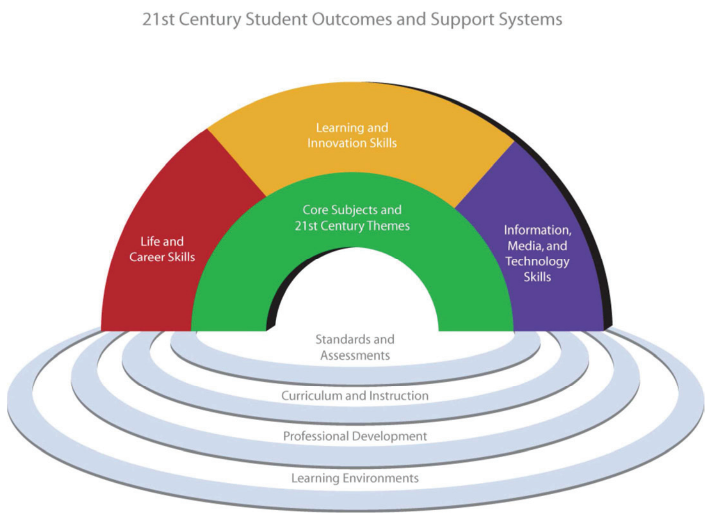

Fig. 1. P21 framework of 21st century student outcomes

1.3 Research question

The research question is: *Which '21st century skills' does a (team of) social media architect(s) need(s) for which professional activities and professional results?*

2 METHODOLOGY

We conducted a qualitative interview study to describe the professional activities and the associated 21st century skills of an SMA. According to the practitioners, this new profession consists of six roles, which taken together, form the professional profile of an SMA: strategist, designer, copywriter, content manager, videographer and a team head.[3]

2.1 Respondents and procedure

Five SMAs were interviewed for approximately 75 minutes each (see table 2). The semi-structured interviews were conducted using an interview template with six blocks of questions. Each interview started with general questions about their age, educational background, professional experience. The second block contained questions concerning the area of activity, such as stakeholders, sectors and emerging economic and social trends. This was followed by blocks of questions about the professional activities and the qualifications and competences to meet the objectives of an SMA. The interviewees did not get a list of 21st century skills, but they got questions such as: What is absolutely necessary to do the job well? What would you look for if you want to hire a colleague in your role? Finally, there were questions relating to the motivation for the job and career development. The interviews were recorded and transcribed. All transcripts were then analysed with a software programme, using the six blocks of questions. Finally, the results obtained were evaluated in a workshop with three SMAs, (including two interviewees), two teachers and three researchers.

Table 2. Background of the respondents

	Role	Background (study)	Professional experience
1	Strategist	Commercial communication management (higher vocational education)	7 years: communication officer/ manager (at a large tech company); 4 months at SMA agency
2	Designer	Associate degree in graphic design and art college (UAS)	3.5 years at SMA agency
3	Copywriter	Upper vocational secondary education in business and administration	Graphic designer in Screen printing shop; designer and copy writer ad agency; (Chief) editor publishing company; 6.5 year at SMA agency
4	Content manager	Communication and Media (Erasmus University); Master Corporate Communication	Full time in restaurant business; online marketer; 4 months at SMA agency

[3] In the near future, the role of designer and videographer will be combined. This role will be defined by the word: ‘creative’.

		(University of Amsterdam)	
5	Videograph/teamhead	Economics at university of applied sciences (minor at art college)	Video-head at large e-commerce company (3 years, in total 7.5 years at this company) + own company (in film/video, such as wedding videos); 3 months at SMA agency

The five interviewees are all working in the same company, which is a small, innovative company with 16 employees, located in a city in the Netherlands. The roles in Table 2 are assigned to the employees and they operate in this role in one of the three full service teams that exist within the company. Nearly all the interviewees are about the same age: 28-29, apart from one respondent, who is 52 years old.

3 RESULTS

3.1 Professional activities related to 21st century skills

In the aforementioned workshop three SMAs, two teachers and three researchers defined what is most important for an SMA. They conducted a so-called ‘why’ session with the following result:

‘A social media architect is immersed in the needs of the customer and target group, and translates this in co-creation to (digital) content to ensure the conveyed message touches and moves the target group.’

For example, one assignment is about generating positive media attention during the period that an important tunnel is closed in the city. In order to create understanding among the public, who often used the tunnel, so-called ‘fixed columns’ have been created, generating a constant stream of media attention. When monitoring the impact, it shows that the interaction is good, thus ‘engagement’ continues to rise. Every now and then the team SMAs try their hand at ‘newsjacking’. At Christmas time, the idea was to make a short movie, ‘our building heroes’ about the people who renovate the tunnel, to acquire an attention peak on social media and ‘to surprise those algorithms again’. (After the strategist's story).

The ’21st century skills’ needed to achieve the aforesaid objective with a team of SMAs, are shown in Figure 2.

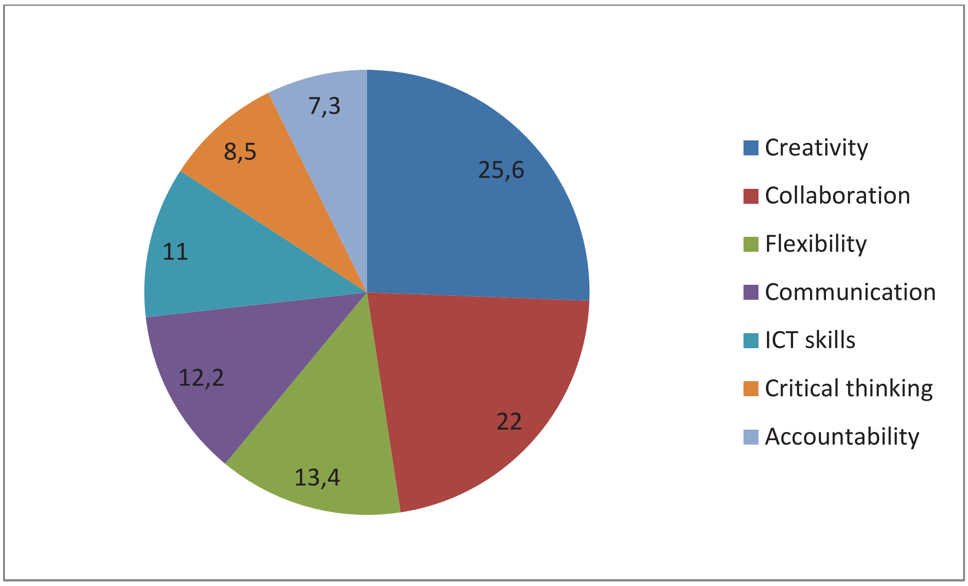

Fig. 2. Frequently mentioned 21st century kills of an SMA

The two most frequently mentioned skills are ‘creativity’ and ‘collaboration’. These are two big clusters of skills that seem to be important. The second largest groups are ‘flexibility’, ‘communication’, and ‘media and technology skills’ (in short: ICT skills). The third most important groups of skills are: ‘critical thinking’ and ‘accountability’.
The narrative of these important groups of skills can be defined as follows. In this company, SMAs work as a team. To achieve their common goal they have to be creative (together). They are communicating with each other frequently and thoroughly, as well as with the client. Furthermore, as a person, they have to be flexible, media literate and able to apply technology effectively. Finally, as an SMA, you have to manage time and projects successfully and take responsibility for the final results.

3.2 The meaning of 21st century skills per role

Roles and tasks of SMAs differ in the team and with it, the emphasis on particular skills. A strategist seeks for the question behind the clients question and converts it into a communication or media strategy for a specific target group. A designer designs the images and a copywriter writes short, well-chosen texts and scripts. A videographer makes appropriate, surprising videos and a content manager spreads the message that a client wants to communicate. He/she literally posts on Facebook. Finally, a team head (in this case also a videographer), ensures that the team functions well.

The results of the most frequently mentioned 21st century skills: creativity, collaboration, flexibility etc. are not enough to recruit new entrants to the profession, and/or to educate pupils or students for future jobs. Therefore, we dove deeper into the matter and we made a summary of the professional activities and results per role, the essential knowledge, and the most important 21st century skills that come with it, according to the respondents. Furthermore, we looked at their value proposition, asking questions like: What makes this so cool and interesting for you?

When we take a closer look at what **creativity** entails, we discover what it means for different roles. For a strategist, it means to use idea generation techniques to gain new ideas (together) and to turn these ideas into a (media) strategy or approach that has an effect on people. Creative thinking and a useful contribution to the client (the result of creativity) are the most important elements. Whereas for the designer, creativity mostly means to be able to demonstrate originality and inventiveness in concrete work, e.g., a logo. A content manager can be confronted with negative reactions after posting a message, and s/he should be creative in re-thinking, which was described as: 'to analyse and evaluate own ideas and flip them to the positive side'.

To be able to work as an SMA at this company you should be a '**team player**'. All SMAs have to demonstrate their ability to work effectively within a team. Each play a part in a theatre piece, or a music band, so to speak. They value each other's contributions, have a willingness to be helpful and to make compromises to accomplish a common goal. 'We talk a lot with each other. It's a new industry, it's new work, so there are no paths we can take. […] Within the team we always consider: are we doing this because we did this last time, or because it works best.' (content manager). They also work together with external parties: printers, website builders etc.

Yet, this collaboration requires something different from a copywriter than from a videographer. Although they are both part of a team, the latter can make a video all by him/herself from start to finish, whereas a copywriter's work is often fragmented. S/he should revise many texts of colleagues, or write small texts for different multimedia presentations. This requires **flexibility both in time and mindset**: 'If something needs to be online this afternoon and colleagues want to have it checked, I can say that I don't have time for that, but that won't help anyone.[…] But it also means switching from writing something for a cycle repair shop to writing for a lawyer'. A copywriter must be able to adapt to schedules and contexts and has to work in a climate of changing priorities. Adapting to changes also applies to the content manager in relation to the client: 'Imagine your content is ready for this week and then the customer calls: "something is happening now and that needs to be communicated quickly". […] Then all content goes to next week, or to the trash and then you start creating something else.'
Especially creators of tangible products such as texts (copywriter) and images (designer) mentioned that being flexible also means incorporating feedback effectively. 'If a colleague thinks something is ugly, you must not relate that too much to yourself'. Also with the client, both gave examples of understanding, negotiating and balancing diverse views to reach workable solutions. 'If you get the answer [from the client] "that it doesn't feel right", they actually mean that it is not entirely how they

see it. But if that is what their target group is aiming for, if it does what you want to get done, it's best to think about it for a while. […]. At first I do not agree. I want to talk with the client again.' (copywriter) Another example of understanding and balancing diverse views: 'As a designer, you must be able to work for someone else. Sometimes you have to be careful with your own style. We never make things that we don't like, but sometimes you have to make concessions.'

The core-business of an SMA is **communication**. Almost all SMAs emphasise <u>the ability to listen and to read emotions</u>. Customer empathy is important for the strategist to ask the right questions to get to the real problem; for the designer to get information about the context and intentions; for the copywriter to understand the target group better; and for the content manager to develop a relationship with the client: 'they should see you as a colleague'. All SMAs <u>use communication for a range of purposes</u> and <u>utilise multimedia and technology</u>. Their core knowledge is about <u>how to judge their effectiveness a priori as well as assessing their impact</u>. The reason that **information, media and technology skills** did not comprise the most important group of skills may be that they take their ability to <u>access and evaluate</u> information, to analyse media and to apply technology effectively for granted.

Regarding the **knowledge** component, <u>disciplines</u> such as marketing/sales, psychology, communication, and journalism are mentioned. Up-to-date information on <u>legislation</u> (AVG), <u>software expertise</u> (knowledge about packages and programmes, knowledge about the operation of websites, algorithms) and of course <u>role-related knowledge</u> are also mentioned; for example, for the videographer, knowledge of camera equipment and technical expertise about making videos: 'what makes a nice shot?'. Nearly all SMAs talk about <u>awareness of new (technological) developments</u>. 'What's new in social media?' Upon asking this question, current trends according to the respondents are: more images, ultrashort, personalisation, passion for data.

To have some understanding what **drives and motivates** SMAs, we asked: What are you most proud of? Four categories emerged from the data:

1. Happy customer: 'Who is really satisfied and his expectations have been exceeded'
2. Teamwork: 'A final result that everyone has contributed to'
3. Results: 'Seeing the result if you pass it or if it is on social media.' 'Starting with nothing and creating something very beautiful that tells a story.'
4. Effect on the target group: 'If it elicits responses that you had hoped for, yes, then I am proud.'

4 CONCLUSION

In this paper, we investigate which '21st century skills' a (team of) social media architect(s) need(s) for which professional activities and results. A social media architect (SMA) is a new profession. It combines several roles: strategist, designer, copywriter, videographer, content manager, and team head. Teachers of secondary school and higher education do not know how to introduce pupils and students to new professions and how to prepare them for jobs that do not even exist today. At the same time, small enterprises of social media architects are growing rapidly and they are in need of more detailed information on the skills of new hires since they cannot fall back on appropriate study programs or work experience.

The job of an SMA and the approach we took to investigate this profession thoroughly serves as an example of many new professions, such as ethical hacker, digital detox therapist, urban farmer, smart-home expert, privacy consultant, and crowdfunding specialist.

If we compare the 21st century skills that emerged from our data with the P21 framework of 21st century skills (see chapter 1.2), we conclude that of the famous 4 Cs in the learning and innovation skills cluster: creativity and collaboration are the most important skills for an SMA. If we take a closer look by comparing all the creativity quotes for the roles an SMA can take, a strategist should be good at 'creative thinking' (together), a designer and copywriter should provide 'creative work' (with others) – meaning demonstrating originality and inventiveness in work – and a content manager should be good at 'implementing creative innovations'. Communication, especially customer empathy, and collaboration are of utmost importance since these SMAs work in a team that considerably depends on each other's individual contributions. Although stated less often, 'critical thinking' was mentioned in the sense of solving different kind of problems in innovative ways, and reading statistics: interpreting information and drawing up conclusions on the effect of media messages on the target group, as well as making an analysis upfront. Given the trend to work in a more data-driven manner, the importance of this skill may increase over time.

From the cluster of life and career skills 'flexibility and adaptability' and 'productivity and accountability' stand out. An SMA should be adaptive to change, and has to work effectively in a climate of ambiguity. As a team, they are very structured. They work with planning tools which makes it easy for people to assign tasks to each other. However, something unexpected often happens and the deadlines are tight, because SMAs often respond to current events and they want to have a consistent stream of content online. From our findings, we do not see any quotes concerning 'cross-cultural skills'.

Surprisingly, the information, media and technology skills cluster was mentioned less often, but was named in conjunction with the required knowledge of an SMA. Moreover, we think that SMAs take the ICT-related skills for granted. If the social media architect is known for anything, it is known for its cross-over between (social media) communication and (multimedia) technology. An interest in social media, customer empathy and creativity go well with creating media products and using digital technologies effectively. You can't have one without the other. We see the same development in our research on professions in transition [5]. An HR-advisor should understand HR analytics, an accountant should become a data-analyst with financial knowledge – or the other way around?

In our approach, we do not advocate making job profiles for new jobs in a traditional way based on job demands. We recommend taking a holistic view when attracting and educating pupils and students about (new) professions. It should be clear in which kind of environment an SMA must show what kind of 'skills', in the broadest sense, thus including attitudes etc. Which combination of skills is necessary to be successful in which role within this team, and what drives every individual? What is he/she aiming for? What makes him/her proud? The motivation of professionals and the working context should be clear in every information clip for students or interview with applicants.

The strength of our approach is that we make complex material accessible to a wide audience because we bring new professions into focus by making them concrete and personal. We do this by:

- Focussing on professional activities and professional products;
- Combining knowledge and 21st century 'skills' (broadly defined);
- Showing the interaction between different roles and skills;
- Relating to what motivates people;
- Using information directly from employees themselves;
- Putting it into context;
- And supporting it by data (from interviews and observations): experiences and practical examples.
- And next (not in this paper), designing future-oriented professional images in co-creation, which are realised in a collaborative process that is already shifting the mindset.

Technology is at the core of many jobs, but engineering and technology-related jobs are context specific. Many times are over, professionals can do the same work everywhere. A programmer contributing to the energy transition should understand this domain thoroughly and its key players [6]. The same programmer cannot be easily transferred to another domain (anymore). Therefore, our main message to every (pre)professional is to know yourself, and to explore and choose for the context or domain you want to make a contribution to, and in which role, instead of relying to job titles and job descriptions.

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Implementing 21st century skills in education at NTNU and DTU

B. Sortland
Norwegian University of Science and Technology
Trondheim, Norway

H. Løje
Technical University of Denmark
Ballerup, Denmark

Conference Key Areas: New notions of interdisciplinarity in engineering education, Diversity in Engineering Education?

Keywords: Interdisciplinary, teamwork, skills

ABSTRACT

NTNU (Norwegian University of Science and Technology) and DTU (Technical University of Denmark) have established compulsory courses to provide students with interdisciplinary teamwork skills:

- The students work in interdisciplinary teams
- They work on real-life challenges
- At the same time, they take a meta-perspective on their own cooperation in the project.

NTNU's Experts in Teamwork course is compulsory in all master's programmes and programmes of professional study at NTNU and is offered to 2,500 students each year. About 100 members of the teaching staff are involved, and 200 learning assistants are employed each year.

Innovation Pilot is a compulsory course in all bachelor of engineering programmes at DTU and is offered to approximately 800 students per year. Some 20 members of the teaching staff are involved, and 10 learning assistants are employed each year.

In both courses, the students develop teamwork skills by reflecting on and learning from specific situations of cooperation in carrying out a project in interdisciplinary teams. The students' own team experience forms the basis for their development – how they and others contribute, and how the team functions, are subjects of discussion, reflection and feedback. The courses provide students with 21st century skills and are an important contribution to the engineering education field.

1 INTRODUCTION

1.1 21st century skills and their importance

A key social mission for higher education is to contribute with competences that uphold society and develop it further. From society and industry alike, there are increasing demands for skilled and well-educated engineers who can develop new solutions through innovation, and for creating successful innovation interdisciplinary teams with a focus on solving problems are necessary.

A key question is: How can we best help and prepare our students to cope with the more uncertain, rapidly shifting, competitive and inter-connected world?

Different studies conclude that students are lacking in some basic skills as well as a large number of applied skills called the “21st century skills” [1]:

- Oral and written communication
- Critical thinking and problem solving
- Professionalism and work ethic
- Teamwork and collaboration
- Working in diverse teams
- Applying technology
- Leadership and project management

In Scandinavia several universities working with experienced-based and interdisciplinary learning have established an “Experts in Teams” network founded by The Nordic Council of Ministers (Nordplus). The network's main objective is to train students to utilize their academic competence in interdisciplinary settings in order to reach enhanced project outputs. This is achieved by focusing on teamwork skills. The work methods in the Experts in Teamwork course at NTNU have been developed over two decades and have influenced the development at other universities. The network has established a conference called “Interdisciplinary Teamwork Skills for the 21st Century” (Its21), and initiated the process of developing cross-Scandinavian learning material and practical training of teachers in interdisciplinary teamwork skills; see: http://nordicexpertsinteamsnetwork.org/

This paper presents two initiatives aimed at giving students interdisciplinary teamwork skills. Although the origins of Experts in Teamwork at NTNU and Innovation Pilot at DTU are different, the courses have ended up fairly similar. Both courses bring students together from different study programs, include working with external companies to solve challenges provided by the companies, and also has focus on the collaboration in the team.

It is a fact that active and collaborative learning practices have more significant impact on students’ performance than any other variable. By engaging students from different study programs and place them into an interdisciplinary learning environment, the idea is that they will make use of different viewpoints and different competences in order to solve case problems for the involved companies. Thus, both courses focus to a large extent on the “21st century skills gap”. By training the students' interpersonal collaborative skills, it is our belief that the training may also facilitate innovative processes.

1.2 Introducing interdisciplinary skills in education

Experts in Teamwork was established in 2001 as a compulsory course as part of a major revision of the Master of Science program at NTNU. The course was developed in response to a request from the industry in Norway for students with the necessary skills and tools to work across disciplinary boundaries [2]. The course required a radical change of teaching, from lecturing and instructing to facilitating, i.e. to facilitate the development of abilities in cooperation, reasoning and decision-making in teams. At that time, the change was hard for many teachers, and it took several years of planning and testing to implement the desired changes [3]. In 2002, the board of the university decided that Experts in Teamwork should be included in all programmes of study at master degree level.

In 2014, the first version of the newly developed CDIO-based bachelor of engineering programmes (B.Eng.) programmes was launched at DTU [4]. The programmes were the result of a comprehensive merger process of former diploma programmes, namely the programs at Engineering College of Copenhagen (now DTU Diploma) and the Technical University of Denmark. The most significant new activity in the programmes was the introduction of a compulsory course in innovation in the later part of the programmes. The course was named Innovation Pilot. The idea behind this course is to give students the opportunity to collaborate on interdisciplinary real-life projects. This course strengthens not only innovation skills but personal and interpersonal skills as well [5]; [6]; [7].

1.3 How can we train the development of teamwork's skills?

Students develop teamwork skills by reflecting on and learning from specific situations of cooperation in carrying out a project. Interdisciplinary teamwork is used as an opportunity to develop collaborative skills that make teamwork more productive. Open-ended challenges from civic and working life form the basis for teamwork, and the results achieved by the teams are used to benefit internal and external partners.

The learning method is experience-based. The starting point is students' experiences together with each other "here and now". This means that they relate to situations arising in the team, they share their thoughts and feelings about each other's patterns of behaviour and approaches to situations in their teamwork, and then reflect on this.

Interdisciplinary teamwork skills can be described as both knowledge of the prerequisites for effective interdisciplinary teamwork, and skills in finding solutions to a variety of open problem formulations in cooperation with people from other disciplines. It includes skills to identify key aspects of the teamwork, and reflect on the essence of these aspects in order to develop the team. It also includes skills to change teamwork patterns to make the team more productive and create a positive, constructive and social climate for the cooperation.

Relating to each other in an ongoing work process is intellectually and emotionally demanding and causes the students to become deeply involved in their teamwork. This creates learning experiences that help to improve the learning outcomes. When theory is presented to the students, the main aim is to contribute to a greater understanding of the group dynamics in their own team.

To make experienced-based learning work well, the teacher roll has to change accordingly. It is not enough to simply tell the students to work together. The teachers will also have to be experts at the same 21st century skills they are imparting to their students and be aware of their role as facilitators. This necessitates training of the teachers, also with regard to facilitating the innovation process (train the trainers).

1.4 Two cases – NTNU and DTU

Experts in Teamwork at NTNU

Experts in Teamwork is a 7,5 ECTS compulsory course for all master's degree students across all eight faculties at NTNU. The students are organized in classes called "villages" of 20 to 30 students. Each village is taught by a member of the teaching staff and two learning assistants acting as facilitators, and has a broad overall academic theme (real-life challenge) that forms the basis for the students' project work. The villages may have external partners that represent the theme and who may be advisers and recipients of the students' work.

Innovation Pilot at DTU

Innovation Pilot is 10 ECTS compulsory course in the final year of all 18 study programmes of the bachelor of engineering programmes at DTU. The students are divided into classes of up to 60 students called "labs". Each lab is allocated to a company or several companies providing open-ended real-life challenges for the students, and is run by a facilitator team consisting of two facilitators or one facilitator and one learning assistant.

Common for the two courses

The overall learning outcomes and methods are more or less the same for both courses. The students work in interdisciplinary teams with five to six participants from diverse programmes of study. The student teams are mixed from across all programmes of study, they are allocated to the labs or villages on the basis of their preferences, and no more than two students from the same study programme is allowed in each team. The teams hand in both a project report and a team process report (reflection report) at the end of the course.

The learning assistants in both courses are students employed on part-time basis with training in observation and facilitation. The facilitators' role is to initiate reflections by highlighting aspects of the team dynamics that may be less evident to the team itself and to guide the students though the innovation process.

2 METHODS

In this section, we compare the two courses with respect to intentions behind the courses, the learning method, and training of the facilitators and how the learning objectives are achieved.

2.1 Intentions of the courses

The course description for Experts in Teamwork specifies that relevant problem areas from civic and working life should form the basis for the students' project work, and that the students should reflect on the social usefulness of their project. Interdisciplinary project work in teams with such goals helps to create a deeper understanding of the relationship between project work and innovation.

In Innovation Pilot the companies provide the teams with open-ended projects which take their starting point in actual challenges observed by the company. The teams explore the challenge by doing research into the problem, the needs and the context, including the use of different tools to re-define the problem definition before focusing on the problem solution. This will train the students in how to work systematically with innovation as an exploratory process. Furthermore, the course provides training of communication of needs and solutions to relevant stakeholders by pitching, prototyping and written presentations [6]; [7].

The expected learning outcomes in the two courses particularly contribute to the development of what is called the general competence (central parts of 21st century skills), and is formulated:

General competence developed in Experts in Teamwork

- *Students have extended their perspective on their own specialized knowledge in their encounter with skills from other disciplines. They can communicate and apply skills they have developed in their own field in collaboration with students from other disciplines.*
- *Students can collaborate with people from other disciplines, and they can contribute to realizing the potential of their combined interdisciplinary expertise*.

General competence developed in Innovation pilot

- *Enable you to solve complex challenges in companies through using your engineering knowledge and thereby train an innovative mindset.*
- *Provide insight and experience in working and collaborating across engineering disciplines as part of your engineering professionalism.*

Even though the courses are on different levels, the overall intention of the courses based on learning outcome is fairly similar. For both courses it includes the skill related to communicating and using discipline knowledge together with others to solve complex challenges. It also includes the skill of collaborating across disciplines.

2.2 The learning method

The basis for the students' development of skills in cooperation is their own experience from working together in the team – how they and others contribute, and how the team functions as a dynamic whole. Experts in Teamwork is based on Kolb's pedagogical model of experiential learning [8] in four phases:

1. Students gain practical experience in interdisciplinary teamwork.
2. They reflect on how their teamwork is influenced by their own behaviour patterns and attitudes, as well as those of others.
3. The students identify and describe their teams' behaviour pattern based on their reflection and team theory and discuss needed changes to be made to make the team more efficient.
4. The students try out new behaviours to improve the dynamics in the team when they continue work on their project. The effect of the changes has to be evaluated in retrospect.

Innovation Pilot also apply the Kolb learning cycle but has a more explicit focus on the innovation process than the team cooperation.

Most of the teaching staff in Experts in Teamwork and Innovation Pilot have little or no previous experience in the type of learning activity that is central in both courses, and most of the learning assistants in Experts in Teamwork have not taken the course themselves because it is late in the study programme. The teaching staff in both courses is therefore offered experience- based training.

2.3 Learning activities

Real-life teamwork situations are the subject of discussion, reflection and feedback throughout the Experts in Teamwork and Innovation Pilot courses. Structured social exercises, questionnaires and facilitation are used to encourage progress, effectiveness and innovation. Theoretical knowledge is woven in to provide a perspective on teamwork quality.

Experts in Teamwork
Students in Experts in Teamwork write both personal reflection papers and team-based reflection papers on the interaction in the team (thoughts and emotions) [9]. To support their personal reflections, each student receives a reflection journal [10] which includes information about reflection writing and blank pages for their own reflections. In teams, the students share and discuss their personal reflections and evaluations. This involves becoming aware of the teams' behaviour pattern in decision making, participation, conflict resolution, information sharing, taking care of their well-being and motivation among other things. For this to happen, it is important that the village leader and learning assistants create a safe space for learning.

The team process report that the student teams in Experts in Teamwork hand in at the end of the semester builds on the teams' reflections [9]. In the report, the students reflect both as a group as well as individuals on their experiences of specific situations, which leads the team to construct general principles that can be applied in future settings. The report addresses the innovation process, the team process and the learning outcome. Theory is used as a tool to illuminate and structure their experiences.

Innovation Pilot

Likewise in the Innovation Pilot course, the teams and the students individually write logbooks that describe and reflect on the course activities and how they have been handled in the groups and for the individual. The logbooks provide the basis for the final reflection and learning reports, which the students hand in at the end of the course.

In the final reflection and learning report, the teams evaluate and reflect on the interdisciplinary process, the role of themselves and others in the innovation process, and how they have managed professional and personal differences, and how their own and others' competencies have been used in the solving of the company challenge [6], [7].

Common for the two courses

Reflection is both a learning activity during the semester and a skill that the students develop for use throughout their lives. The overall learning goal is that the students should be able to identify and reflect on key aspect of a teamwork process to develop the team to make it more productive and create a positive, constructive and social climate for collaboration.

2.4 Training of the staff

Both learning assistants and village supervisors in Experts in Teamwork are jointly offered two-days training programmes every year. The training is intended to develop skills in experienced-based learning, and to build effective, productive and confident teams consisting of a village supervisor and two learning assistants. It is especially important for the facilitator teams to work well together when they are to stimulate students' development of teamwork skills. The learning assistants are in addition offered a one-day practical seminar with roll-play based training of facilitating teams.

In Innovation Pilot the learning assistants have recently taken the course Innovation Pilot themselves, for which reason they can relate many of the "challenges" to their own situation and provide supervision based on their own experience. The facilitators and the learning assistants in Innovation Pilot are also offered a two-day training course.

The Experts in Teamwork academic section has developed a handbook for the village supervisors and learning assistants [11]. The book describes the learning methods and provides information on how to plan and carry out the learning activities and contains several group exercises and more. The same book is used in parts in Innovation Pilot.

3 DISCUSSION

3.1 Learning of teamwork skills

It seems to be a widespread belief that collaboration is learned as a "by-product" of work in groups during education or in the workplace. Teamwork competence at the level of Experts in Teamwork or Innovation Pilot is not fully learned through practice-makes-perfect. Our experience is that learning through practice alone is not sufficient to meet the needs of working life for skills in interdisciplinary cooperation. Reflection on the collaboration and peer-feedback do not normally take place without facilitation, and thus normally do not take place in the workplace. Such skills call for formal education. The facilitation in Experts in Teamwork and Innovation Pilot makes it "permissable" and "secure" to talk about the relationships, and helps the group see what is happening between them. The facilitators create the conditions for the students' experienced-based learning in a way that provides insight into the prerequisites for effective, innovative and productive teams. Together with the facilitation, development of a cooperation agreement and structured social exercises in the team help to improve students' learning outcome.

3.2 Feedback from the students

Each year we investigate students' perceived value of Experts in Teamwork through both quantitative and qualitative data. The quantitative data have been collected through a course evaluation instrument from 2007, with response rates above 80% in all years.

Since 2007, the students in Experts in Teamwork have been asked about their overall satisfaction with the course [12]. There is a clear increase in students' overall satisfaction from 2007 to 2014, and from 2014 more than 90% of the students have reported somewhat satisfied, satisfied, or very satisfied on a five point scale. The steady increase in student satisfaction is the result of a continuous development of the teaching method and training of the teaching staff. Also, it has taken many years to establish a climate, and a culture, where students (and teachers) not only accept, but also buy into the collaborative format of the course.

The students have also been asked to evaluate their own experience in the Experts in Teamwork course and the extent to which it will help them in the future. In general, the students perceive their Experts in Teamwork experience to be relevant for later work life and feel that it prepares them for future tasks. Especially receiving feedback from other students on their behaviour pattern is considered very valuable. The students also acknowledge the importance of the Experts in Teamwork experience and believe that it has given rise to new thoughts and ideas that will be valuable when working in teams in the future.

Below is a statement from an Experts in Teamwork brochure from a student who has taken the course:
Through [Experts in Teamwork], I have been able to develop my personal characteristics to a far greater extent than I had expected at the start of the project. I have gained greater insight into my positive aspects. At the same time, I have had the opportunity to work with things that used to be difficult for me. To give feedback and to receive it in a good way has been challenging. Through the exercises and the group interaction we've been through, we gained experience with this, and I emphasize this experience as the most positive thing that [Experts in Teamwork] has given me.

Feedback from society
In 2005, a Norwegian report from an independent research institute concluded that: *"[Experts in Teamwork] thus succeeds in giving the students more of what is often termed 'generic' knowledge, i.e. knowledge that is common to all disciplines, and especially in the field of 'socio-communicative skills'"* [9].

3.3 Need for training of the staff

At NTNU and DTU the Experts in Teamwork and Innovation Pilot courses act as a platform for academic development that is unique. The teaching staff at the universities usually has no experience in creating the conditions for the students' experience-based learning in ways that provide insight into the prerequisites for effective, innovative and productive teams. Therefore it has been necessary to provide training for the teaching staff to enable Experts in Teamwork and Innovation Pilot to function as intended. This training also represents a significant contribution to development of the teaching staff, training the universities' academic employees in alternative learning methods. At NTNU 100 staff follow the train every year.

For other institutions that are planning courses to give their students interdisciplinary teamwork skills, we strongly recommend to start training the teachers in experienced-based learning.

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The Ethical Culture of a U.S. Research University in Transition: Understanding, and Working with, Undergraduate Curriculum Change in a Complex Pedagogical Community

Thomas William Staley
Diana Bairaktarova
Stephen Biscotte
Samuel Snyder

Virginia Tech, United States of America

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ABSTRACT
This paper describes the development of mechanisms to understand, assess, and support a comprehensive reform of the general education curriculum at a major U.S. research university. In particular, we focus on how the university's ethical culture has been, and will be, influenced by the process of developing, implementing, and now working within this new educational framework, in which ethical reasoning is integrated across the general education curriculum. We employ the perspective of Asset-Based Community Development [ABCD], an established framework for identifying and mobilizing community resources for the benefit of its members. This approach is based on a pragmatic vision, focused on identifying key changes in skills and practices that result from the curriculum change process. By treating a university as a complex community in which we ourselves participate, rather than a more conventional corporate organization for example, we aim to understand and facilitate the development of a robust culture of STEM ethics. This involves questions at several levels regarding perceptions and involvement of faculty and administrators, the structure of larger social network(s) emerging from this initiative, as well as outcomes of students. We have developed a range of novel instruments to examine these issues, including surveys of faculty and student perceptions, perspectives, and competencies; interviews and focus groups; textual analysis of student competencies; and social network analysis. Data gathered in our analysis is being used as feedback to the curriculum change process, to help facilitate its implementation and foster the diffusion of an ethical climate for STEM practice.

1. BACKGROUND: THE PATHWAYS CURRICULUM

Virginia Tech (VT) is an institution in the process of profound transformations in its university-wide curriculum structure. In particular, the "Pathways to General Education" (or simply "Pathways") curriculum aims to provide all undergraduate students with a meaningful program of study beyond their particular field of specialization. As defined by the Association of American Colleges and Universities (AAC&U), general education is "the part of a liberal education curriculum shared by all students. It provides broad exposure to multiple disciplines and forms the basis for developing important intellectual and civic capacities. General education can take many different forms." Rolled out in Fall 2018, Pathways constitutes the first significant change made to the general education curriculum at Virginia Tech since 2002 and the first complete course-by-course overhaul since the university moved from quarters to semesters in 1985.

Among the most distinctive aspects of this plan is the mandatory integration of learning outcomes in either *ethical reasoning* or *intercultural and global awareness* (or both) into all general education program courses. These outcomes are defined as follows:

> **Ethical Reasoning Concept**: Ethical Reasoning is the principled evaluation of moral and political beliefs and practices. Foundational learning of ethical theories, issues, and applications provides tools that enable students to deliberate and to assess for themselves claims about ethical issues in their personal, public, and professional lives. Courses addressing this outcome must meet a majority of the following learning outcomes: (1) Explain and contrast relevant ethical theories; (2) Identify ethical issues in a complex context; (3) Articulate and defend positions on ethical issues in a way that is both reasoned and informed by the complexities of those situations.
>
> **Intercultural and Global Awareness Concept**: Intercultural and Global Awareness supports effective and appropriate interaction with a variety of people and different cultural contexts. Courses addressing this concept must meet a majority of the following learning outcomes: (1) Identify advantages and challenges of diversity and inclusion in communities and organizations; (2) Interpret an intercultural experience from both one's own and another's worldview; (3) Address significant global challenges and opportunities in the natural and human world.

In addition to the integrative component, students can choose from among three different options: (1) a traditional set of independent courses that combine to fulfill these requirements (known as the distributive model), (2) a structured "Pathways Minor" that pursues an interdisciplinary theme connecting 18+ credits of coursework, or (3) an independently designed "Alternative Pathway" unique to the needs of the individual student. The option generating the greatest excitement among faculty and students are the Pathways Minors. Unlike traditional minors, which consist of highly focused learning (e.g. Biology, Finance) often restricted to students from a particular college, Pathways minors are interdisciplinary by design, open to all undergraduates, and embed ethical and intercultural learning across the curriculum. Pathways minors include junior/senior level course-work that builds and integrates foundational learning, culminating in a capstone experience where students apply their learning through authentic projects, undergraduate research, study abroad, and/or service learning.

Pathways Minors explore big issues in STEM including (among others): *Pathways to Sustainability* which looks at sustainability practices from scientific, ethical, and sociocultural perspectives, *Data and Decisions* which offers opportunities for students to gain skills in gathering and analyzing data while examining societal impacts (e.g. use/misuse, bias), and *Global Food Security and Health* which combines courses on world hunger and modern agriculture with a study abroad experience to apply knowledge in Africa. These multi-course trajectories through general education, paired with the integrative concepts embedded across the program, provide students with repeated opportunities to engage ethics from multiple disciplinary perspectives, providing sustained opportunities for ethical reasoning development.

Our primary task in this project is to examine how the implementation of this new curricular strategy may foster a stronger “culture of STEM ethics” within the university, and what lessons might be transferable from observed successes in the process. As active participants in the curriculum reform, we also aim to facilitate this process of change by identifying approaches and resources that are proving most productive and disseminating them to relevant groups.

A key conceptual issue here is that the notion of a “culture of STEM ethics” is far from clear. A research university is, by any reasonable standard, a complex institution – combining multiple missions (education, research, outreach, etc.); employing, serving, even sometimes housing, entertaining, and feeding thousands of students, faculty, and staff; organized into dozens of independent departmental units under multiple collegiate or trans-collegiate affiliations; including individuals with diverse cultural, linguistic, geographic, and disciplinary backgrounds; and pursuing a spectrum of intellectual, social, and professional activities. As such, any *a priori* attempt to define the “culture” of a university is likely a vain pursuit, and limiting one’s attention to a “culture of ethics” or a “culture of STEM ethics” does little to simplify the task. We have thus approached this concern pragmatically, and rather than attempt to theorize formally about the constituent elements of culture, we have instead framed the problem through the following questions: (1) How does STEM ethics relate to general education in this case?; (2) Why and how might the Pathways approach prove specifically productive, based on established models for STEM pedagogy? (What to look for as plausible outcomes?); (3) How does one identify and conceptualize relevant elements of “university culture” that can be leveraged here?; and (4) How does the injection of cultural and ethical subjects into pedagogical practices feed back into the university environment to foster “ethical culture” more broadly? (How does increased focus on teaching and learning in this area translate into changes in individual and collective beliefs and practices?). The next section details the development of our conceptual framework for this study through these guiding issues.

2. A CONCEPTUAL FRAME FOR UNIVERSITY CULTURES OF ETHICS

At VT, the central ground of this academic transformation is the set of global-scale ethical considerations associated with developments in STEM. By moving from a model in which such issues are either absent from – or compartmentalized within – the undergraduate experience to one in which they are a ubiquitous element of general education, the university is promoting a culture of ethical STEM engagement that will prepare its graduates to contend more effectively with the complexities of the 21st Century intellectual landscape. To contextualize this realignment in the general education framework, let us step back to consider some recent trends in higher education that centralize interdisciplinarity and – even more particularly – transdisciplinarity. For example, Frodeman and Mitcham [1] review the history of modern Western university education to highlight ongoing tensions between specialized disciplinary fields (particularly, but not exclusively, in emerging technical fields) and various boundary-crossing initiatives in both research and pedagogy. They emphasize that the record of the past century has shown a continuous trend toward ever narrower disciplinary demarcations across the university, and argue that this has led to a particular crisis in academia with epistemological, political, and metaphysical consequences. Confronted by issues whose scale, scope, and synthetic character cannot be addressed effectively by compartmentalized research methods, with public implications that demand sustainable results, accountability to social needs, and attention to human value concerns, the contemporary university is portrayed as needing fundamental changes. Frodeman and Mitcham describe these necessary shifts in terms of “broad, deep, and critical interdisciplinarity.” However, while some are geared towards work between disciplines (including proposals to investigate the dynamics of disciplinary formations themselves more closely), most might be more properly considered transdisciplinary as they are oriented towards the creation of more synthetic knowledge forms using multiple perspectives to understand increasingly complex phenomena. This critique of the status quo is congruent with a much broader body of literature on educational practice and reform (see, for example, [2,3]). Such analyses typically point to a small set of contemporary concerns about human sociotechnical systems, including globalization, technological change, sustainability of natural and built environments, and the intersection of facts and values (epistemology versus axiology). They also indicate specific roles for the arts, humanities, and social sciences in developing the tools to address such fundamentally human concerns.

In this context, a general education program designed to integrate ethical reasoning and intercultural awareness throughout the curriculum, with thematic minors fostering connections between multiple complementary fields on practical issues of common concern, has much to recommend it, in principle. The basic idea, which has recently been codified by the image of the “T-Shaped Student”, is not itself novel, but the best way to organize this to accomplish various desired outcomes remains in question. In our particular case, where the fundamental concern is how to cultivate a culture of STEM ethics among undergraduates at a major research university, there are a number of elements to consider. Most obviously, we might look for apparent learning gains in measurable ethical competencies among STEM majors, but this is really just the tip of the iceberg. The arguments for interdisciplinary reform described above would suggest, in addition, that instruction in culture and ethics may complement and mutually reinforce one another; that practice in viewing subjects synthetically and repeatedly from multiple perspectives may deepen appreciation of both relevant facts and relevant values; and that broader and deeper instruction in a range of humanistic, artistic, and social scientific subjects may be a positive end in itself in solving the problems of the future. As such, each of these elements may play its own role in contributing to the university’s culture of ethics. The tools we have developed to probe the effectiveness of the new curriculum are geared to capturing such contributions, and to identifying those pedagogical strategies and contexts that prove most productive in that regard.

A foundational argument of this project - advertised already above - is that the university is best viewed as a complex and multifaceted community. Here, we are responding to limitations in some common conceptions of ethical culture, in which approaches originating in the analysis of business organizations have taken center stage since the 1980s [4]. This dominant narrative, geared largely toward improvement of management and productivity, has been exported to other types of organizations with some difficulty. The study of universities, for example, has been a conspicuous case where insights from organizational management have proven limited. Kuh & Whitt [5] detailed a far richer vision of university culture, drawing upon sociological and anthropological resources to highlight the multiplicity of roles, goals, and subcultures that more typically characterize a university. More recently, Harold Silver [6] has gone even further to suggest that the conception of "university culture" presupposes a level of cohesiveness that may not exist at all. Such critiques of the notion of "university culture" as either structured or unitary underpin our approach.

Fortunately, per Frodeman and Mitcham's observations above, the humanities and social sciences provide ample other resources to characterize culture – and to situate ethical concerns within culture. Returning to such perspectives in this discussion is useful here for two reasons: The sociological-anthropological approach to culture brings in features that critics note as absent from the organizational literature. These same resources, we note, are central to the general education strategy under investigation in our case. In particular, we wish to highlight some key features beyond organizational typology, including a vision of culture as pluralistic, multifaceted, and dynamically evolving. Individuals and groups participate in multiple cultures, sometimes conflicting with or overlapping one another. Cultures, in addition, exceed their contractual, formal, or structural elements, and also include resources to develop, connect, and reflect – such as symbolic acts, communal activities, a sense of purpose, and space and time.

Ultimately, we contend that, studying a university culture of ethics is simply a special case of studying a large and diverse community and its values. Our particular study aims to characterize not just a university culture of ethics, but the effect of a major transition in general education on such a culture. This process, amounts to a new and systematic focus on axiological education – aiming to develop skills in the understanding of values in general, with ethics as a subset, and STEM ethics as a subset of that. Here, importantly, the features of the new curriculum structure itself are designed to integrate ethical reasoning and intercultural awareness into the entire undergraduate general education program, using the same conceptual approaches just introduced to create a broad interdisciplinary context for education in ethics and culture. In other words, the transition under study injects the subject of culture itself into the university culture in a concentrated way.

3. METHODS

The activities of this project will be geared toward a systematic analysis of developments in the culture of STEM ethics at VT as the new Pathways curriculum is implemented, and the potential transferability or collaborative extension of successful strategies to other sites. This analysis will involve qualitative and quantitative data collection to assess several interrelated outcomes of the transformation process: (1) the efficacy of the new programs themselves; (2) the dynamics of the individual, collective, and institutional processes evident in their implementation; and (3) the overall utility of the theory of change employed in implementing Pathways.

Since this project explores the institutional ethical STEM culture, all 29,000 undergraduate students enrolled and over 1500 faculty working at Virginia Tech are eligible to participate. However, a specific focus will be placed on those students who have entered since Fall 2018 when the new general education program was implemented, approximately 13,000 students. Although every student is required to complete the program by the time they graduate, to date over 400 students have pursued a Pathways Minor as means to complete a portion of those requirements, which will serve as a particular point of inquiry. Since the period of study also affords us the opportunity to compare the outcomes of students whose undergraduate experience (partially or completely) predates the implementation of the new system, we are also including a longitudinal (pre-post) component in the analysis of student surveys.

3.1 Student surveys

We plan to investigate the development of student ethical competence through analysis of secondary data such as student assignments and conduct of surveys of students in Pathways courses and elsewhere. We intend to compare outcomes between students who enrolled in the Pathways minors and those who did not. We will further examine learning through proxy indicators developed based upon conscientious review of faculty reports of teaching in the Pathways program. We will survey students within Pathways courses and students who are not enrolled in Pathways courses. We will engage in a targeted recruitment strategy to ensure that we have adequate numbers of students in ethics-only, ethics and global awareness, and non-ethics focused Pathways courses in order to conduct between group analysis of their responses. We will use a closed survey protocol with no open-ended answers as we expect that the pertinent content of open-ended answers will be reflected in artifacts from student assignments. Our survey questions will use a combination of Likert-type responses, dichotomous (like/dislike), marked semantic differentiations. Students enrolled in Pathways courses will be surveyed at the beginning of their courses and at the end in order to assess any differences in response. Through coordination with the Office of General Education and relevant academic departments, we will endeavor to re-survey students who took an ethics-focused pathways course one academic year after the completion of their course to test for durable effects.

3.2 Faculty surveys and interviews

We will explore faculty perceptions about their ethical teaching competence using a combination of narrative interviews and participant observation of courses. Interviews will investigate faculty perceptions, concerns, and challenges related to implementation of ethics in their courses. Second, based on data gathered in this phase, we will work within existing faculty communities and training programs to develop and offer specific faculty ethics education opportunities and resources. These will likely include a faculty development summer institute, workshops, and course redesign opportunities. We are currently conducting semi-structured interviews with faculty currently teaching in the Pathways program who have and have not completed the Pathways Summer Institute as well as faculty who are teaching non Pathways affiliated courses that are part of the VT general education curriculum. We expect to find differences between the three groups' perceptions of the meaning of ethics teaching and challenges associated with incorporating ethical perspectives into their courses. We also expect to find variation in the course assessment mechanisms used by instructors of ethics-focused courses and courses without an ethics focus. Sample questions span these three areas of concern-- perceptions, challenges, and variations-- and include examples such as, "Before you began working with the Pathways program, what was your perception of ethics teaching in a collegiate classroom? Has that perception changed since you have been teaching your course? How has your perception changed?". We are audio recording each of the interviews, will have each directly transcribed, and will use Computer Aided Content Analysis to identify emergent and consistent themes throughout the interviewee's descriptions. We will use standard sentiment analysis techniques on the varieties of ethical speech to determine what perceptions, challenges and variations the three groups of faculty have of ethics material in STEM courses.

To investigate what are the transferable lessons learned from this project including elements applicable to, or adopted by other institutions [Propagating Transferable Elements] we will characterize faculty and students' role as change agents in university culture. The structure of the new curriculum, featuring developmental course sequences and cross/inter-disciplinary interactions, and with faculty participating in more cross-disciplinary teaching, make it likely that both faculty and students will experience changes in the skill sets they require over time. For example, as students' level of ethics understanding increases, we expect that they will seek new and different opportunities for meaningful learning in their courses, and as faculty engage in more cross-disciplinary teaching, they will make different demands on university systems (e.g., library programs). Determination of how changes in student and faculty cultures lead to changes in university administrative support structures will be a novel contribution of this project.

3.3 Social Network Analysis

Social network analysis (SNA) [7] will be applied as a tool to both measure progress and guide the next steps of ABCD to build a community improving STEM learning at VT and other schools. Because there is limited empirical evidence documenting the impact of ABCD on community development [8] and ABCD has not been applied previously to university transformation, this research will contribute new knowledge for the fields of STEM education and more broadly, institutional change theories. For our project, the social network is defined as the individuals and units (actors) linked to the general education reform process. Connections between actors are made where there are collaborations and relationships. As the steps of ABCD are applied, the social networks will be analyzed to measure growth and strengthening of the community [9] and to identify emerging leadership opportunities (actors with many ties). Both quantitative (surveys and network analytics) and qualitative (interviews and focus groups) methods will inform the construction and analysis of social networks. These methods will also provide data about what network members are doing to improve STEM learning and the extent to which participation in the communities influences and supports this work.

4. Asset-Based Community Development & Agents of Change

Virginia Tech is engaging in a university-wide general education reform project as a means to infuse a culture of STEM ethics by integrating ethics education as a cross-cutting outcome, with extended learning experiences through the Pathways Minors. Culture changes in higher education institutions require successful use of multiple change strategies at multiple levels; many change efforts fail because change agents do not realize the need to activate these different strategies, as documented by Henderson, Beach, and Finkelstein [10]. In addition, as Kezar [11] outlines, a change agent must have a variety of institutional change theories (e.g. social, scientific, etc.) in their toolbox to utilize on a case-by-case basis throughout the reform effort. To reign in this potential spiralling complexity, a framework is needed that is both clear and simple enough to guide the change agents at each step of the process and flexible enough to allow for the deployment of varied change strategies along the way.

The VT curriculum reform process has been explicitly guided by an Asset-Based Community Development (ABCD) theory of change [12]. ABCD provides change agents with a positive strategy for transformation that focuses on community members' diverse strengths and seeks to engage all stakeholders in the change process, centered within the context of the unique institution. This strengths-based focus contrasts with organizational change theories utilized to address a singular stakeholder deficit (e.g. 'students are underprepared for the course' or 'instructors are ill-equipped to provide engaging learning opportunities in large classes'), as a response to an external pressure or peer competition (e.g. 'the state requires more global focus in the curriculum' or 'a peer institution has created a center to address that research gap so we should too'), or within a clearly structured power hierarchy (e.g. 'the CEO wants the company to expand into a new market so the whole company follows') [11]. Because a general education reform is complex (incorporating all of the issues above and more), ever-evolving, institution-specific, politically-charged (internally and externally), and requires multiple change theories and initiatives operating simultaneously, ABCD is an appropriate framework to guide complex change.

In addition, in ABCD lasting positive change is built upon a widely held recognition that each individual possesses assets (e.g., talents in teaching, disciplinary knowledge, leadership skills) to contribute to ongoing community development. Stakeholders are citizens in the community, not clients buying a product [13], so phrases like 'faculty buy-in' or 'resistance to accepting change' are not as applicable in this framework. ABCD guides strategy for building and assessing networks of faculty, students, and community members committed to improving and infusing a campus ethics culture. This approach has been effective in facilitating change in social work and community development, but has not yet been applied to the university at this scale.

ABCD is a 5-step framework: 1) map the assets, 2) build relationships, 3) mobilize the assets, 4) convene a broadly representative group, and 5) leverage the resources. In step 1, a proper asset mapping inventory elucidates physical, individual, associational, and institutional assets that can contribute to the desired community development. In this case, the long-time chair of a curriculum committee can bring historical knowledge and lessons learned while the Registrar's Office has access to policies and procedures that align with the change efforts. In step 2, a great deal of time and effort is spent on building relationships among the community members. At Virginia Tech, stakeholders like curriculum committees, advising personnel, and community partners are brought together through matchmaking, networking, and joint professional development events. To mobilize the assets in step 3, a general education website (common resource repository) is constructed, an awards reception is held, and a grants program is offered to bring recognition and financial support to community members. In step 4, change facilitators bring the community together to develop a unified plan of action, in this case new policies, procedures, and structures to support the general education community broadly. Finally, in step 5, both internal (budgets, faculty lines) and external resources (e.g. NSF grants and community partnerships) are leveraged to expand the successful components and fill the financial gaps.

Change agents rely on ABCD for the framework and mindset in which to operate. In the context of general education reform, university administrators assume the role of facilitators (‘mobility agents’ in ABCD terminology) who identify community assets and provide opportunities for relationship-building and asset mobilization to foster ongoing improvement and create widespread engagement in building a culture of ethical STEM. The administrators facilitating the general education transition have researched, attended workshops on, presented workshops on, and modified and built on the tools provided by ABCD literature and professional development support [12]. As the project progresses, training would expand to mobility agents beyond central administration.

The role of the mobility agent is “to support networks that foster mutual learning and shared commitments so that people can work… together in relatively coherent and equitable communities.” [7] At all stages, but particularly during the ‘building relationships’ and ‘mobilizing the assets’ stages, the mobility agent helps members build social and trust capital through support provided and connections made. Without trust, change leaders cannot progress through the steps of community development, thus sustainable long-term culture construction and change cannot be achieved.

By addressing all four domain areas in Henderson et al.’s [10] change strategy schema - changing curriculum and pedagogy; offering faculty development opportunities; making concordant policy; and developing a shared vision (in this case for ethics education across the university) -- and guided by an ABCD framework, mobility agents can cultivate and infuse a campus culture of ethical STEM.

5) Conclusions

Virginia Tech is undergoing a major transformation of their general education curriculum, infusing both ethical reasoning and intercultural and global awareness into each Pathways course. Pathways look to explore the intersection between scientific, ethical, and sociological perspectives and apply these various frames to interrelated societal contexts, providing students with a broad yet interconnected experience, partially motivated by an increasingly siloed and disciplinary higher education environment. This project looks to evaluate the university’s ethical culture as it goes through this transition while also looking to ascertain the impact of an integrated general education curriculum has on this community of scholars. To measure this cultural shift, this project will utilize a variety of methods to determine perceptions of various participant groups throughout the university-wide change. The project utilizes surveys of both faculty and students, interviews of faculty and staff, textual analysis of student assignments, and social network analysis in a holistic attempt to map the existing networks and assets of individuals and and departments across Virginia Tech. In alignment with both the goals of the institution and the proposed ABCD model for change this project seeks to measure the ethical climate and facilitate sustaining cultural change at Virginia Tech.

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Scrumban learning – agile, lean and transparent framework for practical learning experience

Harri Sten
Doctoral student
Tampere University, Unit of Computing Sciences
Tampere, Finland
harri.sten@tuni.fi

Ulla-Talvikki Virta
Project researcher
Tampere University, Unit of Computing Sciences
Tampere, Finland
ulla-talvikki.virta@tuni.fi

Tero Ahtee
Lecturer
Tampere University, Unit of Computing Sciences
Tampere, Finland
tero.ahtee@tuni.fi

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ABSTRACT

Large, mid-large and/or wide practical work is important part of engineering education in almost any development field. In the practical work, student groups innovate, plan and implement usually large outcome. Because of teamwork and often-complex topic, creation of the outcome is challenging for students. Furthermore, often teachers have limited visibility to practical work itself, its phases and related progression in group or student level. Based on our study and experience we have created new framework for practical learning experience called Scrumban learning. It is compilation of two development frameworks; Scrum and Kanban. In this paper, we introduce a new detailed framework for practical work development in the engineering education. The created learning framework has following main dimensions; iterative design methodology based on a cyclic process of creation of practical work outcome, incremental model where the outcome is innovated, planned and implemented incrementally until the desired outcome is finished and creation of visualisation, where students, group and teachers are able to see student level tasks, plan for development and progression of work. We have tested the practical work framework with more than 110 practical works and 450 students during one academic year in two implementations of same engineering course. Benefits of the framework are clear and furthermore, three set targets for iterative and visualized practical work with room for formative assessment have been achieved. Study results presented in this paper are useful for any engineering learning organization to create and implement their practical work establishment based on this Scrumban learning framework.

1 INTRODUCTION

Practical works are important part of engineering education in almost any development field. In practical work, student groups innovate, plan and implement usually quite large outcomes, which can be anything from design documentations to solution implementations. With mid-large to large and/or wide practical work, managing the execution of the practical work introduces challenges for both students and teachers.

Challenges from the students' point of view include team management and producing suitable outcome for the practical work. Students may work in groups with previously unknown students so team management may include; defining motivational goals, establishing ways of communication, ways to divide responsibilities and ways to make sure each group member completes their responsibilities. To produce acceptable outcome, students must be able to estimate the time required to complete the work so they reserve enough time for work, to identify complex areas, and to follow which parts are completed and which require more work.

Challenges for teachers are related to observing and supporting the groups during their working phase. If teachers have limited visibility to the progression of the groups and involvement of individual students, teacher cannot offer support to groups that are falling behind and problems during practical work surface only when it is too late.

To manage the challenges, we present a concept of Scrumban learning: a framework that combines Agile and Lean methods to iterative process to support the practical work advancement. Teachers provide the backlog of items that must be completed to finish the practical work, but student groups are responsible for deciding how the backlog items are divided into more manageable tasks and how the work is allocated between students. Students are instructed to work in Sprints between the deadlines and the iterative process supports continuous feedback and formative evaluation.

Each student group maintains a Kanban board, which supports the students' team management but also offers window for teachers to see how students are dividing their tasks, how much of the work they have completed and if there are clear discrepancies with participation between students.

The framework was tested on two consecutive course implementations with over 450 students and 110 groups in total. Feedback data from students was collected from dedicated survey made for students in the latter course. Teacher feedback was collected with group discussion session.

The paper is structured as follows: Chapter two discusses the concepts of Agile and Lean and describes the Scrumban method, and related work. In Chapter three we present the Scrumban learning framework and discuss the experiences gained from using it with practical work during software engineering course, from both teacher and student perspective. Chapter four summarizes the work.

2 AGILE AND LEAN APPROACHES

2.1 Agile concepts

Use of Agile methods and iterative model has been continuing to increase in engineering education. Today it is increasingly used, mostly in software engineering industry, but in other fields as well. The Agile Method is a special approach to project management that is utilized today in many industry areas. This method assists groups in responding to the unpredictability of constructing products and uses incremental, iterative work cycles that are called Sprints. The Sprint is a period of time allocated for a special implementation phase of a project. During the time period Sprints are planned to be complete and there will be no more work on that certain phase of the project. These development cycles continue until the remaining phases of the project are implemented or the product developed is ready enough. Agile methods focus on the following main principles; people, individuals and interactions over processes and systems, implement rather than document, outline plans over detailed specifications and customer collaboration over contract negotiation. [1]

Scrum is the main and mostly used method in Agile principles family. Scum has key roles, ceremonies and artifacts. Main roles are Product owner, Scrum master and a Scrum Team. Ceremonies are Sprint planning, Sprint review, retrospective and daily scrum meeting. Artifacts are Product Backlog, Sprint Backlog and an increment of potentially shippable version of the product. The product owner creates a prioritised list of product features (Product Backlog) to be implemented. The Product Backlog is changing during the development of product and product owner should refine and modify it when needed. In the Sprint planning a team, Scrum master (facilitator) and product owner (if necessary) break down the selected few items from Product Backlog to be implemented in coming Sprint and list of those tasks is called Sprint Backlog. During the Sprint team is implementing tasks from that prioritised Sprint Backlog. In Scrum method team is having daily Scrum meeting to follow the progress and there team members are telling what they have achieved, what they are doing next and then discuss if there are any challenges, issues and help needed. At the end of Sprint, all planned work should be completed and Sprint review meeting is held to inspect implemented features and unfinished tasks. Usually product owner facilitates this meeting and together with customer accepts or rejects the work done. Last ceremony of Scrum method in every development cycle (iteration) is retrospective where team will discuss how they have been performing and is there anything to be changed in their daily work in name of continuous improvement. [1]

The use of Agile methods in education, starting from its origin, has so far been focused to software engineering education, but is increasingly coming to other education fields of engineering. When using Agile methods in software engineering education [2] it is also helping students to learn about modern software engineering processes [3]. When applying Agile methods in larger scale in the engineering field it has included changes in teaching approaches [4] and supporting teamwork [5]. Scrum is an iterative process framework for Agile development and can be used in education field. It provides a useful framework, where learning can take a place e.g. in area of practical works inside engineering courses. In education field, it is framework which has been successfully applied in schools as one way to give better and transparent control over students' learning [6]. [7]

2.2 Lean concepts

Lean development is the focusing on Lean principles in product development. Lean got its start in manufacturing, as a way to optimize the production line to minimize waste and maximize value to the customer. These two principles are relevant to any product development. It is also focusing to follow a repeatable process and requires special quality standards. Furthermore, it relies on the collaboration of a group of professional workers in order to get the work done. Applying Lean principles to any knowledge work requires a shift in mind-set, in terms of how waste, value, and other key Lean concepts are already defined. Lean has seven principles for development;

eliminate waste, build quality in, create knowledge, adapt to commitment, deliver fast, respect people, and optimize the whole development. [8]

Kanban is one of the Lean principle implementation methods. It has roots as a scheduling tool developed by Toyota for Lean production of car industry to help improve production and inventory control. As Kanban means “visual card” in Japanese, it helps making scheduling more visual and helps support Just-In-Time (JIT) manufacturing. Furthermore, it helps reducing flow times within production and response times from suppliers and to customers [9]. Kanban board is good tool to visualise the workflow by using cards progress through specified columns in the board. Those columns can be named simply e.g. “Todo”, “Doing” and “Done”. This visualisation is useful for every stakeholder the development project has. Kanban board has a Work In Progress (WIP) limit, which means that there is a limit how many tasks can be in “Doing” at the same time. Kanban boards are widely used management tools. A task board allowing evaluation and further planning (break down) of the development project and furthermore, also being able to keep customer and other stakeholders informed the changing status of the product development.

In education field, when using e.g. practical works as part of engineering course, task board, like Kanban board, provide efficient visualisation tool for tracking student groups with status updates. It keeps every stakeholder of the course up-to-date how work is proceeding and can be physical (classroom whiteboard) or virtual board (e.g. Trello tool) having a working area divided to different columns presented already.

2.3 Scrumban

The similarities between the two methodologies (Scrum and Kanban), on one hand use transparency to improve processes and differentiating aspects on the other hand. Since Kanban is not a process method, it is typically used in conjunction with some other method. As Scrum has been a popular selection, Scrum and Kanban are brought together formally in Scrumban [10]. With Scrum the amount of development work that is ongoing is limited by the Sprint time box, but in Scrumban there are no time-limited Sprints, so the development team must make limitation itself through the use of WIP limits on the board [7]. This is how Scrumban was born – approach in software development that calls on technical and methodological compromises between these parent methodologies [11]. In engineering education Scrumban is very useful method with good collection of principles and way of work inherited from its parent processes. Scrumban can be seen as a useful process for e.g. practical work in the engineering courses. Later in this paper we present Scrumban as a learning framework for engineering courses and feedback from our experiences from use of it.

2.4 Related work

The concept of design and using Agile as an approach to engineering education is not a new idea [e.g. 12]. There is a rich collection of different articles providing information about research and practical approaches for both teaching Agile (“the what”) and using Agile as a pedagogical approach (“the how”) [12]. This fundamental difference between approaches can be seen among research papers. Our target was to create framework for using Agile method(s) as teaching framework. Dewi and Muniandy [13] have created quite large-scale literature review for contribution of the Agile methodology towards teaching and learning finding answers to research question, among others, what are the suggested Agile related approaches and methods used to improve teaching and learning. There are also some research papers for overall Agile learning principles [e.g. 14], saying Agile learning applies the processes and principles of Agile software development to context of learning. Gary et. al. [15] have approached from different angle and published a platform for applying Agile principles for learning evaluation and creating formative feedback for students.

Research of certain Agile method or methods have also been published during last decade. Royle and Nikolie [1] introduces pedagogical method delivered from Agile work practices, particularly the Scrum method of project based learning. Also Cobric's [16] paper is to describe, evaluate and discuss a method for teaching Agile project management and Agile is not only a subject domain in that paper, also teaching method itself is based on Scrum. Sharp and Lang [12] present in their paper both Agile methods, XP and Scrum, related articles on the area of Agile teaching and learning. Also Alfonso and Botia [17] presents use of an iterative and Agile process model with Scrum and XP features to serve both as an educational technique (for teachers) and as a subject of learning (for students) in the area of software engineering. D'Souza and Rodrigues propose in their paper "Extreme Pedagogy, a student-centred teaching-learning conceptual framework to have higher quality in engineering education" [18]. Extreme Pedagogy aims at continuous improvement of student learning, trying to keep students' needs and satisfaction as its focus.

In the area of Lean and Agile education Parsons et. al. [7] presented Scrum and Kanban methods and specially usage of Trello as virtual tool for an approach in combined Agile and Lean methods. Noguera et. al. [19] presented methodologies from other fields to be incorporated to enrich their educational model and they were especially interested in Agile and Lean methodologies. As a result of a literature review, a pilot test to implement Agile learning in virtual contexts was proposed. Taking into account the benefits of the Agile method for teamwork, Noguera et.al. [20] analysed the usefulness of Agile strategies (like Scrum and Kanban) for team regulation and project management in online higher education. Kanban as part of education approach can be found from papers Ovais et. al. [21] as part of Software Factory related education and Bacea et. al. [22] for teaching Agile product development processes to provide centralised team tracking with frequent task status updates.

3 SCRUMBAN LEARNING

3.1 Scrumban learning framework

Our concept for practical work framework in education is called Scrumban learning. It is based on Software Engineering Scrumban method, which is collaboration of special features from Agile Scrum management method and Lean Kanban method. *Fig. 1* presents our Scrumban learning framework.

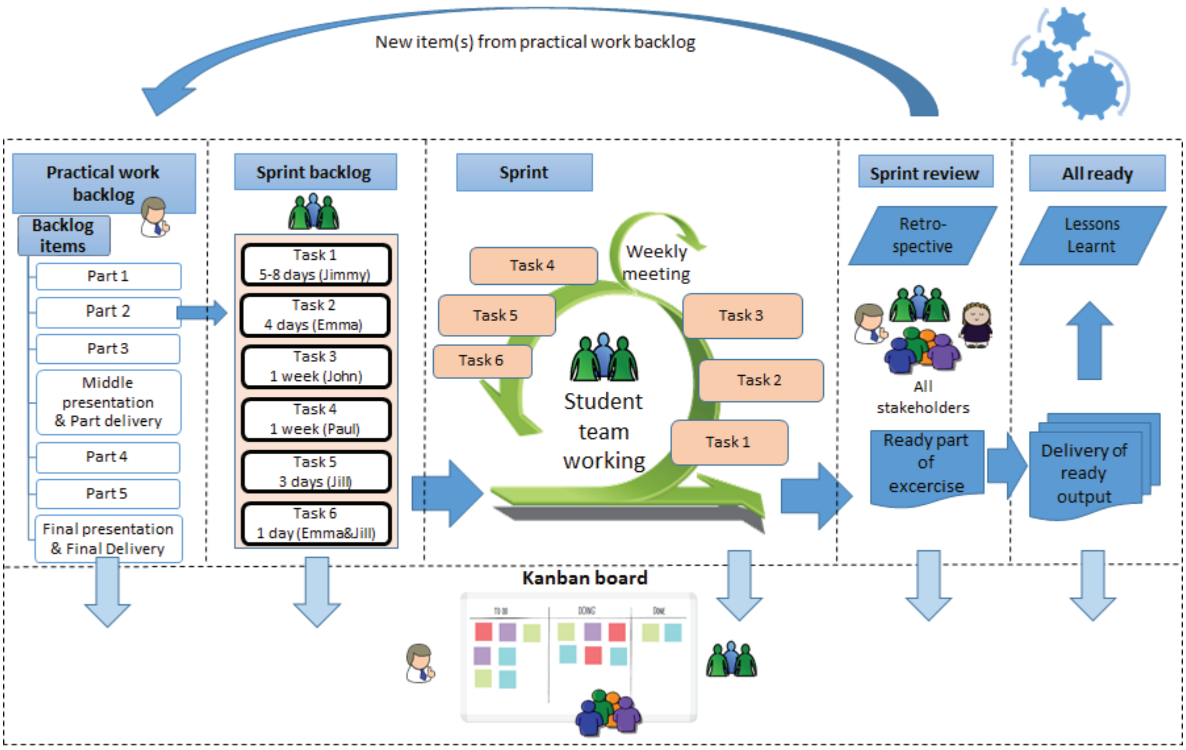

Fig. 1. Scrumban learning framework

As a first action, in our framework, teacher creates practical work backlog for students to implement. Backlog items can be divided based on the subject and usually are divided based on subject related features, incremental add-ons for selected core knowledge of the subject or iterative working implementations of the subject. Our framework consists also middle and final presentations and deliveries which are examples and not necessarily needed in every practical work implementation in engineering education. Before student can start the implementation, teacher can guide students to Scrumban framework and content of practical work. Furthermore, Kanban board (virtual or physical) and first column ("Todo") for it needs to be created.

Overall plan how many Sprints for given course schedule needs to be created by the group of students, considering implementation of whole practical work with possible milestones. Before first iterative implementation Sprint starts, student group (4-8 students) selects first set of items from practical work backlog which they planned to implement in first increment (Sprint). Then they need to break down those items to smaller pieces (tasks) and plan who is responsible and what will be an estimation of workload (week/days/hours) for each of those tasks. Result of that planning is Sprint Backlog of first Sprint and needs to be published in Kanban board as content column e.g. "Next Sprint".

When implementation of first tasks begins, those "task cards" in Kanban board will be moved to next column "Doing". While Implementation (Sprint) is ongoing the group cannot be disturbed by other stakeholders. Group will have regular meetings (e.g. weekly) to present their doings and possible problems to other group members. When all tasks planned for Sprint are implemented, it is time for Sprint review. Sprint review can be done by the group, group with teacher/course assistant, group with other student group or all stakeholders together. In the review group presents the planned work done and not done. There is also room for feedback and peer evaluation as guidance and part of formative assessment of the course. After each Sprint in Kanban board all implemented “task cards” need to be moved to third column “Done”. Before group continues to plan for next Sprint, they need to discuss shortly their way of work in previous Sprint as part of continuous development (retrospective). These iterative and incremental implementation rounds (Sprints) continue until all items from practical work backlog has been implemented or deadline for practical work has been achieved and the latest reviewed outcome will be the final one.

This created framework has several improvements compared to traditional practical work implementation in engineering education where given topic for work is given in the beginning and numerical evaluation is in the end. From the students’ point of view iterative approach help students to split the work better for smaller manageable pieces, resource and schedule tasks in better level to divide work for the whole time period given for this kind of work. This framework also gives opportunity to better cooperation between students and increase collaboration in common tasks. Continuous improvement gives room for better results and positive learning curve for individual students. Furthermore, framework gives room for better communication and visualisation through used Kanban board.

From teacher point of view the framework gives room for better possibilities to observe groups’ working, as well as room for formative feedback and assessment options. Visualisation with Kanban board gives teachers better overview and it elucidates status of work while at the same time improves possibilities to guide groups in their process way of work. Teacher can also see individual students’ contribution to teamwork from Kanban cards. Teacher can implement several formative assessments e.g. peer feedback (group to group, or individual students to each other within a group), self-evaluations, review meetings for giving feedback to groups and continuous feedback via Kanban board for groups way of work.

3.2 Scrumban learning experiences

Our Scrumban framework has now been used at two Bachelor course implementations, namely two-period (14 weeks) and five credit units course Introduction to Software Engineering, first in Autumn 2018 and then in Spring 2019. More than 450 students and 110 groups implemented the practical work. In the beginning of practical work, students were introduced Agile methods and Kanban, and after that Scrumban framework used at our courses. Both courses had similar relatively large practical work for software system requirements phase, which was made in two phases; first a preliminary requirements documentation, and final requirements documentation.

In the end of both phases student group presentations were held and furthermore, there were room for peer-evaluations, self-evaluation, and teacher feedback. Evaluations were handled by Peer Review Program (PRP), a web application made at our university. The focus on middle presentations was in stakeholder analysis, and on requirements and diagrams on the final presentations. Course staff acted as a customer, while student group represented the software company.

Groups used Trello tool as Kanban board to plan, create and track their Sprint Backlogs (traditional Todo-Doing-Done), and some groups also put meetings and deadlines in cards at their own column. Teacher gave feedback to groups via own cards Trello at board. Most groups used to have weekly meetings during the Sprints.

Framework was tested with qualitative teacher discussion and quantitative survey and results were used as primary data. Students’ feedback about the Scrumban process was collected on the latter course with separate, non-mandatory but bonus point giving survey. From the 166 students, 127 answered the survey. In the survey, students were asked to reflect on the usefulness of different aspects such as the Kanban board, iterative process and formative evaluation in the Scrumban learning framework.

When asked about the formative evaluation in the Scrumban process, 91% of students considered it better to receive feedback during the execution of the practical work rather than only afterwards. Only 6% of answerers felt that the process did not support giving feedback to students.

Fig. 2 shows the results of how positively students felt about the iterative process and dividing the work into smaller pieces. Students could choose as many of the options as they felt suitable. In the same question they could also pick if their group followed the iterative process actively (32 % of answerers picked that option), followed the iterative process moderately (picked by 61 %) or did not follow the process either by working in last moment or as a big chunk (picked by 9 %). It should be noted that some answerers did not pick any of the options regarding how their group followed the process and some picked more than one. Students felt positively about the iterative process and dividing the work into smaller pieces, even though some of them did not fully utilise it during this course.

Fig. 3 shows the results about how students viewed the usage of Kanban board in their practical work. Students could pick as many of the options as they wanted. Vast majority (90%) considered it helpful for visualizing the work.

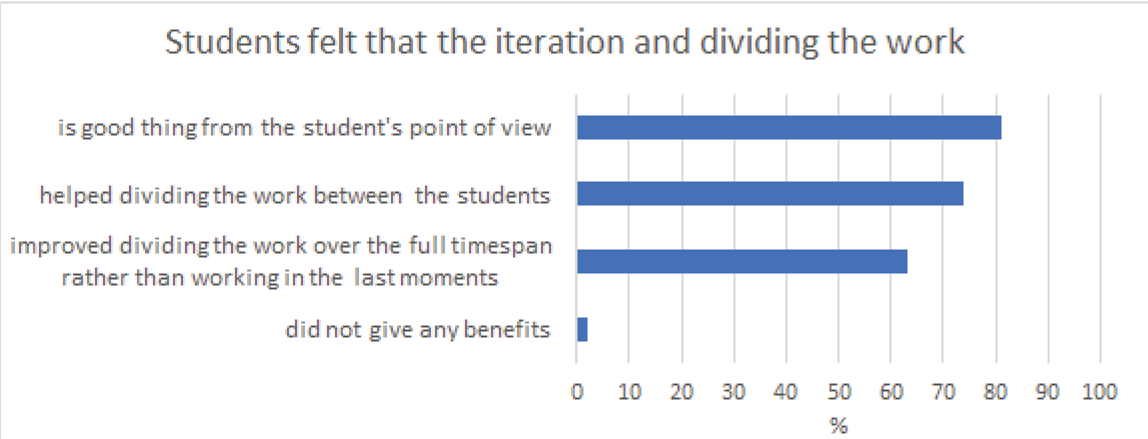

Fig. 2. Iteration and dividing of work

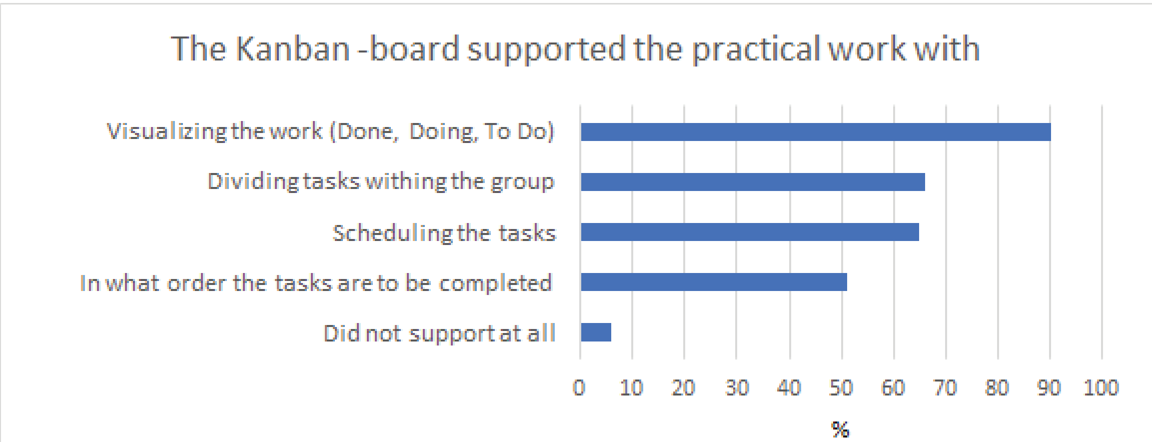

Fig. 3. Kanban board support

Teacher feedback was collected in discussion session where the course staff from the both course implementations was present. Discussion focused on four topics: How did the teachers feel about the change from traditional practical work process, did the process improve options for evaluation and feedback, how did the Kanban board work from teacher's perspective and what kind of possibilities the visualisation offers, and would the teachers use the framework on other courses.

Teachers noted that the communication with students was more distributed over the course periods instead of focusing in the last days before the deadline as the students worked iteratively. In addition, the grading and evaluation work is more distributed over the course. This needs to be taken into account while planning the work load as it may not be possible to use the teaching intermissions for the grading and evaluation. On the other hand, as part of the grading can be done during the course, it lessens the workload after the final deadline as earlier parts are already evaluated, though on practical works where the integrity and consistency between different parts is a requirement for students, teachers might have to review the already graded parts again, increasing total workload slightly.

Teachers felt that evaluation has stronger basis when there is information available through the whole process and it is possible to guide the work towards better end result based on the partial deliveries. Framework also supports feedback from other sources than the teacher, peer reviews or stakeholder evaluations can be given from partial or final deliveries.

Using the Kanban board gave with relatively quick glance a good picture about how the group is progressing. Using tool that shows history in addition to the current situation allows teacher to periodically check the progression and work division between the groups. Also possible "free-rider" students in groups could be detected. However, if there are multiple groups that the teacher is overseeing, the amount of work will be non-negligible and should be again taken into account while planning suitable workload.

4 SUMMARY AND CONCLUSIONS

Created conceptual framework for practical works in engineering education is presented in this paper. Framework is based on combination of Agile method called Scrum and Lean method called Kanban. Framework is tested in engineering course with quite large practical work during two implementations of the course. More than 110 student groups have used the framework and in the end second implementation of the course additional feedback was collected and analysed. Goals for this Scrumban learning framework seems to be achieved. Feedback shows framework has been useful tool for practical works from students' and teachers' point of view. Main improvements for traditional practical work implementation are iterative approach for quite large and usually quite unknown subject of work, transparency through visualisation of ongoing work, visualisation of tasks and responsibilities, and dividing work both earlier and better during the time-box given and between team members of the student group. Teacher discussion also gave conclusion that framework works also for other fields of education, but needs understanding the ideas of related Agile and Lean principles and techniques. Furthermore, framework gives more opportunities for formative assessment and feedback, like teacher observation via visualised process, collaborative feedback between groups and students as well as self-evaluations. Trello as a tool for Kanban board was used to track student groups' and group members' work process along the course. Trello is recommended for this kind of approaches, because of its ease of use, flexibility, and many useful features.

Research related Agile learning environments will continue to find even better solutions in the area of the engineering education. Will be seen how combination of other different principles from engineering field will be researched and experienced in the engineering education.

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Understanding and Evaluating a Business Case and Improving Interdisciplinary Competences among Bachelor of Engineering Students

C. Stisen Flyger
Professor
Technical University of Denmark
Ballerup Campus
E-mail: csfl@dtu.dk

N. C. Kjaersgaard
Associate Professor
Technical University of Denmark
Ballerup Campus
E-mail: nckj@dtu.dk

Conference Key Areas: New notion of interdisciplinary in engineering education, integrated learning environments for the digital native learners

Keywords: Business case, finance, cases, workshop

ABSTRACT

Being able to prepare and analyze a business case is relevant for most engineers. The engineer´s technical knowledge cannot stand alone, and must be combined with financial considerations. Therefore, interdisciplinary competences are necessary [7-9].

A business case tool was developed in order to analyze and evaluate the financial aspects of a business case. The tool was used for different engineering programs with different types of business cases. In order to ensure relevance for each engineering program the cases were developed in cooperation with the program directors.
During the development phase of the business case tool special attention was paid to user friendliness, the use of traditional economics theory and the possibility of illustrating practical use and understanding of the economics theory.

The development was an iterative process. The first versions of the business case tool were tested and optimized in cooperation with experts with different perspectives and competences

The four hour workshop starts with a short introduction to basic economics theory and the business case tool. The duration of the introduction depends on the extent and level of the economics prerequisite of the specific engineering program.

During our workshops, we have documented that the tool can be successfully used within most engineering programs. With a limited teaching effort of four hours, it is possible to give engineering students with varying economic prerequisites a good understanding of the business case and how to analyze and evaluate a business case.

1 INTRODUCTION

The aim of this paper is to describe our work and experiences with designing and arranging workshops introducing all DTU Diplom students to the economics tool: The business case. Data from an e-learning workshop mid July will be analyzed and presented at the conference.

2 BACKGROUND

In the companies where our graduates will be working after finishing their education, the single most decisive factor for whether a project will be started or not is how profitable the project is. This is valid for most kind of projects whether it relates to new products, new production processes or other kinds of process improvements. Therefore, being able to analyze and document that there is a business case for the new product, production process etc., is a very important skill for our engineers. DTU Diplom will be offering all students to obtain that skill by participating in business case workshops.

Furthermore, at DTU Diplom business understanding and economics are considered one out of seven constituent elements, which all engineering students should be able to apply after completing their studies. This ensures that the business case activities receive managements support and involvement.

Since 2010 the engineering programs at DTU Diplom have been based on the educational framework CDIO (Conceive-Design-Implement-Operate) [5] and a typical semester for the 10 different engineering programs consists of three to four individual courses (20 ECTS-points in total) as well as an interdisciplinary semester project (10 ECTS-points) where the students apply the knowledge obtained in the individual courses. The semester projects most often are a CDIO Design Build project.

The extent and level of economics course requirements varies among the different engineering programs. Some programs have two to three separate economics classes of 5 ECTS-points each in addition to applying economics concepts in the semester projects as well. Other programs have almost no economics course at all. This makes it necessary to include a short module in the workshop introducing the most necessary basic investment and cost theories, for some of the engineering programs.

By participating in the workshops, the students will be able to use and understand the concept of the business case as well as what companies can obtain by using this structured way to evaluate and choose among different investment projects. The students will have an important tool that can be used in upcoming projects at both DTU Diplom and in the companies after completing their education.

3 GENERAL METHOD

It was our experience that the students at DTU Diplom needed a simple tool for evaluating the profitability of business cases in their semester projects and bachelor projects. We therefore decided to develop this tool.

During the development process, we asked users from the industry with different skills to test the tool in order to improve it further.

When the tool was ready, we wanted to give the students an opportunity to learn about the tool so they would use it in their projects afterwards.

In cooperation with the management at DTU Diplom we decided to implement a workshop for the students at all engineering programs

In order to ensure the greatest outcome for the students we produced course and learning objectives for the workshop:

General course objectives for the workshop:

The students must demonstrate the ability to

- Use the business case tool in order to evaluate the financial consequences of a business case and carry out a financial risk evaluation.
- Present the results of the business case for a decision maker.

Learning objectives:

The student who has met the objectives of the course will be able to

- Identify relevant data for a business case.
- Use the business case tool in order to evaluate the financial consequences of the business case.
- Identify which assumptions that are highly critical for the results of the business case.
- Carry out a risk evaluation on the highly critical assumptions.
- Present a recommendation to the target group based on the business case.

The first two workshops were conducted as pilot workshops in order to achieve experience and to further improve the tool and workshop. The students targeted in the pilot workshops were from the Global Business Engineering Program and the Production Engineering Program. Until now, the workshops have been completed at 5 of the engineering programs at DTU Diplom, and will in the near future be offered to the remaining engineering programs. The business cases are adapted to the specific engineering programs and the results of the workshops in the spring and summer 2019 has been collected and analyzed.

4 THE BUSINESS CASE TOOL

The business case tool is based on Excel. The tool includes a short description of the investment project, critical assumptions, risk evaluation etc.

The students must further add the following input data for each year during the project lifetime into the tool:

- Investment costs.
- Net payments from revenue, variable costs, fixed costs, other incomes and other costs.
- Discount rate.

Based on the input data the tool calculates Simple Payback Time, Dynamic Payback Time, Net Present Value (NPV), and Internal Rate of Return (IRR) of the investment [1][6].

5 THE WORKSHOP

During the workshop, groups of students are working on a business case adapted to their engineering program. The duration of the workshop is four hours.

The workshop is adjusted to the qualifications of the students from the specific engineering program.

For those who have no or only very limited economics knowledge there will be a general introduction to basic economics theory. It will last for approximately 35 minutes and will include the following subjects [1]:

- Understanding of costs and income with focus on the distinction between variable and fixed costs and between cash flow and cost/income.
- Sunk costs and incremental costs.
- Methods for evaluation of the profitability of an investment.

For all engineering programs there will be an introduction to the business case tool (approximately 10 minutes) and a presentation of the specific case (approximately 15 minutes).

Each business case includes a “six steps recipe” which the students must follow during their work. These six steps are the following:

1. A brief description of the project including the suggested solutions.
2. Identify gains and losses related to the suggested solution.
3. Consider how it is possible to monetize the pros and cons.
    a. Which information/data do you need?
    b. How can this information be obtained at the company?
4. Estimate the value of these pros and cons.

5. Identify the most important assumptions and make a risk analysis (most likely, best case and worst case).
6. Complete the business case

The students are working on the business cases in groups, with the lecturer acting as a supervisor. The students must identify relevant data, understand the criticality of the assumptions they use for the evaluation of the business cases, and carry out risk evaluations on the highly critical assumptions by adding different scenarios into the business case tool.

Each group presents their results for all the students in plenum for approximately 30 minutes.

The workshop is also conducted in a mandatory course for Bachelor of Engineering students called Innovation Pilot. The outline for the course is that the students work in multidisciplinary teams with specific real-life challenges offered by the involved companies. The company is the problem owner and the students should involve the context reality of the company in solving the challenges. The students are responsible for finding ways to apply their unique skills and knowledge to create value in the projects.

As there are no traditional lectures in the Innovation Pilot course the business case workshop was developed as an e-learning program. The program consists of 5 videos:

Video 1: An introduction to the workshop
Video 2: A general introduction to investment theory and some basic economics
Video 3: A presentation of the business case tool and an introduction to the 6 steps recipe that should be followed in order to make a business case
Video 4: An introduction to the case the students should work with
Video 5: A discussion of the solution to the case

A Delphi survey [3] has been conducted and both the method and the results will be presented in part 7 and 8 in this paper.

6 DEVELOPMENT OF BUSINESS CASES

The hypothesis was that it is important to adapt the business case to each engineering program in order to ensure the relevance for the students at the specific program.

The first two workshops were conducted as pilot workshops. The students were from the Global Business Engineering Program and the Production Engineering Program. We prepared two different cases, one for each of the two engineering programs. Our hypothesis about adapted cases was correct. It turned out that the students from the two programs had quite different approaches to solving the exercises because their focus and competences were within different areas. The students from the Production Engineering Program rapidly was asking for additional information regarding Operations Management issues, such as whether or not the production process is a bottleneck, or details to the process flow. The students from the Global Business Engineering Program was soon gathering information from different data bases regarding market data for competitive products. In both programs it was clear that the students applied their interdisciplinary competences. The students from the Production Engineering Program used both technological, economics and management competencies. The students from the Global Business Engineering Program used technological, economics and marketing competences.

It was clear that they applied their interdisciplinary competences, as they used both technological, economics, marketing and management competencies.

Based on experience from the pilot workshops it was decided to extend the workshop to additional engineering programs at DTU Diplom. For each of these programs meetings were set up with the program directors to inform about the business case tool, how to use it, and the relevance to the students. Based on this information the program directors appointed a relevant lecturer to help prepare the business case for the specific program. Different topics for the business case were discussed and a business case was prepared.

7 DATA COLLECTION AND ANALYZIS

In order to evaluate the effect of the business case and the workshops data has been collected and analyzed using the Delphi method. Two workshops have been selected to provide data for the analysis. The first workshop was a physical workshop with students from the Production Engineering Program and the second was an e-learning workshop with students from Innovation Pilot.

After the first workshop with the student from the Production Engineering Program, the students from this program were introduced to three themes and asked to come up with statements regarding the business case and the workshops. The three themes were the following:

1. Usefulness in later projects and in the work life
2. The relevance for an engineer from that specific field the student have, hereunder the necessity of having interdisciplinary competences (management, technology and economy)
3. What was the outcome of the workshop

For each of the three themes the students came up with multiple statements each. Afterwards the statements were grouped after similarity. That ended up with 4-6 statements for each theme:

Theme 1: Usefulness in later projects and in the work life

- Question 1: The business case is an important tool for risk evaluation of an investment project
- Question 2: The business case is an important tool in their job after finished education
- Question 3: The business case is an important tool in later projects in the university
- Question 4: Using a business case results in a larger success rate for my project ideas in the companies after finished education
- Question 5: Using a business case makes the assumption of the investment project more visible
- Question 6: Using a business case visualize how the investment is affected by changes in the assumptions

Theme 2: The relevance for an engineer from that specific field the student have

- Question 7: Interdisciplinary competences are necessary in order to make a business case
- Question 8: The business case is a highly relevant for that specific engineer (the student)
- Question 9: Interdisciplinary competences contributes to ensure that pros and cons for the will be more realistic
- Question 10: In addition to the technical background, it is important to have financial knowledge, as the profitability of a project is essential

Theme 3: What was the outcome of the workshop

- Question 11: The workshop gave a good basis for using the business case tool
- Question 12: The workshop has been fruitful
- Question 13: A better understanding for variations in the project´s profitability depending on different scenarios as a result of changes in assumptions (most-likely, worst- and best case)
- Question 14: By using the tool in the workshop I have gained an understanding of which elements it is important to focus on in order to present an investment project for the management of the company

The students from the Production Engineering Program were then presented to the 14 statements and asked to indicate how much they agreed/disagreed on a scale from 1-5, where 5 is strongly agree and 1 is strongly disagree. Of practical reasons, the survey was conducted two working days after the workshop, which is the reason why only 14 out of the 20 students participating in the workshop responded.

The students from Innovation Pilot were presented for the same 14 statements via the e-learning activities and requested to upload the questionnaire. This resulted in a lower response rate.

8 FINDINGS

8.1 Production Engineering workshop

There were 20 participants in the first workshop and 14 questionnaires were collected.

Theme 1	
Question	**Average**
1	4.5
2	4.3
3	3.9
4	3.7
5	4.5
6	4.1
Theme average	4.2

Theme 2	
Question	**Average**
7	4.4
8	4.9
9	4.6
10	4.6
Theme average	4.6

Theme 3	
Question	**Average**
11	4.6
12	3.8
13	4.4
14	4.2
Theme average	4.3

Table 1: Scores for the themes

In general theme 2 regarding relevance was receiving the highest scores with an average of 4.6. Theme 1 and 3 also received high scores with averages of 4.2 and 4.3. That means that the students in general agree with the statements. Looking further into the data some variations within each theme can be seen.

In theme 1 especially question 3 and 4 differ with lower values. Question 3 regarding the business case as an important tool in later project in the study received the score 3.9 and question 4 regarding larger success rate for project ideas in companies after finishing education received 3.7. The lower score in question 4 was expected, as it can be difficult to know exactly how decision processes are in companies. However, the score in question 3 was a bit unexpected, as the student have more experience in university project than in company projects. Comparing to question 2 regarding the use in the work life after finished education this is even more remarkable.

In theme 2 question, 8 regarding the relevance for that specific engineer differed with a very high score of 4.9. The exact reason can not be seen, but might be influenced by the use of adapted cases. Question 7 and 9 with a score of 4.4 and 4.6 respectively, shows that the students finds that interdisciplinary competences are necessary for making the business case.

In theme 3, question 12 regarding if the workshop was fruitful received a score of 3.8. Question 12 is a more general question whereas the other questions in theme 3 are more specific and received a higher score (4.2-4.6). This could indicate that the students finds that the workshop has given them a good understanding of using the business case tool. The reason for the relative lower score could be that the students at the Production Engineering Program already have a good understanding of investment theory, but not to the specific business case tool.

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Industry-oriented Fluid Mechanics Project Laboratory (WiSPr) as part of the MINT^{grün} orientation studies at TU Berlin

C. Strauch[1]
Research Assistant
Technische Universität Berlin
Berlin, Germany
E-mail: carsten.strauch@tu-berlin.de

P. Sabrowski
Chief Executive Officer
dive solutions GmbH
Berlin, Germany
E-mail: sabrowski@dive-solutions.de

S. Przybilla
Research Assistant
Beuth Hochschule für Technik Berlin
Berlin, Germany
E-mail: sabine.przybilla@beuth-hochschule.de

C. Heller
Research Assistant
Hochschule für Technik und Wirtschaft Berlin
Berlin, Germany
E-mail: c.heller@htw-berlin.de

Ch. Oertel
R & D Engineer
BSH Hausgeräte GmbH
Berlin, Germany
E-mail: christian.oertel@bshg.com

P. U. Thamsen
Chair of Fluid System Dynamic department
Technische Universität Berlin
Berlin, Germany
E-mail: paul-uwe.thamsen@tu-berlin.de

Topics: New Notions of Interdisciplinarity in Engineering Education
Keywords: MINTgruen, industry-related education, fluid mechanics project, University-business cooperation

[1] Corresponding Author

INTRODUCTION

Since 2012, the Technische Universität Berlin offers a special orientation program in the subjects of mathematics, informatics, science and technologies (MINTgruen; English: STEMgreen[2]). It is a one-year program, which is designed to help high school graduates to find the right study course and prepare them for their later studies. Students can choose between regular MINT subjects and specially developed MINTgruen laboratories. After two semesters the students can decide, which study course they want to continue with. Gained ECTS of completed subjects, which fit into the chosen study course, are considered.

The department of Fluid System Dynamics at the TU Berlin contributes to the orientation of young students by offering two different project laboratories dealing with fluid mechanics in applied mechanical engineering: The *“Fluid Mechanics Project Laboratory (FMPL)”* introduced in 2017 [1] and 2018 [8] at SEFI as well as a newly designed *“Industry-oriented Fluid Mechanics Project Laboratory (WiSPr[3])”* covered in this paper.

Both laboratories use the teaching concept of problem-based and project-based learning:

Besides many facts, problem-based learning teaches the ability to develop strategies to solve a problem.[4]

Learning as a problem-based process is executed in a specific, scope-related context. Trainees learn from an example and are able to transfer their knowledge to a new similar problem or situation.[5]

WiSPr provides fundamental engineering skills by teaching students basics of common engineering software (such as Excel, SolidWorks, Python) and guides them through advanced usage. It also imparts structured working methods and teaching the importance of sustainable engineering. Students achieve basic and advanced engineering skills (software and working methods) as well as exploring the multi-facetted nature and the importance of resource-friendly production at the example of everyday objects like coffee machines, dryers, washing machines, and dish washers. The interdisciplinary of these everyday objects is explored by many excursions to different project partners.

Since launching the projects, they have been continuously evaluated by the students. The results show a very good rating for the teaching approach and first analysis reveal that more than half of the students participating in the orientation program choose a MINT topic for their later studies.

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[2] STEM: Science, Technology, Engineering, Mathematics
[3] German: **wi**rtschaftsnahes, **s**trömungstechnisches **Pr**ojektlabor; **WiSPr**
[4] Analogously translated from [5] p. 3; Similar definitions in English can be found in [7]
[5] Analogously translated from [6] p.18; Similar definitions in English can be found in [7]

1 OVERVIEW OF MINT^{GRUEN} (ENGLISH: STEM^{GREEN})

1.1 Structure, numbers and trends

After graduating from high school, young people have to decide what they want to do professionally. Some choose to take an apprenticeship for about 3 years, whereas others choose an academic career. German universities offer a wide range of possible study courses. Most pupils feel overwhelmed by the countless possibilities and are unsure which course to take. They are expected to decide on "the right" study course which they will be practicing for the rest of their lives. This causes a lot of pressure and makes decisions even harder. Young people feel the need to be guided. Therefore, Technische Universität Berlin launched the orientation program in 2012, MINT^{gruen}, to show graduated pupils the variety in the fields of science, technology, engineering and mathematics. Since initiating the orientation program, the numbers of participants are steadily rising (**Fig. 1**).

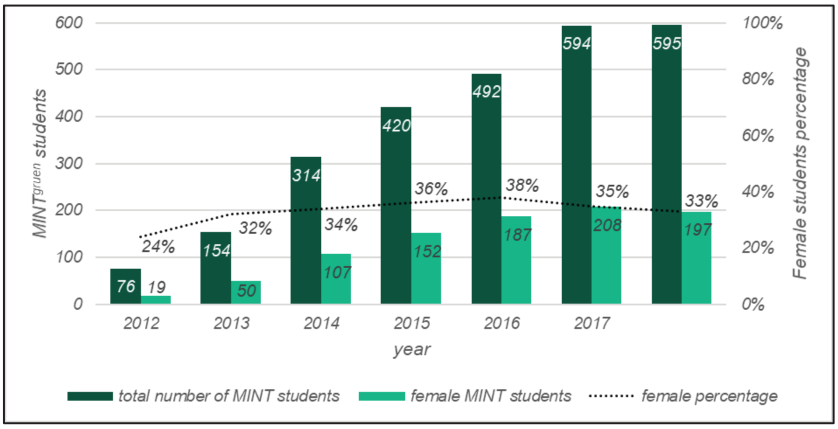

Fig. 1: Numbers and trends of the MINTgruen orientation program

Fig. 2 displays the contents and structure of the orientation program, which lasts two semesters. The "Scientific Window" and the "Study Program Decision" are obligate courses, where students gain all necessary information on how to orientate themselves. In the "Scientific Window" the students have to deal with current research topics in the MINT sector and discuss these in terms of sustainability and sustainable development. They share and reflect their experiences in a separated orientation course. This helps students to get a good impression of different fields and makes the decision easier. The other modules are facultative and consist of basic lectures (i.e. engineering mathematics) and so-called Project Laboratories, which are explained in the next section. After taking the two-semester program, most of the courses can be transferred to the student's chosen course of study.

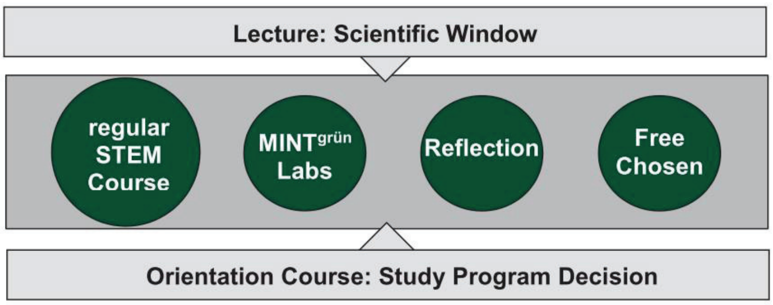

Fig. 2: Structure of MINT^{gruen} study orientation program

1.2 Project Laboratories

Above-mentioned Project Laboratories specifically designed for MINT^{gruen} students are one characteristic feature of the orientation program MINT^{gruen}. Especially in the earlier stages of study courses subjects are more theoretical. For a successful orientation, it is mandatory that students discover their practical and project related potentials. Furthermore, students have to work on projects in their future jobs too and this is a first good practice, which usually appears not until the fourth bachelor semester.

The department of Fluid System Dynamic at the TU Berlin contributes to the orientation of young students by offering a laboratory dealing with fluid mechanics in applied mechanical engineering.

2 STRUCTURE OF WISPR

Due to the nature of a study orientation program, people are going to get attracted to the university. That does not automatically mean, that studying at universities fits a person best. The majority of TU Berlins Project Laboratories contribute to the orientation of young students by using the teaching concept of research-based learning (see also [9], [10], [11]), therefore being university-oriented. For a well-balanced student orientation, there is also a need to design industry-oriented laboratories. WiSPr Laboratory is the first industry-oriented lab at TU Berlin.

2.1 Idea and scientific background

Engineers fulfil an important role in our culture. Engineers find solutions for society's changing problems in a challenging world. Engineers implement innovations, which the community depends on. All these solutions and innovations serve a greater good. Therefore, it is important to align engineering education to fulfil society's needs.

Engineering education must become relevant to the needs of the profession in a rapidly changing world and move from its current focus on engineering science to providing graduates with the expertise to responsibly apply technology to the benefit of their communities. [12, p. vi]

Most engineering study courses (i.e. mechanical engineering, civil engineering etc.) at TU Berlin do not differ from each other in the first semesters, because they do have the same lectures to impart basic knowledge. By experience, it is hard for students to abstract what this knowledge can be used for in the later study stages or in their later jobs. Consequently, young students are not able to understand their upcoming responsibility and how society will benefit from them.

The idea of WiSPr Laboratory is to create the link between study matters and society's needs. Furthermore, a connection between different engineering disciplines is created right at the beginning of their studies. A good way to fulfil employer's requirements is to design a course collaboratively and prepare students for their later jobs. Therefore, an everyday object (i.e. coffee machines, dryers, washing machines, etc.) is taken and looked at in detail. The multi-facetted engineering nature of these products is underlined and interdisciplinarity is emphasized.

2.2 Design and Execution

At the example of a washing machine paddle (**Fig. 3**), students experience development processes in the industry. Therefore, they visit research and production facilities and get to know the industrial routines. Moreover, the students apply innovative, numerical methods for flow simulation (see also **Chapter 5**). In a laboratory session, results of the simulation are compared with reality by using a test bench.

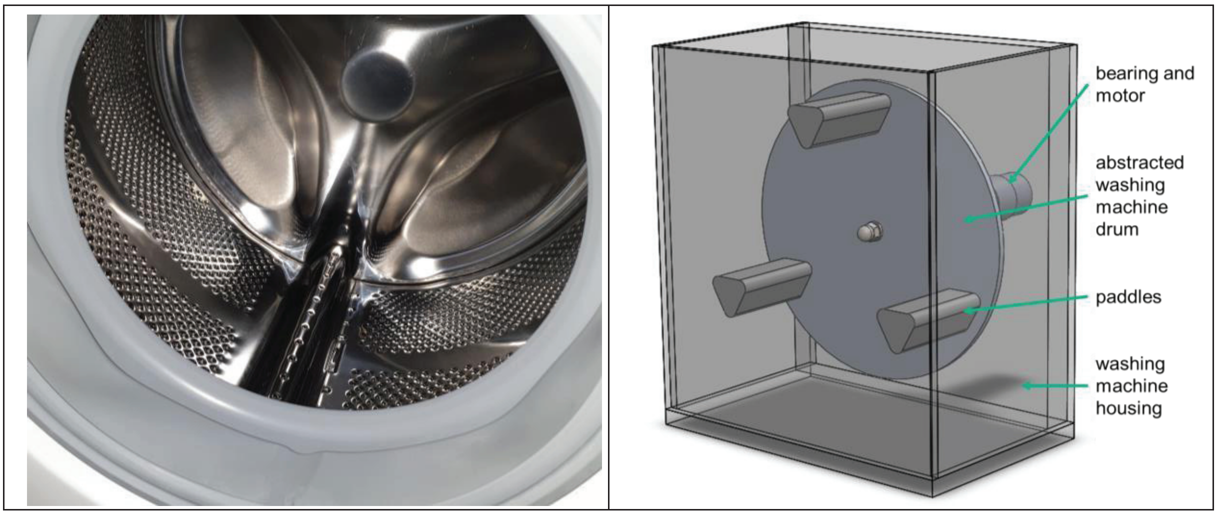

Fig. 3: Washing machine paddle inside a washing machine drum (l.) and washing machine test bench for investigation purposes (r.)

Even if it does not show, a washing machine paddle (**Fig. 3**) is one of the most complex elements inside a washing machine. Given task for the students is to simplify the washing machine drum and design their own paddles with certain chosen abilities. The whole design process is supported by different industrial project partners and research assistants. WiSPr Lab splits into five steps as illustrated in **Fig. 4**.

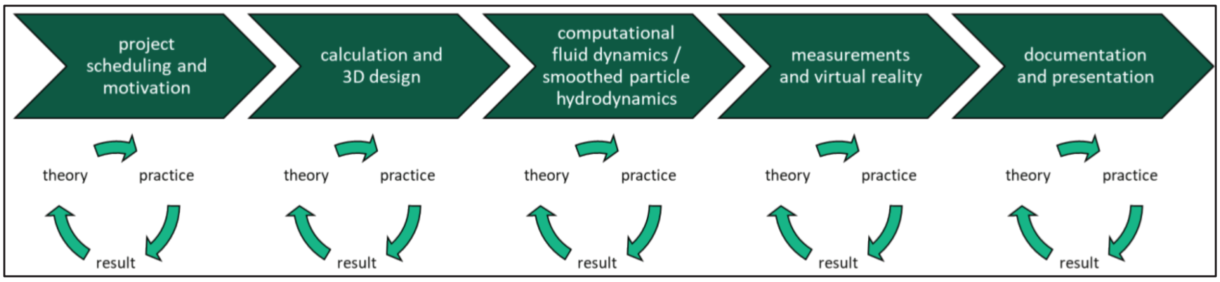

Fig. 4: Design process in WiSPr Lab according to problem-based learning philosophy

The first step contains motivational excursions into research and development facilities of different industrial project partners. Students gain insight on washing machine design, product life cycles, washing processes and textile testing. Time and project management skills are taught.

After understanding the purpose of washing machine paddles, students are encouraged to design their own washing machine paddles in groups of four by choosing a number of requirements their paddle has to accomplish. Students design their paddle in a way they think it would fulfil set requirements by using a 3D-CAD[6]

[6] CAD: Computer Aided Design

software called “SolidWorks” (step 2). Afterwards, in step 3 these paddles are used for numeric fluid simulations using a smoothed particle hydrodynamics software called “DICE[7]”. The results of the simulation are used to investigate if the paddles accomplish previously defined requirements. If not, the design of the paddle is changed and iteration processes are started. **Fig. 5** shows all paddles designed in winter term 2018 after their last iteration.

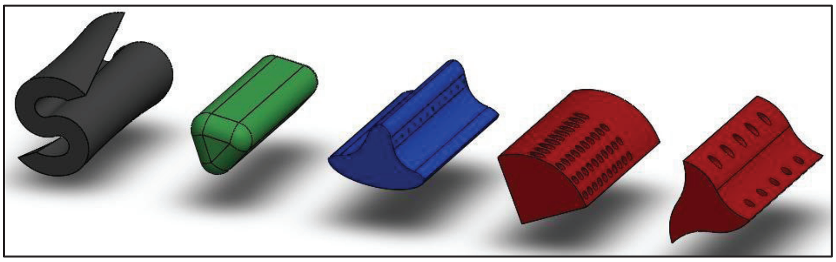

Fig. 5: Paddles designed by students using a 3D-CAD software in winter term 2018 (each paddle was created to fulfil previously set requirements)

Step 4 is used to impart knowledge about product design using virtual reality and to prepare for upcoming measurements at a test bench. Therefore, an excursion to a Virtual Reality room called “CAVE” is arranged. By wearing shutter-glasses the designed paddles are projected into the room, therefore appearing 3-dimensional in front of the students. A tracking system and the rising immersive effect allow students to interact with their geometry. Furthermore, students’ paddles are put into a virtual test bench to explain upcoming (real) measurements. Step 4 is completed by executing measurements on the real test bench and comparing results with previously done simulations.
Fig. 6 compares the simulation result with test bench investigations for the blue paddle rotating counterclockwise. Looking at the vortex formed in the middle bottom, simulation and measurement show an accurate conformability.

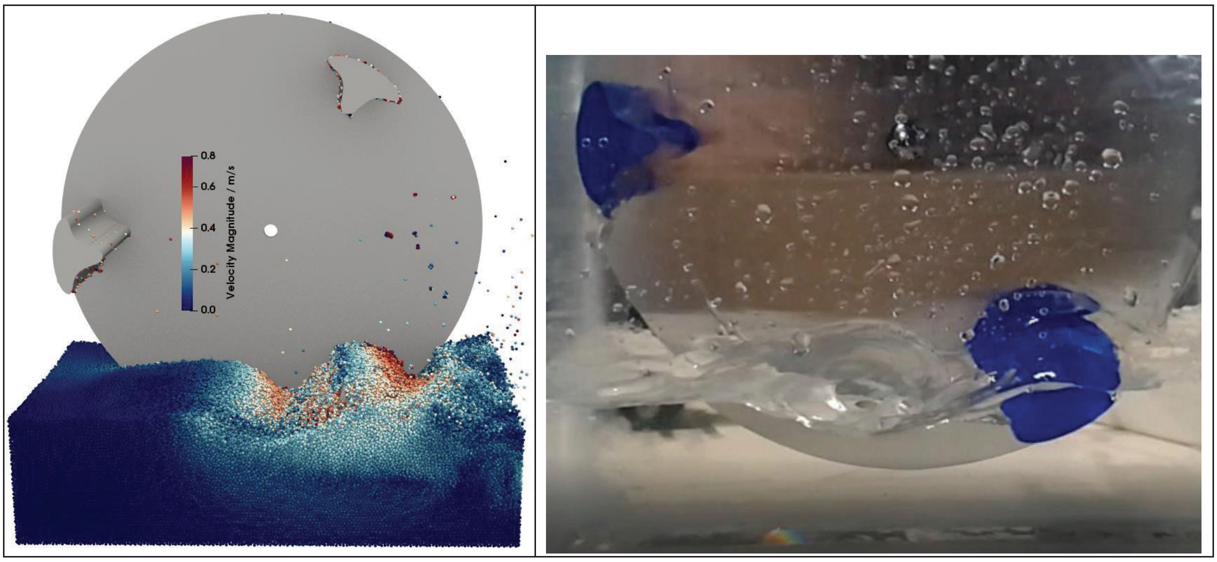

Fig. 6: Results of numerical simulations using smoothed particle hydrodynamics (l.) showing a washing machine paddle diving into water compared to test bench investigations (r.)

[7] For further information please visit www.dive-solutions.de

Last but not least, step 5 covers scientific writing and presentation skills. Students create templates using MS Word and MS PowerPoint, which can be used for their later study courses. The results of each group are presented in front of all MINT^{gruen} lecturers and students.

During the steps mentioned above and illustrated in **Fig. 4** several engineering skills are achieved by the students. The most important points are summarised in **Fig. 7** including duration and contents of each step.

Step	**Duration**	**Contents**	**Achieved skills**
1	*4 weeks*	Motivation and topic introduction, Interdisciplinarity in engineering, Project management	Organisation of group projects, Time management, Creating project schedules with MS Excel, Excursion into Research and Development center, Excursion into Textile Material Testing Laboratory, Connection between mechanical engineering and textile & clothing technology
2	*3 weeks*	Basics in Computational Fluid Dynamics (CFD) and Smoothed Particle Hydrodynamics (SPH)	Basic knowledge in Fluid Dynamics, Proper usage of SPH-software (dive solutions' dice), Basics of post-processing software (Paraview)
3	*2 weeks*	Computer aided design (CAD)	Introduction into 3D modeling, Basic usage of CAD software, Advanced usage of CAD tools (scripts & macros), Manufacturing of student's washing machine paddle
4	*3 weeks*	Measurement techniques, test stands and virtual reality	Purpose of test, Product design by using virtual reality, Usage of sensors, Measurement of each group's paddle, Advanced usage of MS Excel (graphs, functions)
5	*3 weeks*	Writing and presentation skills	Creating templates for MS Word, Basic usage of MS PowerPoint, Scientific writing recommendations

Fig. 7: Contents and achieved skills in WiSPr Laboratory

3 RESULTS AND TEACHING APPROACH

Analysis reveal that more than half of the students participating in the orientation program in 2018 choose a MINT topic for their later studies (**Fig. 8**).

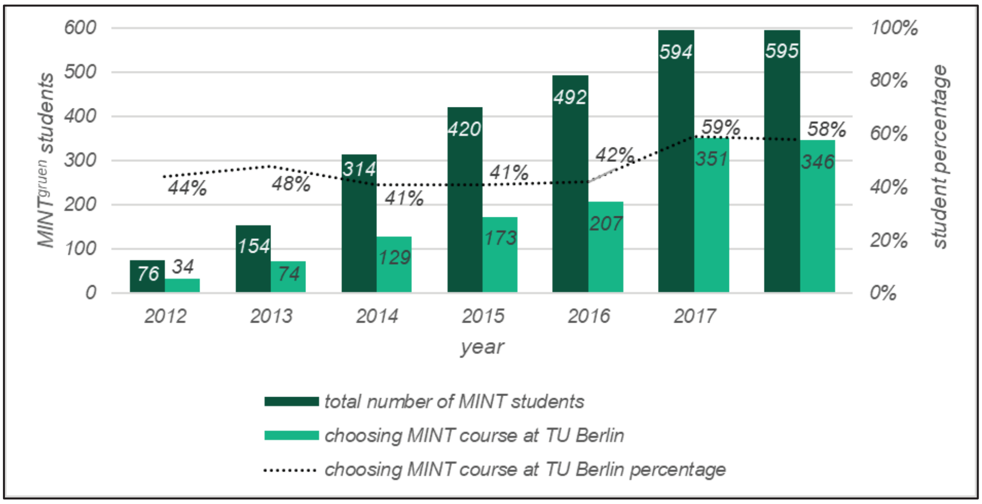

Fig. 8: Number of students considering a MINT related study course at TU Berlin

Even students who leave the university and start an apprenticeship consider the contents of WiSPr as useful for their later jobs. The WiSPr Laboratory as a whole was rated in the winter term 2018 with “very good” (**Fig. 9**). Despite the simulation part (advanced numerical fluid mechanics) students consider WiSPr Laboratory equally difficult compared to other courses attended (**Fig. 10**).

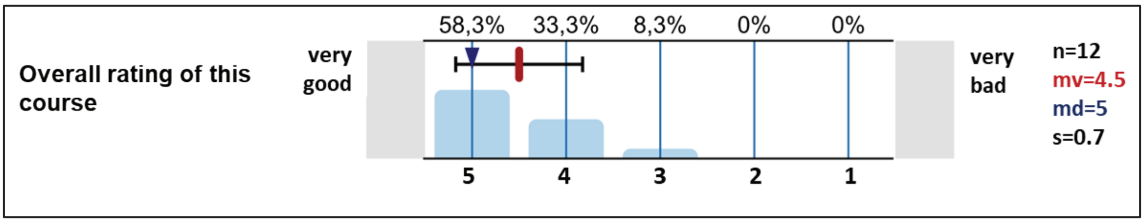

Fig. 9: Students’ overall rating of WiSPr Laboratory in the winter term 2018

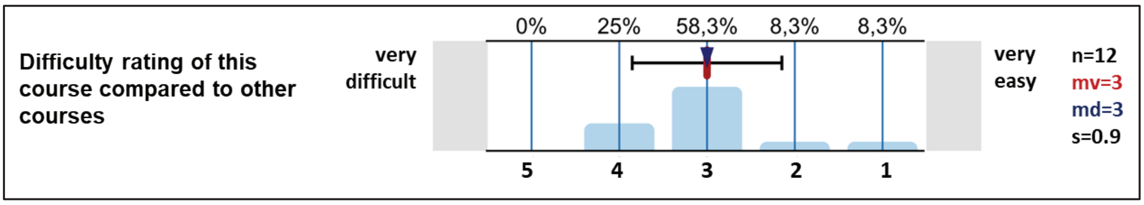

Fig. 10: Students’ difficulty rating of WiSPr Laboratory compared to other courses in the winter term 2018

4 SUMMARY AND ACKNOWLEDGEMENTS

Whereas lectures mostly use frontal teaching methods the Project Laboratories focus on practical tasks and give students the possibility to create a STEM-related object on their own. The teaching concept of this Industry-oriented Project Laboratory contributes highly to the orientation of our students. A huge field of fluid mechanical engineering is covered. Students gain a diversified insight on fluid mechanic related topics and their field of appliance. Due to the practical concept of the laboratory students achieve various engineering skills and working methods which can be used in many study courses, apprenticeships, or even in their later jobs. Due to the teaching of basic and advanced skills regarding engineering software (Python programming language, MS Excel, MS Word, MS PowerPoint, SolidWorks), students are well prepared for their course of study. In this program students get supported in general studying related aspects as well as fluid mechanic related topics.

5 APPENDIX – SMOOTHED PARTICLE HYDRODYNAMICS (SPH)

Smoothed particle hydrodynamics (SPH) belongs to the meshfree methods in computational fluid dynamics (CFD). Whilst traditional CFD uses grids to solve numerical fluid dynamics, the simulation method Smoothed Particle Hydrodynamics approximates fluids as an accumulation of particles moving freely in space. Every particle can be seen as a moving interpolation point. The physical field can thus be evaluated at those points by interpolating the properties of surrounding particles (see **Fig. 11**). This eliminates the need for grid generation and easily solves some of the most challenging cases of fluid mechanics. SPH efficiently solves multiphase and free surface flows, as well as moving machinery (such as gear boxes lubrication or mixing tanks). Many use cases are shown below (see **Fig. 12**).

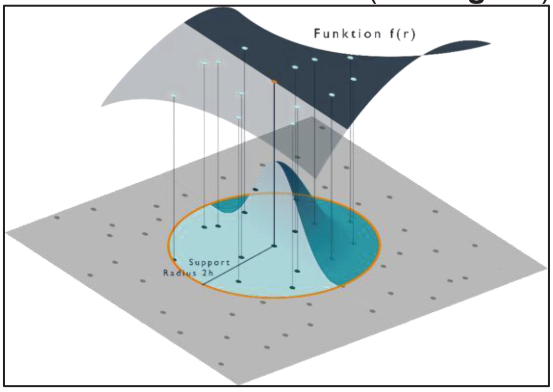

Fig. 11: Decreasing influence of a particle (center) on its direct neighbours

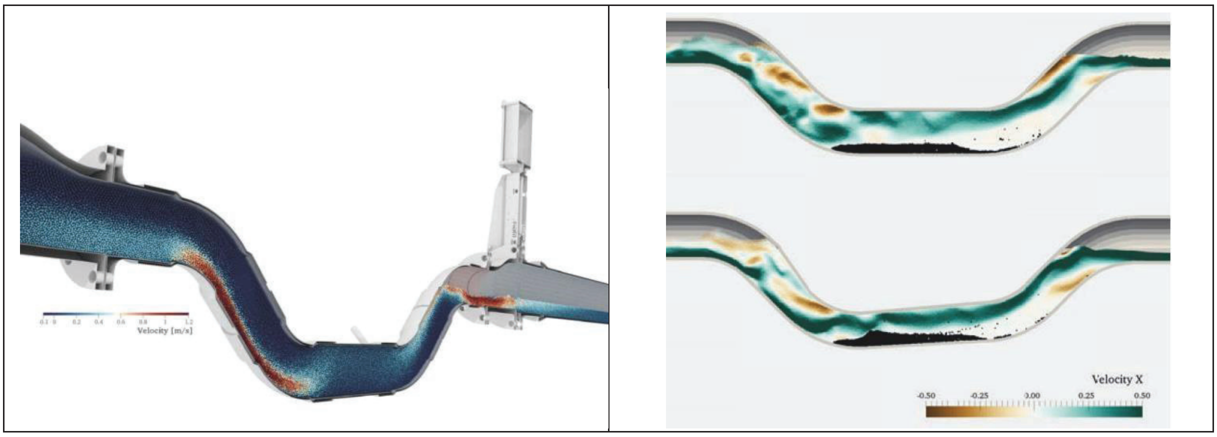

Fig. 12: Extraction of use cases for Smoothed Particle Hydrodynamics
Gear box lubrication (top l.), fluidic oscillator (top r.),
sewer system (bottom. l.), sedimentation transport (bottom r.)

Feel very welcome to visit www.dive-solutions.de for more information.

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A new model of entrepreneurship education for engineering students

V.I. Sucala[1]
University of Exeter
Exeter, United Kingdom

S. Carroll
University of Exeter
Exeter, United Kingdom

C.Z. Cory
University of Exeter
Exeter, United Kingdom

Conference Key Areas: New Notions of Interdisciplinarity in Engineering Education

Keywords: Entrepreneurship education, Models of engineering education

ABSTRACT

The paper describes the process of designing and launching a new model of entrepreneurship education in engineering by a British university. The main driver behind this initiative has been engineering department's strategy to deliver education aligned to the global state-of-the-art practices, focused on user-centered design, technology-driven entrepreneurship, problem-based learning and a focus on rigor in the engineering fundamentals. This complemented the university's initiative to embed entrepreneurship across all its programmes.

Traditionally the entrepreneurship education originated in business or management schools. In the last decades many educational institutions have introduced entrepreneurial education in the engineering curriculum. There are three main models used by the first academic institutions in the United States for entrepreneurial education. A decade later, another study undertaken on more than two hundred universities in five countries suggested five models of entrepreneurship education for engineering students.

The paper is focused on the new and more complex model that has been developed, consisting in an entrepreneurship initiative pursued independently by engineering and the business school, supported by the university's innovation and business support team, and by external partnerships with entrepreneurship centres based in schools of engineering. Moreover all university's students are exposed additional extra-curricular entrepreneurship training.

The Engineering & Entrepreneurship undergraduate programme was launched in September 2018. The paper discusses the process of designing the engineering & entrepreneurship programme's innovative structure, content, and assessment, within the frame of the evolution of similar programmes.

[1] Corresponding Author
V.I. Sucala
i.sucala@exeter.ac.uk

1 INTRODUCTION

The paper describes the process of designing and launching a new model of entrepreneurship education in engineering by a British university. The main driver behind this initiative has been engineering department's strategy to deliver education aligned to the global state-of-the-art practices.

The report *The global state of the art in engineering education* [1] is particularly useful for the understanding of the role of technology-driven entrepreneurship in engineering education. According to the report's conclusions, practices such as user-centered design, technology-driven entrepreneurship, problem-based learning and a focus on rigor in the engineering fundamentals are common to the current leaders in engineering education. The engineering curricula of the future will become more socially-relevant and outward-facing by emphasising student choice, multidisciplinary learning and societal impact, coupled with a breadth of student experience outside the classroom, outside traditional engineering disciplines and across the world. Therefore it can be concluded that entrepreneurship and innovation in engineering are features that characterise the education delivered by the current leaders in engineering education and are also socially-relevant and outward facing. This is one of the main arguments behind the strategic decision to launch a new undergraduate programme in Engineering and Entrepreneurship. This complemented the university's initiative to embed entrepreneurialism across all its programmes.

1.1 Models of entrepreneurship education addressing engineering students

Traditionally the entrepreneurship education originated in business or management schools. However, in the last decades many educational institutions have introduced entrepreneurial education in the engineering curriculum. There are today more than 400 engineering schools offering some entrepreneurial and business courses [2]. Luryi et al argued that entrepreneurial education is of great benefit for engineering students, and there are three core requirements for the success of an entrepreneurship educational component:

- The entrepreneurial components should be compulsory to all engineering students and should involve hand-on business experience based on innovating engineering projects.
- The entrepreneurial activities should be based on multidisciplinary teamwork projects because mixing students from different backgrounds is adding versatility and functionality to the teams and is broadening their entrepreneurial experience.
- The entrepreneurial components should include competitive activities encouraging the engineering students to act on their talent and ideas [2].

The Standish-Kuon & Rice study outlined the approaches taken more than two decades ago by academic institutions in the United States and suggested a typology of three models [3]. The authors investigated how traditional science and engineering students were taught entrepreneurship at six American universities. The most important objectives of teaching technology entrepreneurship were new venture creation and, to a lesser degree, research. The most important drivers behind the initiative were internal champions and interest on the part of alumni and current students, while the lack of elective credits in the engineering curriculum was identified as the most common barrier. The three models outlined by the authors have as their distinctive characteristic the location of the entrepreneurship programmes. For the Business School model the entrepreneurship education is delivered by the business school, the technological entrepreneurship curriculum being developed through active collaboration with engineering school, The Engineering School model has the engineering entrepreneurship education based in the engineering school, co-existing with other entrepreneurship courses offered by the business school. In the Multi-School model the technological entrepreneurship curriculum is developed through active collaboration of business school and one or more technical schools.

Another study undertaken on more than two hundred universities in five countries suggested five models of entrepreneurship education for engineering students [4]. The purpose of this research was to determine if the Standish-Kuon & Rice typology was representative of present-day entrepreneurship initiatives for engineering students, and if this typology could be applied to other entrepreneurship initiatives for engineering students outside the United States. The authors argued that a total of five models were used to develop entrepreneurship initiatives for engineering undergraduates. These results showed that the Standish-Kuon & Rice typology required updating to reflect present-day initiatives for engineering undergraduates. These findings, as a result, laid the foundation for the emergence of a new typology, which was subsequently entitled the Entrepreneurial Engineering Education, or EEE, typology. In addition to the three models identified by Standish-Kuon & Rice, Fraser et all added two other models. The External Partnership model is similar with the Engineering School model but the development of entrepreneurship initiatives stemmed from collaborative efforts between the home institution and external partners such as external networks that supported the development of entrepreneurship education, local organizations that contributed resources to entrepreneurship initiatives, or other tertiary-level academic institutions. The Institution model described entrepreneurship initiatives derived from efforts to educate the entire student body about entrepreneurship, regardless of the degree the students are enrolled in.

The history evolution and success of embedding enterprise and entrepreneurship in the British engineering education had been also investigated for almost two decades. Substantial evidence for the effectiveness of innovative programmes has been identified but it has been also argued that it would be difficult to embed such programme in the UK for few reasons such as: resource limitations, lack of training in synergistic methods, finding suitable entrepreneurs to take part in the programme and finding space in the timetable and curriculum [5]. Delivering successful content related to enterprise appears to depend on appointment of non-traditional staff [6] which is a challenging issue in the highly competitive environment in British higher education. According to the same authors, company related knowledge should be incorporated in ‘enterprise tracks’ along the whole degree rather than in just few isolated modules, the lecturers should be members of the engineering departments rather than of the business schools, and students should be provided with knowledge, skills and enterprise experiences in a way that connects to the core subject.

2 DRIVERS OF CHANGE

In this particular case, the Engineering & Entrepreneurship programme had few external drivers. The first one has been an alumnus of one of the university’s engineering programmes who have had a strong entrepreneurial record, and who supported the initial design and launch of the programme. This support consisted in a philanthropic donation that has been secured by the university in 2017. The donation aimed to trail-blaze a new approach to entrepreneurship which helps to catalyse a university-wide transformation in all faculties’ approaches to entrepreneurship education. Following this event, the initial structure of the Engineering & Entrepreneurship programme was designed in 2017-18 and the advertising campaign and recruitment have started at the end of 2017. The process of designing the undergraduate programme was centred on its innovative structure, content, and assessment, integrated with consistent extra-curricular activities.

The highly competitive environment and the need to keep and improve the position within the group of research intensive British universities has been the second driver of change. Therefore the engineering department has embarked into a comprehensive review process aiming to deliver an exceptional experience for students. Its starting point was the need to improve engineering education aligned to the current world's best practices and to the future trends of engineering education and as well aligned with the university's education strategy. The review and re-design process has started in 2017 and it aims to launch the new engineering programmes in 2020.

Calls for change of the traditional engineering education content and methods are not new. In October 2006 the Journal of Engineering Education published the Special Report entitled *The Research Agenda for the New Discipline of Engineering Education* [7]. According to its authors, a transformational change rather than incremental improvements in the way engineering students are recruited and educated is acutely needed in order to be able to confront future challenges. This transformational change must be grounded on 'rigorous research-based approach to our educational system, similar to the way in which research is performed and used in the traditional engineering disciplines'. While the need to ground transformational decisions on hard evidence is undisputable, collecting relevant evidence on the educational system has been a challenging issue especially in the wide and diverse area of engineering. However, the relatively significant body of knowledge summarised briefly in the Introduction has been extremely useful in this endeavour.

Besides the comprehensive review of the existing engineering programmes which is discussed by another paper, the new Engineering & Entrepreneurship programme is a critical element of this process. The overall review process has also provided the opportunity to embed entrepreneurship elements in all engineering programmes as it will be described below.

3 ENTREPRENEURSHIP FOR ENGINEERS

Based on all these arguments discussed above, a new model of entrepreneurship education of engineering students has been developed, consisting in an entrepreneurship initiative pursued independently by engineering department, supported by the university's innovation and business support team, and by external partnerships with entrepreneurship centres based in schools of engineering of two US universities with a strong record in entrepreneurship education.

3.1 Entrepreneurship for all engineering students

In this education model used by this university all engineering students complete a common first year which heavily emphasises fundamental engineering science and mathematics. Entrepreneurship has historically not featured at all within the engineering curriculum. In the new structure a thread of entrepreneurship is running through years 1 and 2 with dedicated modules that develop students' skillset and awareness of topics such as rapid product and prototype development, company formation and professional networking. Two modules (courses) have been developed for this purpose: *Entrepreneurship Skills Development 1* and *2*. In these modules all students will work in teams as businesses bidding to win a tender from a client to design and manufacture a product. These products will be aligned to existing companies that are represented on the department's industrial advisory group, and amongst the portfolio of companies engineering department currently works with. Assessment of the module will be authentic to real-world situations and will encourage students to think about materials, efficiency, sustainability, durability and profitability. They will also give a presentation to pitch their idea, develop drawings and write a report on the development process.

3.2 The main features of the Engineering & Entrepreneurship programme

Following the year 1 which is common to all engineering programmes, specific entrepreneurship content will be delivered in years 3 and 4. Utilising problem based learning, students will be presented with a selection of engineering problems that industrial partners are currently facing. In addition to academic study related to the engineering principles behind the problems, students will also have input from innovators and engineering entrepreneurs through seminars, guest lectures and workshops to help develop the values, spirit and skills essential to entrepreneurial thinking and idea development. This includes modules such as *Introduction in Economics and Company Finance*, *Technology Entrepreneurship*, *Industrial Awareness and Problem Solving*, and *Global Entrepreneurial Marketing*.

At the end of year 3 the students will have the opportunity to compete for 10 awards made annually in the year 4 of the programme. Each award worth of £12,000 will equip the winning students with the time and space they need to launch their business. This innovative structure will see selected students truly learning by doing as they start-up their own businesses based on the ideas developed over the third year. The successful students will be part of a dynamic learning environment in offices alongside high-technology businesses undertaking research and development. Each student will be assigned a mentor from industry in addition to an academic tutor from the engineering department. There will be no formal teaching on this module as it is entirely student-led. Assessment will be made through the creation and maintenance of a Professional Development Portfolio containing business plans, designs, market research and marketing plans, finance and tax documents pertaining to business administration, and several critically reflective accounts of their entrepreneurship at key stages across the year. Successful completion of the module is not tied to the success of the business, instead it is based on the engagement and critical reflection of the student, whatever the outcome. The module runs across all terms of year 4. If not successful in their bidding the student will have a normal taught year 4 concluded by a final dissertation. Students following both pathways will graduate with MEng award.

A dedicated space in which students from across the university are able to experiment with technology, devices and software to develop concepts and early minimum viable product (MVP) solutions has been provided by the university. Named *The Deck*, this space is also allowing Engineering & Entrepreneurship students to collaborate on ideas is essential to help build balanced teams and blend different experiences.

Partnerships with universities abroad will provide efficient knowledge transfer from other entrepreneurship centres based in engineering schools with a consistent record. These partnerships will be providing additional content that will help students acquire the relevant knowledge and will also provide training to the academic staff.

4 SUMMARY AND ACKNOWLEDGMENTS

This paper is presenting the process of development and the main features of a new programme in Engineering & Entrepreneurship launched by a British university. This model consists in an entrepreneurship initiative pursued independently by the engineering department, supported by the university's innovation and business support team, and by external partnerships with entrepreneurship centres based in schools of engineering. The main drivers that have motivated the university's engineering department to create and launch this programme are also described. The authors would like to acknowledge the continued efforts of their colleagues in working towards successful delivery of the new Engineering & Entrepreneurship programme.

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Using Moodle data for early warning of dropping out

S. J. Suhonen[1]
Tampere University of Applied Sciences
Tampere, Finland

H. Kinnari-Korpela
Tampere University of Applied Sciences
Tampere, Finland

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Keywords: Learning analytics, Moodle, dropout

ABSTRACT

Dropout rates are high in engineering education throughout Europe. According to interviews, the main reasons were life situation, learning or studying difficulties, wrong field of studies and health problems. The interviewees would have hoped more support and guidance during their studies and 70 % of the dropouts were very interested to continue their engineering studies. Sometimes support at the right time to right students might solve the problem and studying would continue normally.

How to find those students that are at risk of dropping out? Single teachers might notice absences, but they don't have the whole picture. Study counsellors need to rely on the course completion data on the transcript of records, which is always delayed weeks or months in comparison to the studying actions and possible problems in it. Therefore, not even the study counsellors have a real time view to the student progress.

Many higher education institutions use digital learning management systems (LMS) like Moodle to deliver their online, blended and face-to-face courses. Students leave digital footprints on the platform and this tells about studying habits. Therefore, LMS data has the potential to show decrease in learning activity well before it becomes visible elsewhere. In this study, two engineering student groups are followed during one academic year covering both simultaneous and consecutive courses. With the data, a simulation is run to raise an alarm if a student is at risk of dropping out. These alarms are then compared with the real dropping out information of the groups.

[1] Corresponding Author
S. J. Suhonen
sami.suhonen@tuni.fi

1 INTRODUCTION

Education is largely seen as a key element for a successful life, better income and usefulness as a citizen in society. In the Europe 2020 strategy [1], one of the goals is to increase the percentage of higher education graduates to 40 % in the age group 30-34 years old people. There is still work to be done, as can be seen in Table 1. The table shows course completion rates in some of the EU countries according to the European Commission main report “Dropout and Completion in Higher Education in Europe” [2].

Table 1. Course completion rates in higher education in some EU countries according to 2015 report. [2] * The data from Germany is from 2005

Country	Course completion rate
UK	82 %
Denmark	81 %
France	80 %
Germany	77 %*
The Netherlands	72 %
Czech Republic	72 %
Poland	62 %
Norway	59 %

This paper focuses on the dropouts in engineering degree programs in Finnish universities of applied sciences. Some insight to the situation regarding graduation and dropout can be seen using “Vipunen” data portal. It is education administration's reporting portal operated by The Ministry of Education and Culture and the Finnish National Agency for Education. According to the data available in “Vipunen” [3], the percentage of graduates in ICT engineering after 6 years of studying is 43 %. In engineering the average is 54 % and the average of all fields of studies in universities of applied sciences is 61 %. Figure 1 shows the percentage of engineering students who has earned a degree in their first field of studies (blue line) and in any field of studies (dotted red line) as a function of study year. The nominal graduation time is 4 years in engineering. Clearly, it is worth putting an effort on the helping of the students that struggle in their studies and are in danger of dropping out. It is no wonder that European Commission in their main report suggests institutions to monitor pathways of individual students to identify students at risk of dropout. [2].

The dropout problem is not new. Already in the 50’s there were studies about the influence of student’s personality factors and socio-economic background on the academic success and models were built to understand the nature of dropping out [4-6]. It was pointed out that one should differentiate the dropouts according to the reasons: failure in studies, lack of motivation, voluntary change of studies, health reasons etc.

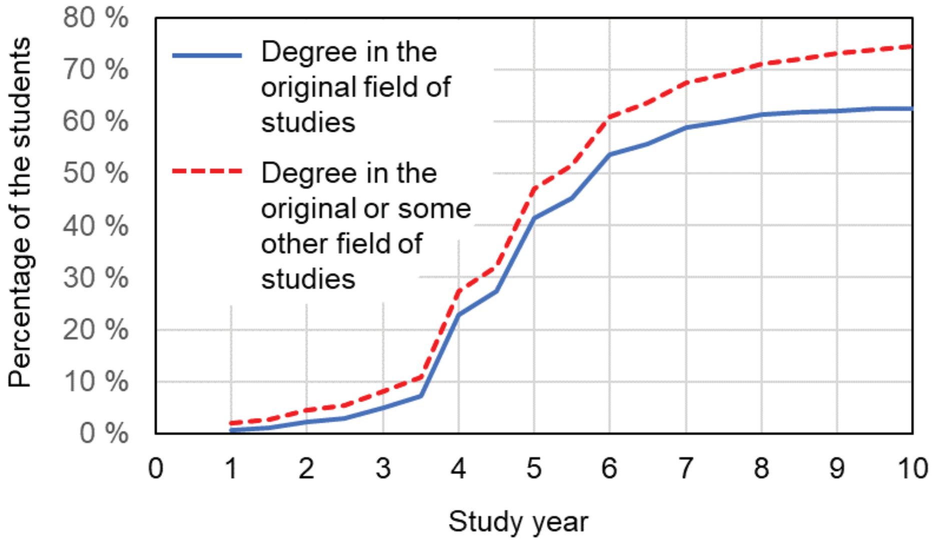

Fig.1. The percentage of engineering students who has earned a degree in their first field of studies (blue line) and in any field of studies (dotted red line) as a function of study year. The data is the average over years 2002-2015 and concerns Finnish universities of applied sciences. Data is from "Vipunen" [3].

Nowadays higher education institutions use digital learning management systems (LMS) like Moodle to deliver their online, blended and face-to-face courses. Students leave digital footprints on the platform and this tells about studying habits. There are studies in which LMS data, like number of logins, number of posts to discussion forums, material openings etc., are used to build predictive models of student success [7-9].

When trying to offer guidance and help to the students at risk of dropping out, the first challenge is the same irrespective of the underlying reason: How to find those students that are at risk? Some universities have built student dashboards and signal-lights for visualizing course attendance. The results for example from Purdue University are very promising: the course attendance has increased and the student feedback about the system is rather good [10]. In the universities of applied sciences in Finland, there is not yet such a system. Therefore, some teachers might notice student absences, but they don't have the whole picture. Study counsellors need to rely on the course completion data on the transcript of records, which is always delayed weeks or months in comparison to the studying actions and possible problems in it. Therefore, not even the study counsellors have a real time view to the students' progress.

This paper shows a case study of using Moodle log file data to recognize the students that are at risk of dropping out. The aim is not to build any predictive model of student success but rather find as easy way as possible to find those students who are at risk. After recognizing these students, it is time for interventions, help and guidance, of course, but those are not on the scope of this study.

2 COURSES AND DATA IN THIS STUDY

2.1 Courses

Two bachelor's level engineering degree programs in Tampere university of applied sciences were chosen for this study: laboratory engineering and ICT engineering. One student group from each program was investigated. The students had started their studies fall 2016 and their studying activity was tracked from the beginning of their studies until December 2018.. From their curricula, several courses, both consecutive and simultaneous, were selected for this study. All these courses are taught face-to-face but they utilize also Moodle using a blended learning approach. The aim was not to include all possible courses to the study, but rather see if it is possible to find students at risk using some key courses as indicators. The selected key courses are mostly mathematics and physics – topics that students sometimes find difficult. The degree programs, selected courses of which the Moodle data is gathered, and course timings are shown in Table 2.

Table 2. The degree programs, courses and their timings.

Program	Courses	Timing
Laboratory engineering	Mechanics	1^{st} year autumn
Number of students: 36	Analytical Chemistry	1^{st} year autumn
	Basics of Measuring and Reporting	1^{st} year autumn
	Working English for Engineers	1^{st} year autumn
	Physics lab. Course	1^{st} year spring
	Electrostatics and Magnetism	1^{st} year spring
	Oscillations and Wave physics	1^{st} year spring
ICT engineering	Geometry and Vector Algebra	1^{st} year autumn
Number of students: 47	Functions and Matrices	1^{st} year autumn
	Differential Calculus	1^{st} year spring
	Integral Calculus	1^{st} year spring

2.2 Moodle data

When a student clicks an object on Moodle page at the main level of course's page hierarchy, a time stamp data is generated to the log file. Therefore, many of the actions a student take, generate a digital footprint. However, learning takes place naturally also outside Moodle. And courses differ from each other quite a lot in structure and Moodle usage. The time stamp data contains the basic information of the action: who did it, when did it happen and what was the clicked object. Perhaps the simplest possible quantity describing student's overall activity is the number of these log events. This can be easily derived from Moodle. It can be argued that the number of log events doesn't tell about learning and somebody can just play to be active by clicking randomly around in Moodle page. These claims are true, of course. Nevertheless, previous studies have shown that the number of log events really tells about the studying habits and student's intention to study [11-13]. On the other hand, the lack of log events certainly tells that a student is not doing the intended learning tasks in Moodle.

In this study, the sum of log events of courses listed in Table 2 was calculated for each student. Due to sickness, holidays, work or other reasons, students sometimes are absent from the university for short periods of time. In this study, a three-week sliding average of the log events was calculated to even out the effect of such short absences on the log data. The weeks included in the data were 35-49 for autumn semester and 2-17 for spring semester. This sliding average of the sum of log events works as a warning signal: if it goes to zero for somebody, that student is hypothetically at risk of dropping out and an intervention would be launched.

The data in this study looks backwards to 2016 and thus the analysis works as a simulation to find out how this chosen parameter works. An example of the data is shown in Fig. 2 showing the Moodle activity in individual courses and also the three-week sliding average for A) a normally studying student and B) a student who has difficulties in studies.

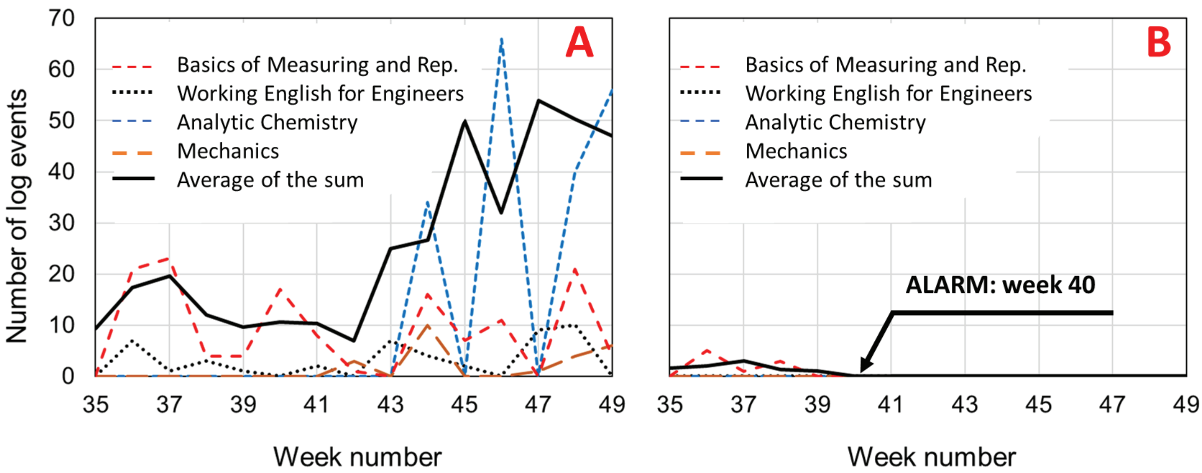

Fig. 2. Moodle activity in individual courses and the calculated three-week sliding average for A) a normally studying student and B) a student who has difficulties in studies. In the simulation student B would have risen an alarm at week 40, 2016.

The courses differ in their Moodle usage and the individual course curves thus differ from each other quite strongly as can be seen in Fig. 2. Nevertheless, the sliding average of the sum of the log events doesn't go to zero for the normally proceeding student. The figure 2B shows data of a student who has difficulties in studying. Clearly, even the overall activity is small, and the sliding average goes to zero at week 40. For this student, the simulation rises an alarm at week 40, 2016. All the students are analysed in the same way and categorized either as "studies normally" or "At risk, alarm: week X"

3 RESULTS

The results of the simulation are summarized in Table 3. The number of alarms in laboratory engineering student group was 10 (26 % of the students). When the progress of these students was examined, it turned out that seven of those 10 were actually dropped out of the university, one was temporarily non-attending and two were studying normally. The coverage of the alarm was 100 % since all the actual dropouts of the group launched an alarm in the simulation. On the other hand, there were two false alarms.

In the ICT engineering group, the number of alarms was much higher, 22 (47 %). This was expected since it was well known that the dropout problem was the biggest in ICT among engineering degree programs. In this "at risk" group, 10 students had actually dropped out, one was temporarily non-attending, one raised a false alarm and five were incoming students. These five were coming from outside the original student group and they had changed either institution or study program. Because of their prior studies they didn't participate in the courses chosen for this simulation and were thus categorized as "at risk". Then there are still five others, who are marked in the table with "other reason". It turned out that these students were present in the university, but they were not actually studying, and their amount of credit units earned was very low in comparison to the nominal amount of credits. This is visualized in Fig. 3. Again, the coverage of the alarm was 100 %. In this student group, of those 22 who rise an alarm, "only" 10 had dropped out. Of the remaining 12 alarms 11 were relevant since those students were special in some way: either non-attending, institution changers or slow in studies. One of the alarms was totally false.

Table 3. The summary of the simulation results.

Laboratory engineering student group:	
Number of students:	37
Studies normally	27
Students a risk:	10
Dropped out	7
Non-attending	1
False alarms	2
Warning coverage:	100 %
ICT engineering student group:	
Number of students:	47
Studies normally:	35
Students a risk:	22
Dropped out	10

Non-attending	1
Incoming students	5
Other reason	5
False alarms	1
Warning coverage:	100 %

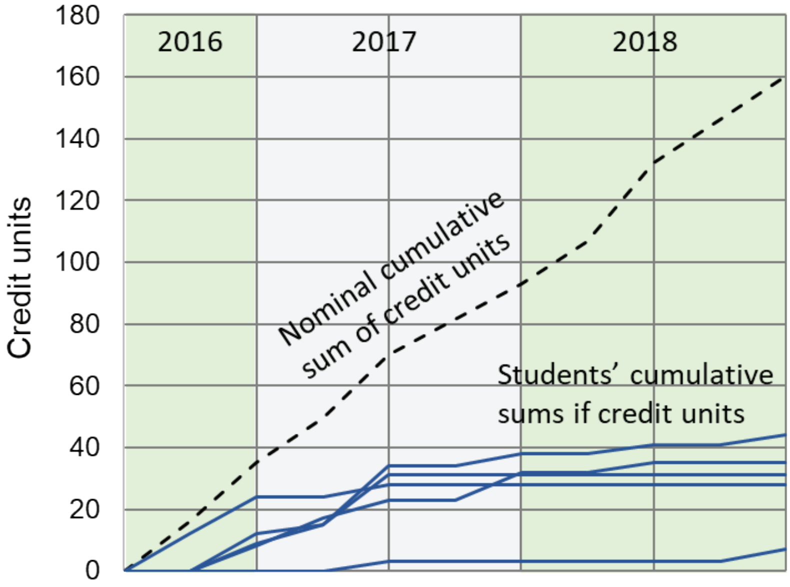

Fig. 3. The cumulative sum of credit units from autumn 2016 to the end of 2018 for those five students ("other reason"), who triggered an alarm.

As an output, the simulation/analysis gave those weeks when students were identified to be at risk of dropping out. Of those students, who had actually left university, the drop-out date was also taken from the transcript of records. The time differences of these dates are shown in Fig. 4. for all 17 students.

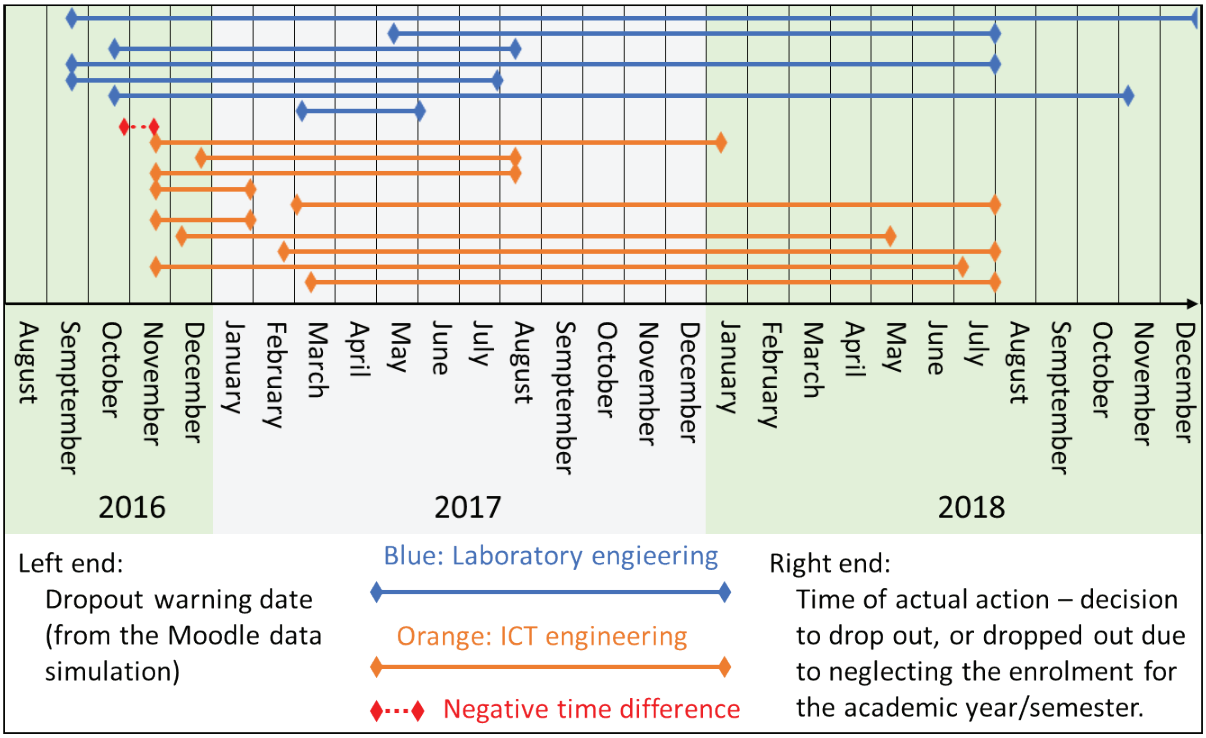

Fig. 4. The time differences between the alarm date and actual dropout date for all 17 students who triggered an alarm and had later dropped out.

It is clear that the studying activity goes down to zero in Moodle much earlier than the students take any actions or decide to stop studying and leave university. Such actions typically happen/occur before these students are detected in the university guidance process. Some of them "drift away" due to neglecting the enrolment for the semester. In this study, the decrease in studying activity was detected in Moodle data averagely 13 months earlier than actual drop-out happened.

4 DISCUSSION AND CONCLUSIONS

The results clearly suggest that the number of events in Moodle log can be used as a measure of student's activity and to identify those at risk of dropping out. The decrease in activity can be noticed much earlier in Moodle than in transcript of records or as student's actual dropout decision. The time difference in this case study was 13 months on average from the "at risk"-warning to actual dropping out.

Dropout rates are high in engineering education throughout Europe. In Tampere university of applied sciences, students were interviewed to find out the underlying reasons. According to interviews, the main reasons were life situation, learning or studying difficulties, wrong field of studies and health problems. The interviewees would have hoped more support and guidance during their studies and 70 % of the dropouts would have been interested to continue their engineering studies. This emphasises the need to find those students who are at risk as soon as possible.

Then appropriate interventions need to be launched for example by the study counsellor or tutor. However, the interventions were not in the scope of this study.

5 ACKNOWLEDGMENTS

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Attracting (female) adolescents into STEM studies – where's the beef?

J. Suviniitty[1]
Aalto University
Espoo, Finland

M. Clavert
Aalto University
Espoo, Finland

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ABSTRACT

The low number of students studying science, technology, engineering, and mathematics (STEM) has been a cause for concern for the past decades in the Western countries. Furthermore, the student body in STEM has narrowed since the number of female students in STEM fields decreases despite outreach activities. In order for the society to have enough appropriately educated work force, STEM attractiveness and increasing it is the focus of this concept paper.

Although the lack of interest in STEM studies has been analyzed widely, we still have not been able to attract more (female) adolescents in STEM fields. Furthermore, previous research has shed light on the variety of STEM outreach activities, but the effects of these activities are not definitive. These concerns are common also in the Nordic countries, which has led to establishing an Erasmus+ Strategic Partnerships project 'Engineering Nordic Future' in 2018. One of the focus areas of the project pertains to the ways of attracting adolescents into STEM studies.

As part of this project, the present literature review identifies the key features that contribute to the effectiveness of STEM outreach activities. The analysis focuses on K-12 activities targeted for (female)[2] adolescents. The resulting model provides criteria for improving the effectiveness of current STEM outreach activities. The criteria may be applied to evaluate the impact of university-led STEM outreach activities and to guide related decision-making.

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[1]J. Suviniitty
jaana.suviniitty@aalto.fi

[2] We wanted to focus on female adolescents, but found that the outreach activities are very similar regardless of the participant gender and, therefore, have not limited the activities included in this study based on participant gender (hence, the female is in parenthesis).

1 INTRODUCTION

As we are currently in the midst of the fourth industrial revolution, which entails digitalization, the Internet of Things, smart factories, and other advanced technological processes and entities, our demand for expertise in those areas is ever increasing. Despite this, it appears that students are less attracted to science, technology, engineering, and mathematics (STEM) related majors in tertiary education. Furthermore, especially in the Nordic countries, the number of female students has decreased notably [1].

The careers within STEM majors are quite varied [1] - [2], but the number of students entering STEM studies is stagnating [1]. Although the situation may have slightly improved from a few years back, we still are not producing enough engineers for the needs of the industry [3]. This gap between the graduating engineers and the required expertise has been predicted to be increasing due to the fourth industrial revolution we are experiencing [4].

This concept paper is part of the research conducted by a 2018 established Nordic initiative[3] related to, among other topics, STEM education and its attractiveness. This initiative comprises a consortium with all Nordic countries as participants. The partners at the consortium are the Royal Institute of Technology in Stockholm (KTH) in Sweden, Aalborg University in Denmark, Aalto University in Finland, Reykjavik University in Iceland, Stavanger University in Norway, as well as the Association of Nordic Engineers (ANE), and NORDTEK (a network of the Rectors and Deans of the Technical Universities in the Nordic and Baltic countries). Focusing on the Nordic countries and their STEM education provides a novel view on this issue while the general aim is to construct an online knowledge hub with the latest information regarding STEM education, teaching, and other related issues. Despite the Nordic view, the aim is to gather STEM education knowledge and conduct studies the results of which may be of global use.

Since the decreasing interest in STEM subjects touches all Nordic countries (actually most Western countries), is was deemed essential to form a consortium and use the power of a team to investigate how STEM could be made more attractive and how that information would be disseminated most effectively [5]. Despite many efforts in changing this declining trend of STEM studies, according to Vækstråd [6], these efforts are not enough in order to meet the requirement of qualified staff in 2025, not to mention beyond that.

For all Nordic countries, except Finland, TIMMS [7] and PISA [8] results have caused serious concerns regarding young people’s performances in science and technology subjects. Despite the fairly good results for Finland [7, 8], they also have declined from the past results. According to some studies (e.g. [9, 10, 11]), poor performance often correlates to low interest for a field, and the fact that our students’ performance is decreasing is a cause for concern. In addition to this, a recent study on how higher

[3] For further information on this initiative, please see nordenhub.org

gender equality, such as present in the Nordic countries, correlates with fewer women choosing STEM fields [12]. Naturally, we do not aim at inequality, but need to find other ways to increase STEM interest in adolescents and females. One of the goals of this Nordic initiative is to present concrete strategies on how to increase the performance and interest in STEM as well as how to enhance the interplay between upper secondary level and university level in order to increase the quantity of young people seeking a career in science and technology.

Although all Nordic countries have several outreach initiatives and programs to enhance the attractiveness of STEM education, see, e.g. [13]-[15], it is still not clear what factors are crucial to achieve positive, measurable, long term effects of these types of activities. The aim of this subproject is to focus on the importance of well-organized and inspiring STEM outreach activities at upper secondary level and how the Nordic countries have succeeded in correlating STEM at the upper secondary level with engineering education and vice versa.

Since STEM subjects and their studying is essential for our future within Industry 4.0, the attractiveness of STEM has been explored already for decades. These studies have looked at, for example, outreach activities and their influence [16], gender bias among STEM [17], parents' level of education [18], pre-university engineering education [19], the transition from secondary education to tertiary education [20], and finally even peer influence on academic involvement [21], to name just some of the approaches to this important topic. Building on previous studies on STEM outreach activities, this study aims to identify which elements contribute in the effectiveness of STEM outreach activities, i.e. *where's the "beef"* in these activities.

2 PREVIOUS STUDIES ON STEM OUTREACH

Although the outreach initiatives have been studied to great lengths, the exact impact of any such program defies measuring. We can use pre- and post-tests to collect varying data and we can obtain information on participants attending the offered activities. The influence of outreach activities is only one piece in an adolescent's life where teachers, peers, and home also impact on the path adolescents choose after secondary level [22]. Qualitative studies on outreach activities would require quite notable efforts and the survey questions/interviews would have to be thoroughly planned in order to obtain the appropriate information on these activities and the views of the participants on them.

Being attracted to STEM studies requires interest, which is a spark to (internal) motivation and both motivation and interest are necessary to accomplish just about anything [23]. Therefore, finding ways to increase interest in STEM studies should in turn motivate students to pursue studies and careers in STEM fields. The present paper is an initial study on STEM outreach initiatives and it aims to identify elements in outreach initiatives that can be seen as those increasing the attractiveness of STEM.

3 METHODOLOGY

To identify the elements that constitute the effectiveness of STEM outreach activities, a literature review of 37 articles was conducted. The studies included in the analysis had to include a clear evaluation of the impact of the activities, i.e., a descriptive study was not enough. Furthermore, studies solely focusing on theory development or different measuring approaches were not included either. Although valuable and informative, also conference proceedings were excluded from the analysis. The excluded 21 studies are provided in Appendix 1.

A total of 16 empirical studies with a focus on the impact of STEM outreach activities targeted to K-12 were selected for the analysis. In these studies, the overall objective of increasing students' interest to study engineering was operationalized into one or more elements of effectiveness. The studies were published between 2001–2018 in the following scientific journals: Journal of Engineering Education (5 articles), Global Journal of Engineering Education (2 articles), European Journal of Engineering Education, Studies in Higher Education, Journal of Higher Education Outreach and Engagement, International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, CBE-Life Sciences Education, Journal of Science Education and Technology, International Journal of Science and Mathematics Education, and IEEE Transactions on Education. The included 16 studies are provided in Appendix 2.

Inductive content analysis (see e.g. [24]) was applied to summarise the informational content of the descriptions related to evaluating the impact of STEM outreach activities on students. The descriptions were categorised according to thematic similarity. The analysis was limited to the empirical part of each study, thus excluding discussion and conclusions from the analysis. Elements that were related to some other target groups than the participating students, such as the facilitators or teachers involved, were excluded from the analysis. The analysis resulted in altogether 17 elements that have been applied in previous empirical studies to evaluate the effectiveness of STEM outreach activities.

4 THE IMPACT ELEMENTS

Out of the total of 17 elements that constitute the impact of STEM outreach activities in previous empirical studies, nine were related to the outcomes and eight were related to the design of the activity. Outcomes referred to the intended and achieved results of the activity, such as learning. Design referred to how the activity was organized, including the teachers, facilities, activities, and equipment. Out of the total of 16 empirical studies included in the analysis, 14 focused on evaluating the outcomes and six focused on evaluating the design.

4.1 Evaluating effectiveness from the perspective of outcomes

In most of these studies, developing understanding of STEM subjects was the main and often the only indicator of effectiveness. *Learning of STEM* resulting from participation in the outreach activity was typically seen as a way of encouraging the students to continue studying these topics. Developing understanding is also relatively easy to measure in relation to the intended learning outcomes. It may also be evaluated by measuring students' *performance in STEM* during or after the outreach activity.

Enhanced understanding of and performance in STEM does not automatically improve students' understanding of their own capability to perform STEM-related tasks. Consequently, evaluation of understanding and performance was often accompanied with of measures of *STEM self-efficacy*. In addition to self-efficacy, evaluating the effectiveness of outreach activities was focused on improving students' *attitude towards STEM,* which is often seen as connected with motivation to study engineering.

Understanding the relevance of STEM was applied as a criterion of effectiveness in reference to both personal relevance and working life relevance. The relevance stemmed from understanding the possibilities of applying engineering to, for example, develop meaningful career paths and tackle personally meaningful challenges. It was also seen to require *knowledge of engineering work*, including career opportunities and different fields of engineering.

While students' knowledge of engineering work may be rather easy to measure, evaluating their *enrollment in engineering studies* after participating in STEM outreach activities often required a longitudinal approach. Further, tracking down the participants' subsequent *engagement in STEM*, such as their participation in additional extracurricular science programs, was deemed challenging. Thus, some studies focused on measuring the participants' aspirations, such as their *aspiration in pursuing a career in engineering,* instead of their actual study choices. To avoid regression of these aspirations over time, the participants should be exposed to several STEM outreach activities during their studies.

4.2 Evaluating effectiveness from the perspective of design

In the design of the activity, some of the studies were focusing on *innovative learning experiences*. These experiences involved student activating hands on learning, exposure to advanced laboratory techniques, participation in hands-on laboratory investigations, clear instructions, informal demonstrations, and overall 'good teaching'. In addition to high quality teaching, the studies emphasized the importance of *interesting and authentic tasks*. In deciding which topics would be interesting for the students to work with, a real-world connection and personal relevance were highlighted. While *enjoyment* and positive atmosphere were explicitly evaluated in two studies only, experiencing innovative learning with authentic tasks was often implicitly aimed at making learning of STEM enjoyable.

When evaluating the effectiveness of STEM outreach activities from the perspective of their design, innovative learning experiences and authentic tasks were often accompanied with *open problem-solving.* Working autonomously with complex challenges exposed the participant to dealing with uncertainty and applying an inquiry approach to learning. On the other hand, some studies emphasized the role of *teacher support*. This category included teacher-student interaction, friendliness of teachers and teaching assistants as well as their availability, knowledgeability and credibility as engineers and scientists.

While teacher support was deemed important, *peer support* and learning from other students and tutors during the process were also evaluated. Peer support could have been critical especially for those student groups, such as young female students, who are often marginalized in the context of STEM studies. For these students, the acceptance of peers could be even more important than the support coming from their teachers.

In addition to the learning process, some studies evaluated STEM outreach activities on how well they provided *information on STEM careers.* Receiving information on career prospects in STEM fields was deemed important for increasing the experienced meaningfulness and usefulness of these studies beyond the immediate course context. This category also involved sharing information on the work of engineers and scientists, engineers' role as problem solvers, and the impact of engineers in the world. Sharing this information could contribute in *fighting stereotypes and misconceptions* related to these fields. This category involved diminishing the perceived psychological and social costs of engaging with STEM, such as being stigmatized as a 'nerd' or a 'geek', and promoting alignment of STEM activities with participants' identity.

The resulting categorization of elements that constitute the effectiveness of STEM outreach activities is presented in *Table 1* below.

Table 1. Elements that constitute the effectiveness of STEM outreach activities

Focus on the outcome	**Focus on the design**
- Learning of STEM [16, 32, 33, 34, 35, 36] - Aspiration in pursuing a career in engineering [32, 33, 34, 36, 37] - Understanding the relevance of STEM [16, 25, 26, 28] - Knowledge of engineering work [28, 32, 36, 38] - Performance in STEM [32, 37, 39, 40] - Enrollment in engineering studies [16, 33, 41] - STEM self-efficacy [25, 31, 42] - Attitude towards STEM [32, 33, 38] - Engagement in STEM [28, 37]	- Innovative learning experiences [25, 26, 28, 41] - Interesting and authentic tasks [25, 26, 28, 37] - Open problem-solving [26, 28, 31] - Teacher support [25, 26, 27, 41] - Information on STEM careers [25, 31] - Fighting stereotypes and misconceptions [25, 31] - Enjoyment [25, 41] - Peer support [26, 27]

As expected, some of the elements are present in the same outreach activities (e.g. [26, 28]) while others are more focused (e.g. [36, 37, and 41]).

5 DISCUSSION

Majority of the outreach activity studies tend to focus on the outcomes rather than on the design of the activities, which has its benefits as the activities often provide information on STEM careers and opportunities while measuring interest in them. Nevertheless, focus on the design aspect would provide teachers and facilitators ideas on efficient ways of organizing various events as well as on what has/has not been tried previously.

The results gathered from the literature included in this study, form an image of multifaceted impact on STEM attractiveness. However, influencing on only one aspect of adolescent lives may not have a desired impact, i.e. more STEM students. At the moment, those students who apply to study STEM subjects, would probably do so despite any outreach activities, parental involvement, or their peers. However, much potential is left untapped if those students whose motivation or interest could be ignited are ignored.

Similar to understanding and learning, the impact of outreach activities is a challenge to measure. It was evident from the studied publications, which were not able to definitively state which elements brought success in increasing STEM attractiveness – at least in terms of adolescents applying to study STEM subjects. Despite the scrutiny of outreach activities, it proves difficult to distinguish those specific activities that genuinely increase student interest for a longer period of time.

Despite the challenging task, the main elements found throughout the articles on STEM outreach activities include authentic, hands-on, real world connection, involvement, and autonomous problem solving in the design end of the activities while in the outcome end interest, motivation, attitude, and understanding are most pronounced.

This literature review outlines a framework of outreach activities and their evaluations and, hence, provides the elements necessary for a successful outreach initiative. As is evident from Table 1, many of the studies focus on similar outcomes and elements. Despite this, differences between the activities and their aims are evident.

These categorizations indicate how, although looking at similar programmes and activities, there still are notable differences in them. This may be one of the reasons why we still do not have the exact answer to what works in an outreach activity and how we could guarantee positive results. When studying human behavior, their aspirations and development, so many elements are involved that pinpointing to one particular one as the influencer would be quite foolish.

Defining the elements influencing STEM attractiveness is not an easy task. Nevertheless, it is an important one and, as the number of students applying to study STEM subjects at tertiary level continues to decline in the Western countries, we need to find the “beef” on how to attract more (female) students to study STEM subjects.

Most outreach activity studies focus on the outcomes of the outreach initiative and the most typical study includes pre and post-tests of some sort, naturally collected before and after the organized event or activities.

Impact studies are rare and it is also rare to find an article in any of the higher ranking journals. Potentially these two facts are related and if so, the situation begs for a change. Our societies rely on adequately educated people with further technological advances waiting to appear when we least expect it. We do not want the industry to be handicapped due to missing qualified personnel. If the future engineers are to save the world, the engineering educators are responsible for attracting enough students in order to educate them to do so.

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From Restricting Competencies to Diversifying Competencies:
Sustainable Development and its Implications for Competency-Based Approaches to Education

Brad Tabas
Associate Professor
ENSTA Bretagne
(EA 7529) Training and Professional Learning

Klara Kovesi
Associate Professor
ENSTA Bretagne
(EA 7529) Training and Professional Learning

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ABSTRACT

This text proposes a new paradigm for thinking about competency-based education derived from an extended reflection of sustainable development as a wicked problem. It suggests that current approaches to thinking about competences are ill-adapted to dealing with the challenge presented by sustainable development, and based on this conclusion it argues that we need to move from what it calls restricted thinking on competences to diversifying thinking on competences.

1. INTRODUCTION

Sustainable development is one of major challenges confronting the future of humanity. It is also of particular relevance to engineers and other technologists. This is because:

1.1 Many of the major environmental issues of today are by-products of the technological transformations that engineering has brought about, and future technological development along the same pathways can and will worsen many current social and environmental issues.

1.2 Despite all of the failures and shortcomings of technological progress, there seems to be no alternative to technology but more, better, and different kinds of technological innovations.

In other words, engineers are both actors in creating the current unsustainability of the modern age and key agents towards realizing any future sustainable society.

The particular relevance of sustainable development to engineers means that sustainable development is also a major concern for engineering education. The following pages will take up one aspect of this reframing of engineering education, with a particular focus on the popular educational model of competency-based thinking. The argument presented below has two parts. The first argues that that competency-based thinking as it is currently understood is ill-adapted to the task of training engineers to possess the innovation mindset necessary to confront sustainable development. The second section offers some suggestions as to how to reformulate competency-based thinking, which we call moving from a restricted competencies paradigm to diversified competencies paradigm, illustrating both the nature of this shift in perspectives and some of the practical implications of undergoing such a shift.

2. COMPETENCY BASED EDUCATION AND THE PROBLEM OF WICKED PROBLEMS

2.1 Competency-based Education

Competency based education is built upon the notion that we can specify, inculcate, and test the skills and competencies required to be counted as competent in a given field (Klingstedt 1972: 7). Within the conceptual framework of a competency-based approach, engineering educators aim to specify the skills that engineering graduates need, and to tailor the training that they receive to make sure that they possess these skills upon graduation. In order to determine these skills engineering schools can address themselves to employers, obtaining information from them concerning engineering jobs and the skills needed to complete them. This vision of education is obviously well-suited to a conception of engineering education in which the expressed objective of engineering schools is satisfying the demands of industry with static and well-known needs. This approach is currently being applied to rethinking engineering education to deal with the challenge of sustainable development (see, for example Wiek et al. 2011). Unfortunately, competency-based approaches, at least as they are currently understood, are poorly adapted to training people to deal with problems like sustainability. The reason for this has to do with the impact of wicked problems like sustainability on our ability to isolate key testable skills.

2.2 Wicked and Tame Problems

The term wicked problem was introduced by Horst Rittel and Melvin Webber. They used this idea to explain why many neat technical solutions to socio-technical problems fail, noting that these problems cannot be solved in the way that ordinary, “tame” scientific problems can be. Tame problems are ones where the problem itself is well and clearly defined, both in terms of the elements concerned and the solutions that might be considered acceptable. Wicked problems, to the contrary, are highly-complex and poorly defined, with their proper formulation itself being subject to controversy. Rittel and Webber list ten characteristics of wicked problems, which unfortunately we will go into here due to time constraints.[i] The essence of any wicked problem is that it has no definitive formulation and no definitive solution.

2.3 Sustainable Development as a Wicked Problem

Sustainable development has often been framed using what Elkington (1999) has called the “triple bottom line”: economy, environment, and society. Framing sustainability as a triplicate balancing act can make it look like a tame problem. Yet let us consider a supposed solution to a sustainability related problem to see how and why the problem is much more wicked than balancing the triple bottom line may make

it seem. “Smart” everything seems to be the answer given by many to the current problem of sustainable development. With smart factories, smart agriculture, smart cities and so on, people argue that companies will be able to balance the profit motive with economic and social responsibility. Yet let us look at this answer more closely.
A smart factory can increase efficiency and thus lower costs and reduce waste. This is both economically interesting and ecologically interesting. Given the lowered production costs and increased production flexibility, more consumers can get cheaper access to better products. Thus Industry 4.0 may seem like a win-win-win situation from the point of view of the triple bottom line. Yet if we look at the same phenomenon within a slightly longer time-frame or feedback loop these victories appear ambiguous. While smart factories can lower the relative environmental burden of continuing on the same path, the flexibility and lower production costs that they promise are likely to stimulate and expand the culture of consumption. It has been noted, for example, that markets do not respond to decreases in the cost of oil by saving their money and consuming less, but rather by taking the money saved and consuming more, thus yielding a net loss in long-term environmental sustainability. While this may not necessarily be an outcome of Industry 4.0, it is certainly a possibility. From a social point of view, the improved quality of social life that will come from access to cheap and high-quality consumer goods may also be accompanied by job losses as human workers are replaced by computerized systems (see MacAffee and Brynjolfsson 2014). Once again, the apparent solution shows itself to raise further problems.

This kind of uncertainty and complexity with respect to possible solutions is characteristic of wicked problems. More to the point, attempting to approach such problems as if they could be solved by neatly balancing an equation actually draws attention away from the real complexity of the problem.

2.3.1 Super Wicked Problems

Sustainability has been classified not only as a wicked problem but as a super-wicked problem by some observers. Levin et al. (2012) add the adjective “super” to denote wicked problems that are also existentially urgent.[ii] In other words, failure to address sustainability, or addressing it poorly, can lead to collapse. Failing to take sustainability seriously by accepting pseudo-solutions will increase the risk of collapse by stifling or delaying other forms of more adequate action. Pedagogically speaking, the risk is training students who mindlessly believe that they have solved a problem without seeing the additional risks created by their partial solution.

2.4 Solving Super Wicked Problems?

2.4.1 Adequate Solutions

Wicked problems cannot be solved, though they can be approached in ways that are better or worse, more or less sensitive to the complexity of the problem, its gravity, and its difficulty. To say that a problem is a wicked problem does not thus condemn us to nihilism, but to the recognition that one-size-fits-all solutions won’t work, and that the success of any solution will only become apparent within the timescale of a long feedback loop. One could say that an adequate solution to the problem of sustainable development would be one that future citizens could look back on and feel that had positively benefitted the becoming of the form of life that they currently enjoy. But they would not see that solution as definitive or without compromises. Any response to a wicked problem will most likely require continual revision through ongoing monitoring and innovation.

2.4.2 Paradigm Shifts?

Generally speaking, wicked problems are open to many different ways of posing, and thus addressing the problem, and sometimes the ability to reformulate problems can be as important as the ability to solve them. Drawing on the philosophy of Thomas Kuhn, we might say that wicked problems are not so much solved, as resolved through a paradigm shift. A paradigm shift would initiate new ways thinking about the same issues, even if these would be (following Hacking (1983)) “incommensurable,” in the sense that the old problems and paradoxes would no longer matter. Bringing about a paradigm shift in the domain that we currently call sustainable development—for instance, by replacing the triple bottom line with another and more subtle tool for thinking about posing sustainability problems—might also be understood as a key skill.

2.5 Super Wicked Problems as a Problem for Thinking about Testing Competencies

Is it possible to rethink competency-based learning to deal with super wicked problems like sustainability? A first response would have to be no: Testability is at the core of competency-based learning, and the very idea of testing someone’s ability to solve a problem that no one can solve is nonsense. It is equally problematic to think that one can test the ability to find innovative solutions in the same way that one can test the ability to solve sums, or the ability to create problem re-framing paradigm shifts in the way that one deduces a formula from a word problem. Confronted with wicked problems the strategy of isolating a set of key skills is doomed to failure. This lack of fit between typical approaches to competency-based learning and super wicked problems like sustainability is clearly recognized by Lonngren (2017). She makes a serious attempt to adapt the competency-based approach to wicked problems by focusing on testing the ability to “address” wicked problems rather than solve them. According to her, addressing capacities can be assessed (though only qualitatively and subjectively). She thus feels that we can establish a limited set of “assessment competencies.” This view is flawed, however, as any ability to assess a problem assumes a point of view on that problem. But what paradigm shift is, is an innovative viewpoint on a problem, and thus a new range of assessment competencies. This brings us to the hard truth about wicked problems: whenever we try to find a limited and simple set of criteria for solving them we end up obscuring the complexity of the problem and impoverishing our student’s by selling them skills that only pseudo-resolve pseudo-problems.

3. From Restricted Competences to Diverse Competences

Our response to this frustration is to shift our thinking. Rather than asking which approaches are necessary for all students, we can ask how we can form more approaches, skills, and competences among all of our students, without necessarily demanding of ourselves that we know which competences these will be in advance. I call this perspectival shift the movement from the restricted competences paradigm to the diverse competences paradigm. Within the diversification of competences approach to competency-based education, the aim is not to inculcate a limited set of key competences, but to discover how to foster as many, and as different, competences as possible among the students in any given engineering program.

Here are some reasons why such a shift might make sense from the point of view of reforming engineering education to deal with a complex problem like sustainability. The more assessment competences applied to any given wicked problem the better. Actors approaching the same problem with different competences will propose different solutions, the combinations between which will almost assuredly yield further innovations. Different competence portfolios will also yield different ways of framing problems, and so will also heighten the likelihood of paradigm shifts. All of this has been demonstrated both via computer models and empirical experience by Page (2004).

Admittedly, this vision of diversification, which aims to increase competence-diversity rather than to reduce competence-diversity towards the expression of a restricted set of recognized key competences, obviously calls for a significant complexification of our reflections on the engineering curriculum, and some revisions in the ways in which we might imagine the future of engineering practice.

3.1 Diverse Competences and Diversity Bonuses

Within the restricted competences approach, one defines a singular image of the engineer and delimits a single set of relevant and well-defined competences. The diverse competences model takes as its paradigm case a collective that will work together to accomplish things that none of them could do individually. A team-based approach to problem-solving is something that research has shown to be a major driver of innovation—providing it is carried out correctly (Sawyer 2007). As Page (2018) explains, cognitively diverse groups benefit from a “diversity bonus” when dealing with highly complex problems. What he means by this is that diverse groups are able to find more perceptive and innovative solutions to complex problems than either individuals or homogenous groups of individually highly competent individuals because diverse collectives can see and do different things by using their differences. The explanation for this phenomenon is that meaningful competence diversity amounts to the possession of diverse perspectives, knowledge bases, and problem-solving heuristics which have been shown to be the key ingredients in innovative teams (Livermore 2016). That said, the diverse competences approach could be applied at an individual level, with schools aiming to foster as many competences as possible. This is one of the possible outcomes of a making-centered curriculum such is found at Olin College, for the openness of creative learning allows each student to develop situation-specific competences that may be other than those anticipated by instructors.

3.2 Meaningful Diversity

If the aim of sustainability-driven engineering education is the diversification of competences for the augmentation of wicked problem-confronting capacity, it is nevertheless true that not just any diversity and difference is meaningful. Some differences are what might be called superficial, while others might be classified as irrelevant. Complexity scholars such as Wolfram (2002) situate complexity between simplicity and the mangle of randomness, with a mangle offering—in opposition to a complex system—no apparent structure. In this light, it is useful to consider what might be a meaningful basis for thinking about how to generate complexification and diversification within a curriculum as opposed mere mangling. One obvious candidate for fostering competence diversification is input diversity. It is likely that upon hearing the word diversity one imagines differences like gender, race, class, and physical ability. Yet it can be argued that input diversity that is not coupled with a concerted attempt to stimulate output diversity will not yield meaningful differences. To the contrary, as diversity scholars have argued, one size-fits all approaches to education often yield both less diversity and less functional teams as minority students strive to repress their differences. Of course, input diversity does contribute to output diversity, but only if effort is made to foster and value differences that make a difference—to promote inclusion, which is to say both an appreciation for and stimulation of competence diversity.

3.3 Multiple Intelligences as a Diversification Principle

The benefit of diversity for problem solving comes from the fact that members of diverse groups have what Page (2018) has described as a diversity of “cognitive repertoire.” Abstractly then, it makes sense to make differing cognitive types the foundation for the competence diversification of engineering education. This is not because this is the only source of difference—but because one cannot include ethnic heritage, sexual persuasion, or other sources of upstream diversity within a curriculum.

By cognitive types we are referring to what Howard Gardner (2006) has described as “multiple intelligences,” which on his categorization include eight diverse kinds of minds: linguistic, logico-mathematical, spatial, bodily, musical, interpersonal, intrapersonal, and naturalistic. The traditional vision of the engineer, and almost all lists of engineering competences currently proposed, primarily focus on logico-mathematical competences. However, at the highly-innovative Olin College, Gardner’s theory of multiple intelligence has been adapted (and streamlined) to yield what they call the “whole” engineer, who knows how to harness the Analytical mind, the Design mind, the Linguistic mind, the People mind, the Body mind, and the Mindful mind (Goldberg and Sommerville, 2014). The aim of a diversifying curriculum would be to help each student go farther in their expansion into the kind of mindedness that fits them best, using problem-based approaches adapted to exploring and expanding their specific kinds of mindedness.

Future engineers would thus possess not only a technical specialization, but also a high degree of cognitive individualization. Such diversification can only function, of course, within the context of a standing and broad-based commitment to diversity and inclusion extending from schools into industry.

3.4 Diversity as Problem

Obviously, aiming to increase the diversity of the cognitive portfolios available within the engineering profession will create challenges at many levels. Diverse teams are sometimes conflictual and poorly-functioning (Livermore 2016). Engineers will need to develop the habit of working collectively, and will need to be constantly ready to learn new strategies to deal with the challenge of engaging with and including their diverse team mates, including constantly attempting to understand their own biases (Mor

Barak 2015). Inclusivity here does not merely mean that varying kinds of cognitive profiles are present within teams, but also that differences are valued and permitted to be expressed within the collective output. Minorities often self-censure of their knowledge claims (submitting to what Fricker (2007) has described as "hermeneutical injustice") a practice that will tend to dilute the diversity bonuses available to any group. Understanding how to train diverse kinds of engineers to engage in inclusive collective work while further discovering and expressing their diversity will require research, but it is above all a matter of practice, itself a wicked problem.

3.5 Complexity as a Problem

Yet a challenge to any diversification of the curriculum integrating the stimulation of diversity within a single course or institution. This is a technical problem relating to the means of teaching. The traditional technologies associated with the development of the curriculum—teacher-centered learning, standard text books and the fixed list of required classes which determine the planning of the hours of the school day—are hardly well adapted to generating cognitive diversity. New technologies and approaches, such as adaptive software, project-based learning, and other alternative and student-centered methodologies can be employed to make possible the complexification and diversification of the curriculum without excessively charging already limited institutional budgets.

3.5.1 Project-based Learning

Project-based learning is a low-tech alternative teaching method that is well suited to accommodating cognitive difference and fostering competence diversification. Team projects can be organized in such a way that each member of the team is able to learn to best contribute to the overall task by developing specific skills, knowledges, and viewpoints, learning through doing and expanding outward their initial difference through practice. Within the context of educating for sustainable development, it would obviously be desirable if these projects were sustainability-oriented. A possible weakness of this approach is the fact that improperly guided diverse teams may well function in ways that reinstate existing hierarchies relative to the contributions of diverse viewpoints. A coaching approach will thus be required to aid students to look for the best ways of diversifying their own skills and resisting falling into Irving Janis (1972) has called groupthink.

3.5.2 Smart Learning Approaches

Adaptive artificial-intelligence driven learning tools are able to produce student-centered and difference-driven learning experiences. What advanced versions of such tools might concretely look like remains to be seen, but just as Google and other companies use predictive algorithms to seduce consumers to purchase new goods based upon their past purchases and searches, to too can learning tools propose new lessons and materials to students based upon their aptitudes and past interests. Clayton Christensen (2011) has written about the ways in which innovative forms of computer-based learning can be used to adapt pedagogy to different kinds of learners and learning styles, and differential forms of learner-adapted technologies can be developed to cater to and maximally stimulate both different kinds of learners and different forms of cognitive diversity.

3.6 Evaluating Diverse Competences

As we have stated earlier, evaluation and evaluability are key elements in competency-based approaches to education. While a limited skill set permits standardized evaluations, multiplying the skills and knowledges acquired by students poses problems for those aiming to put into place evaluative frameworks. Among other things, a fully diversified approach to curriculum would mean that the knowledges possessed by learners would be different from those possessed by their assessors. We have already touched on the fact that Lonngren advocates using more-less frameworks rather than binary frameworks for the assessment of wicked problem assessment skills. She is probably right to recognize that diversification will yield more qualitative than quantitative approaches to assessment.

One way of thinking about evaluation would be to focus not on the skills but on the qualities of the outputs of collective projects involving diverse actors. While the evaluation of made objects is a matter calling for holistic appreciations and individual judgment, it would be unfair to suggest that making-oriented education abandons evaluability. Slightly differently, students working with adaptive smart learning systems could be evaluated not on their specific outputs but on depth of the path that they have travelled. In both cases, the acquired competences may remain a black box to the outside observer. This is no problem, except insofar as it inflicts wounds upon educator's pretentions that total knowledge of a subject is the basis for their authority.

4. CONCLUSIONS

If you are a handyman who has received a call from a client stating that they have a problem, you might spend your time thinking about which limited set of tools you want to bring with you, or to the contrary, you might invest your effort in finding ways to bring a greater variety of tools. If tools and engineers are not exactly equivalent, our suggestion is that many theorists of engineering education opt for the first approach, when we really ought to be opting for the second.

To many, the call for diversity as an approach to dealing with sustainable development that is at the core of this paper may seem reassuring, but the conclusions and general argument may seem radical, disruptive, even disturbing. This text has set out rethink competency-based approaches to engineering education as if meeting the challenge of sustainability is more important than maintaining institutional norms. It has willfully embraced the idea that radical new technologies can reconfigure teaching and learning, heretically suggesting that the teacher can be displaced from the all-knowing center of the learning experience to the position of an accessory or complement to interactions with other learners and smart technologies. From an institutional standpoint these arguments imply that no one administrator will be able to oversee and understand all of the competences being developed within that institution, and that the augmentation of diverse competences, rather than the delimitation of a small set of desired competences, is a good thing. Avowedly, part of the radicality of this proposal is the changes that it demands in the images of the engineer and the educator of engineers. According to the vision presented above, it will no longer make sense to speak of one competent engineer but only of diverse engineers with diverse competences, with the plurality of the profession taken in the strongest sense, given that the practice of problem solving that some might say is the heart of the engineer's métier is here reconceived of as a necessarily collective process.

While the very radicality of these propositions doubtless condemns them to marginality, this communication should be counted successful if it is at very least thought provoking.

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[i] The list that is furnished by Ritter and Webber is as follows:

1) Wicked problems have no definitive formulation
2) Wicked problems have no ends to the causal chains—'no stopping rule'
3) Wicked problems do not have 'true-false' solutions, rather 'good-bad' ones
4) Wicked problems offer no 'immediate' or 'ultimate' tests for a solution
5) Wicked problems mean that every attempt at a solution is consequential
6) Wicked problems do not have an 'exhaustively describable' set or series of solutions
7) Every wicked problem is unique—having at least one 'distinguishing property that is of overriding importance'
8) Every wicked problem points to another wicked problem—each a symptom of another
9) Wicked-problem discrepancies can be explained in multiple ways—each 'choice of explanation determines the nature of the problem's resolution'
10) Wicked problems pose particular problems for those aiming to resolve them—exempting them from the right to be wrong.

[ii] 1.) time is running out
2.) those who cause the problem also seek to provide a solution
3.) the central authority needed to address them is weak or non-existent
4.) irrational discounting occurs that pushes responses into the future

Performance evaluation of university students participating in a simulation game with data envelopment analysis (DEA)

A Tamás[1]
Assistant lecturer, PhD student
Budapest University of Technology and Economics
Faculty of Economics and Social Sciences
Budapest, Hungary

T Koltai
Professor
Budapest University of Technology and Economics
Faculty of Economics and Social Sciences
Budapest, Hungary

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ABSTRACT

Simulation games have an important role in higher education, because their application allows students to test their theoretical knowledge in a risk free practical environment. The learning by doing concept can also be supported by these methods. Simulation games serve several objectives during the learning process. The multitude of objectives requires sophisticated evaluation methods, which are able to analyse the satisfaction of these targets, and are also able to provide an aggregate performance measure for grading purposes. Data Envelopment Analysis (DEA) is able to consider several aspect of simulation game results using sound mathematical methodology which increases the objectivity of the evaluation. Applying DEA for the evaluation of student's performance in a simulation game is a novel area of DEA application. This paper shows how an input oriented constant returns to scale radial model can be used to evaluate the results of student groups in a production simulation game. The paper presents the applied mathematical model, the application environment and summarises the main benefits of this new evaluation tool for grading and assessment purposes.

[1] Corresponding Author
Alexandra TAMÁS
tamasa@mvt.bme.hu

1 INTRODUCTION

The application of simulation games in higher education has become increasingly popular through the last decades. Several studies show that the use of simulation games in engineering education leads to positive attitude towards the subject in which these games are applied and that they present an effective alternative to traditional teaching methods. A large number of papers analyses the impact of simulation games on the participating student and applies various methods for the evaluation of the development of the participants.

In this paper, Data Envelopment Analysis (DEA) is applied for the performance evaluation of student groups in a simulation game. First, the paper reviews the role and application possibilities of simulation games in engineering education. Next, DEA as a method for the evaluation of the results of a simulation game is discussed. The basic concepts of DEA are introduced and the application environment of the presented research is outlined. The production simulation game (Factory Midi from EcoSim) used in the operations management master program of the Budapest University of Technology and Economics is presented and the DEA models proposed for the evaluation of the results of the participating students are explained. Finally, the use of the outcome of the game for course evaluation and the potential insights of the learning process during the game are presented.

2 THE ROLE OF SIMULATION GAMES IN HIGHER EDUCATION

Simulation games embody a new teaching methodology with the aim of helping students to increase their comprehension of course subjects. Used as a pedagogical tool, simulation games complement traditional educational methods and contribute to integrating complex knowledge obtained from different disciplines by following the “learning by doing” philosophy. There is plenty of research dealing with exploring the potential advantages of this method. ([9], [13]) Games can be applied effectively to engage students, motivate them and give them a chance to create a link between theory and real-world problems. [1] They can serve as a method of organized experiential learning, moreover, they may include the element of fun. [8] The chance for immediate feedback helps students to experiment the possible effects of strategy planning and decision making in a risk-free environment, and without real pressure on them. [17]

Among others, Deshpande and Huang [8] surveyed the existing applications of simulation games in engineering education. They collected several simulation game examples reviewing the literature and grouped explored practice according to professional fields. They found evidence of a large amount of applied games in civil, electrical, mechanical, environmental and chemical engineering education. A systematic survey of simulation games used in software engineering education was conducted by Caulfield et al. [3]. Both studies concluded that a large number of games have been developed and used and that as a pedagogical device they are becoming more and more popular in higher education.

For the illustration of the role of simulation games in engineering education, we have collected four application examples at the Budapest University of Technology and Economics.

- Professors of the electric power system laboratory in the Electrical Engineering master's degree program developed an educational framework for the interactive simulation of power exchanges. In the simulation game, participating students play the roles as power plant owners on a single market and they have to compete with each other. The aim of the instructors was to highlight the problems and challenges of the power exchange market and to encourage competition between students to provide an atmosphere similar to the real-world environment. [15]
- In a simulation game used in the Chemical Engineering program, students have to work in groups and plan how to convert the recipe of a specified molecule from laboratory to industrial scale. Besides chemical engineering knowledge, resource planning, time scheduling and the ability of working in a team is also developed during the game.
- The Department of Transport Technology and Economics applies a supply chain simulation game in which students can test their knowledge in a virtual environment as members (manufacturer, supplier or retailer) of the supply chain. Students, acting as companies, have to acquire, stock, produce, distribute and transport multiple products. The main results of the game are that students realized some possible pitfalls in the operation of the supply chains, became familiar with the practical use of the methods learned in theory, practiced presentation techniques and reasoning, furthermore, developed their ability to react quickly under decision making pressure. [2]
- A simulation game is also used in the Service Marketing module of the economic master degree program. During the game, student groups take over the leadership of a virtual hotel and the associated ski centre. Students need to plan a strategy, analyse data and make decisions in order to maintain the hotel's effective operation. With the help of the simulation game, students are able to synthetize knowledge acquired from different subjects related to service management and marketing management and they gain a virtual leadership experience as well.

We have shown that simulation games are widely used in many fields of higher education and they present an effective alternative or supplement to traditional teaching methods. In line with the fact that simulation games provide students with an instant feedback on their performance, in the rest of the study, a new method of the assessment of student's performance will be discussed. The following chapters present how Data Envelopment Analysis (DEA), a mathematical-based decision support tool, can be an appropriate method for the evaluation of students participating in a simulation game.

3 THE BASIC CONCEPTS OF DEA

Data Envelopment Analysis (DEA) is a linear programming model that has been applied to measure efficiency in various areas. The method attracted global attention after Charnes et al. [5] published their paper, which first introduced the term DEA. Since then, a number of research has been presented concerning the application of DEA for performance evaluation in financial sector institutions ([16], [18]), in hospitals and in related health services organizations ([7], [10]), of different types of transportation systems ([4], [14]) and it is widely used in the field of education as well ([11], [6]).

DEA measures the efficiency of a production or service system relative to the best performing ones (called peers). The performance measure is the ratio of the weighted output and the weighted input but weights are determined with the help of sound mathematical models. The production or service systems analysed with DEA are called decision making units (DMUs), because they can independently decide on the amount of inputs used. The inputs and outputs applied in the evaluation should be selected properly to express the performance of DMUs adequately. The outputs are such operational results that are important for the decision maker, and thus for evaluation, and DMUs have to make decisions on the amount of resources used to generate them. In stores, for example, the volume of sales, the satisfaction level of customers, the speed of service or the increase in store turnover can be outputs. Inputs may refer to any resource that the management considers to be important and the amount used of them is a determining factor in the evaluation. In a store, mentioned in our example, the number of employees, the size of the shop floor or the logistics equipment and the service personnel carrying out the delivery of the products can be inputs.

The comparison of the DMUs is based on the weighted amount of outputs and the weighted amount of inputs. Weighting is determined by exact mathematical tools based on the characteristics of the DMUs. The ratio of weighted inputs to weighted outputs can be calculated in two ways. If the purpose of the management is to maintain the current value of the outputs but using less inputs, then the sum of the weighted outputs is divided by the sum of the weighted inputs when calculating the value of efficiency. This case is called input oriented approach. If the aim of the management is to produce as much output as possible with the available amount of the inputs, then the sum of the weighted inputs is divided by the sum of the weighted outputs. This is called output oriented approach.

DEA empirically identifies the efficient frontier of a set of DMUs based on the input and output variables. The result is an efficiency score for every DMU, which reflects the rate by which a given DMU could improve its productivity relative to its peers. The highest value of the efficiency score is equal to 1 and the lowest value is equal to 0. It is important to emphasize that the analysed DMUs are only effective or ineffective relative to each other. Based on the data (inputs and outputs) of a specific set of organizational units we conclude that a DMU works well or not. However, this does not mean that theoretically it is not possible to achieve higher performance.

One of the greatest benefits of DEA that it can take into account a number of factors while evaluating performance. Factors, which are measured in different scales (for example net profit, customer satisfaction, speed of delivery) can be aggregated with the help of the weights. This benefit provides the chance to use DEA in many different fields of performance evaluation. A special such application area is the evaluation of students participating in an educational purpose simulation game.

4 EVALUATING SIMULATION GAME RESULTS USING DEA

4.1 Application environment

To apply DEA for evaluating the results of simulation games is a new and promising area. In the simulation game used in this research, student groups form the DMUs, and their relative performance is evaluated. The production simulation game applied in this paper was developed by EcoSim Ltd. to support production management education. The game is used in the *Decision Making in Production and Service Systems* course of the Production and Operations Management Master's degree program at the Budapest University of Technology and Economics. During this program, students have to acquire different skills from different areas of management. Although we used this simulation game to measure the overall production management knowledge of students, decision making required marketing, financial and accounting skills as well. Thus, we evaluate the application efficiency of production, financial and marketing knowledge obtained in the master program as well.

The objective of the game is to simulate production management decision making in a car engine manufacturing factory. The factory produces three different car engines for five different markets in seven consecutive periods. Each market has its own demand characteristics. Car engines are assembled from parts on assembly lines operated by workers. Decisions must be made by each student group for the next production period in the following areas: sales and marketing, production, investment and financial decisions. The simulation program generates the results of the actual production period. Students get a production report and a financial report based on which each student group tries to increase operational performance of the next periods.

Two outputs, cumulated production quantity and net cumulated profit, and four inputs were applied in the analysis: cumulated number of workers, cumulated number of machine hours, cumulated sum of money spent on raw materials, cumulated value of credit.

4.2 DEA models used in the analysis

The study used two input oriented DEA models for the evaluation of student group performance at the end of the 7th period. We assumed constant returns to scale (CRS) relationship between the input and the output values, that is, the size of the input does not influence the marginal change of the output. In the first case, a CRS model was applied without any restrictions. In the second case, a CRS model with weight restrictions (CRS-AR) was used.

The mathematical formulation of the applied DEA model is based on the maximization of the ratio of weighted outputs and weighted inputs. This ratio is the efficiency score. The weights are the variables of the model, and for each student group the best possible weights are looked for. It is assumed, however, that these best possible weights are used by each student group and the ratio of weighted outputs and weighted inputs must be less than 1. If the best possible weights are found for a student group (for the reference group) and it is equal to 1, then the group is considered efficient. If the efficiency score is less than 1, then the car engine production process operated by the student group is inefficient and the sources of inefficient operation can be explored with the help of DEA.

Table 1. List of notations

Indices:	
j	- index of decision making units (DMUs), $j = 1, \dots, J$
i	- index of inputs, $i = 1, \dots I$
k	- index of outputs, $k = 1, \dots, K$
z	- *running index of weights*
R	- index of the reference DMU
Parameters:	
J	- number of DMUs,
I	- number of inputs,
K	- number of outputs,
x_{ij}	- quantity of input i of DMU j,
y_{kj}	- quantity of output k of DMU j,
$L_{z,i}^{\mathrm{INP}}$	- lower limit of the ratio of input weights z and i,
$L_{z,k}^{\mathrm{OUT}}$	- lower limit of the ratio of output weights z and k,
$U_{z,i}^{\mathrm{INP}}$	- upper limit of the ratio of input weights z and i,
$U_{z,k}^{\mathrm{OUT}}$	- upper limit of the ratio of output weights z and k,
Variables:	
u_i	- weight of input i,
v_k	- weight of output k.

Let us assume that J number of DMUs (student groups) are to be evaluated, when K different outputs are observed and I different inputs are used. Notations used in this paper are listed in *Table 1*. We would like to determine the best possible weights for DMU R. If y_{kj} are the observed output values of output k, and x_{ij} are the observed input values of input i for DMU j, furthermore v_k and u_i denote the output and input weights, then the linear programming formulation for finding the most favourable weights for the evaluation of DMU R is as follows,

$$
\begin{aligned}
& Max\left(\sum_{k=1}^{K} v_k y_{kR} \Big/ \sum_{i=1}^{I} u_i x_{iR}\right) \\
& \sum_{k=1}^{K} v_k y_{kj} \Big/ \sum_{i=1}^{I} u_i x_{ij} \le 1 \qquad j = 1,\ldots,J \\
& u_i, v_k \ge 0 \qquad i = 1,\ldots,I; \quad k = 1,\ldots,K
\end{aligned} \tag{1}
$$

If problem (1) is transformed to eliminate the ratio of variables, and the weighted input is fixed (equal to 1) in order to get unique solution for LP problem (1), then the primal version of the input oriented, constant return to scale model is obtained,

$$
\begin{aligned}
& Max\left(\sum_{k=1}^{K} v_k y_{kR}\right) \\
& \sum_{i=1}^{I} u_i x_{iR} = 1 \\
& \sum_{k=1}^{K} v_k y_{kj} - \sum_{i=1}^{I} u_i x_{ij} \le 0 \qquad j = 1,\ldots,J \\
& u_i, v_k \ge 0 \qquad i = 1,\ldots,I; \quad k = 1,\ldots,K
\end{aligned} \tag{2}
$$

In primal model (2), the optimal value of the weights of inputs and outputs are determined by linear programming. Model (2) must be solved for each DMU, that is, at each solution of the model the reference DMU changes. The results are the optimal weights and the efficiency scores of the DMUs.

Frequently, the value of some weights is zero, that is, when the efficiency score is calculated, some inputs and outputs have zero weight. Inputs and outputs with zero weight are ignored in the evaluation, which is not always acceptable for evaluation purposes. To avoid the problem of zero weight, restrictions can be added to model (2). One possible form of weight restriction is when constraints for all possible pairs of inputs and outputs are given,

$$
\begin{aligned}
& L_{k,z}^{(\mathrm{OUT})} \le \frac{v_z}{v_k} \le U_{k,z}^{(\mathrm{OUT})} \qquad k = 1,\ldots,K; \quad z = 1,\ldots,K; \quad k \ne z \\
& L_{i,z}^{(\mathrm{INP})} \le \frac{u_z}{u_i} \le U_{i,z}^{(\mathrm{INP})} \qquad i = 1,\ldots,I; \quad z = 1,\ldots,I; \quad i \ne z
\end{aligned} \tag{3}
$$

Model (2) is referenced in this paper as the input oriented CRS model and Model (2) completed with constraints (3) are referenced in the model as the input oriented CRS-AR (Assurance Region) model.

Weight restrictions are introduced in order to prevent the inputs or outputs from being over-emphasised or ignored in the analysis. In our case the ratio of output weights was 0.25, that is, the role of an output has always at least 25% role in the evaluation. The ratio of input weight pairs was 0.1.

4.3 Comparison of the performance of student groups

In this paper we analysed data produced by 19 student groups (DMUs). We assessed their performance based on the aggregate data of seven decision making periods. *Table 2.* and *Figure 1.* shows the results of the student groups according to the two DEA models. The table shows the efficiency scores calculated on the basis of the two models, while the diagram illustrates the efficiency changes of the DMUs.

Table 2. Efficiency scores

DMU	CRS %	CRS-AR %
1	98,25	82,51
2	89,94	79,28
3	98,59	86,07
4	**100**	**100**
5	93,80	84,53
6	**100**	99,09
7	**100**	**100**
8	86,28	76,27
9	**100**	97,74
10	**100**	95,11
11	**100**	90,00
12	86,53	75,14
13	87,12	72,78
14	98,41	83,06
15	**100**	99,70
16	96,71	81,12
17	87,29	55,72
18	91,11	78,50
19	**100**	96,82

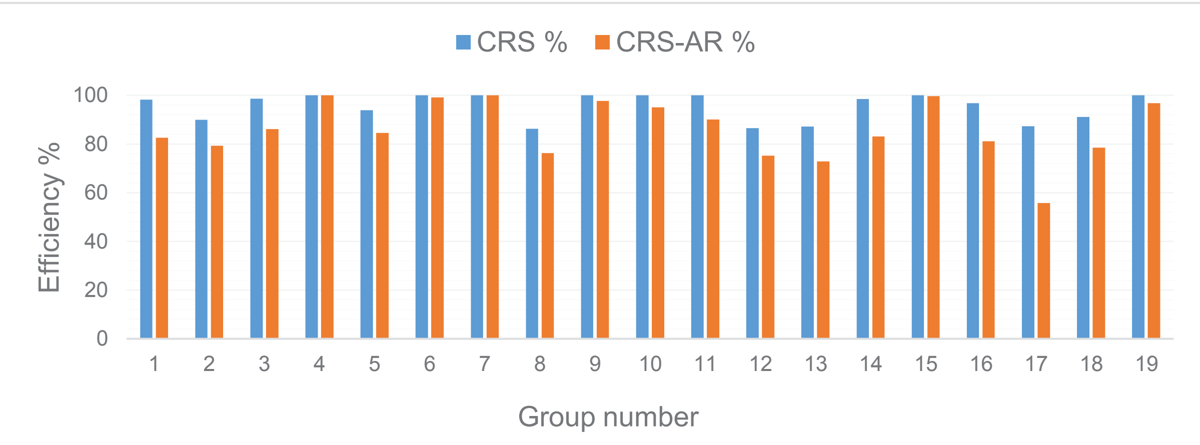

Figure 1. Relative efficiency diagram

The simple CRS model provided eight efficient groups. It means that these teams performed the best during the game, the other eleven groups resulted inefficient. Best performing groups, acting as potential peers, provide the opportunity for inefficient ones to benchmark their activities. For example, the efficiency score of group number 8 indicates that this group achieved an 86,28% performance relative to the best performing teams, that is, it could increase its performance by taking similar steps as its peers. This model shows a relatively balanced competition between the groups, each achieving over 85% performance.

Nevertheless, this balanced trend cannot be observed when using the CRS-AR model. In order to evaluate the performance of the teams without 0 weight on any input or output, we introduced weight restrictions into the model. As a result, none of the factors received too high or too low attention in the analysis, thus, all inputs and outputs were included in each team's performance evaluation. Out of the eight efficient groups from above only two groups (number 4 and 7) remained efficient. In addition, we can notice some relevant set-backs (~15-16%) in the case of groups number 1, 13, 14 and 16, and a huge one (~32%) in the case of group 17. To explain the differences observed between the efficiency scores of the two models we have to examine the basic input and output data and the weights assigned for them (see *Appendix*).

In the example of group 17, it can be seen that while the CRS model yielded an efficiency score above 87%, the CRS-AR model reduced it to almost 55%. Examining the weight data shows that the CRS model assigned weights to only one input and one output, and as a result, the weaker factors were not evaluated in the model. Group 17 produced the lowest net profit of all and used the highest amount of credit. The CRS-AR model put weights on these factors, which significantly reduced its efficiency. The simple CRS model ignored the outlier input and output values with a value of 0 or low weight. The CRS-AR model modified the efficiency data taking into account all factors by weight restrictions.

Table 3. Final results

DMU	Efficiency (%)	Score (points)
1	82,51	21
2	79,28	20
3	86,07	22
4	**100**	25
5	84,53	22
6	99,09	25
7	**100**	25
8	76,27	20
9	97,74	24
10	95,11	24
11	90,00	23
12	75,14	19
13	72,78	19
14	83,06	21
15	99,70	25
16	81,12	21
17	55,72	15
18	78,50	20
19	96,82	24

In order to evaluate students' performance equally, the results generated by the CRS-AR model were taken into account in the final evaluation. Efficiency scores were converted into a score, which is a factor in determining the final grade. Based on the relative efficiencies of the CRS-AR model, scores (or points) were assigned to each student group according to *Table 3*. The maximum available score was 25 points; the minimum was 15. The 10 points between the minimum and maximum value was assigned to students based on a linear transformation of the efficiency scores. The results obtainable from the simulation game represented 25% of the final grade of the course.

5 CONCLUSION

Simulation games have an important role in higher education, because students can test their theoretical knowledge in a risk free practical environment. The learning by doing concept can also be supported by these methods.

This paper listed several examples of the application of simulation games in engineering and management education. To evaluate the performance of participants in these games on an objective way is not easy as a consequence of the several objectives of the learning process. Data Envelopment Analysis is an appropriate tool for considering several evaluation criteria at the same time and for providing an aggregate measure of performance.

The application of two DEA models was presented in this paper to show how the results of a production simulation game can be evaluated. A traditional input oriented radial model was applied first. The results, however, did not contain several evaluation objectives as a consequence of the zero weights found in the results. The application of weight restriction in the assurance region model eliminated this problem and provided a model which expresses better the teaching objectives. The generated efficiency score was directly transformed into grading categories.

The presented application showed that DEA can really be applied for the performance evaluation of students in a simulation game. The analysis of the results demonstrated that careful model selection is required. DEA is based on linear programing, consequently, it is an objective evaluation tool. There are, however, subjective elements of the evaluation as well. The instructor must decide on the important elements of the evaluation process. This subjective element can be influenced by model selection and by the careful parameter setting of the selected models.

The result of DEA is not exclusively the efficiency score, although it is the most important for grading purposes. Additional DEA results, such as the groups of peers, the slack values and the change of efficiency score over time can provide further insights into the learning process (see for example [12]). To explore all the possibilities of DEA in this new area is a topic of our further research.

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APPENDIX

1. Data sheet

DMU	Production quantity	Net profit	Workers	Machine hours	Raw materials	Credit
1	2 988 000	215 200	13 541	2 927 300	5 980 100	2 973 800
2	2 417 100	78 500	10 861	3 005 900	5 076 500	2 258 700
3	3 054 100	756 100	16 265	2 895 800	6 189 500	1 500 000
4	2 757 300	1 961 200	11 747	2 848 500	4 565 000	805 300
5	2 660 900	478 200	11 680	3 066 700	5 416 400	2 025 700
6	2 316 400	1 240 000	10 541	2 594 800	4 524 500	444 600
7	2 809 000	1 711 500	12 166	2 790 200	4 899 200	714 100
8	2 109 500	268 900	10 241	2 717 100	4 195 100	1 138 200
9	3 002 200	1 231 500	12 039	3 505 300	4 713 500	2 885 700
10	3 090 700	870 700	12 229	3 545 500	5 519 400	3 266 500
11	2 466 900	570 600	10 375	2 738 100	4 827 500	906 000
12	2 329 200	120 900	12 791	2 542 700	5 003 500	870 700
13	2 453 400	-59 200	13 341	2 632 500	4 982 200	2 399 200
14	2 621 500	-375 800	10 540	3 423 400	5 739 100	3 213 600
15	3 050 400	1 511 800	13 916	2 851 500	4 833 200	1 029 000
16	2 911 000	184 500	15 521	2 813 900	5 789 700	1 739 400
17	2 112 600	-1 347 500	12 750	2 262 300	4 945 300	4 431 300
18	2 838 500	236 000	13 681	3 046 900	5 920 300	1 757 600
19	3 056 600	1 650 900	14 343	2 971 600	4 799 800	3 586 300

2. Weight values in the simple CRS model

DMU	Production quantity	Net profit	Workers	Machine hours	Raw materials	Credit
1	0,3288	0	0,0398	0,1573	0	0
2	0,3721	0	0,0783	0,0296	0	0,0267
3	0,3228	0	0	0,3453	0	0
4	0,3571	0,0078	0,0561	0,1198	0	0
5	0,3525	0	0,0522	0,1271	0	0
6	0,4317	0	0,0826	0	0	0,2911
7	0,356	0	0,0431	0,1703	0	0
8	0,409	0	0,0906	0	0,0077	0,0349
9	0,3331	0	0,0461	0,099	0,0208	0
10	0,3236	0	0,0479	0,1167	0	0
11	0,4054	0	0,0853	0,0322	0	0,0291
12	0,3715	0	0	0,3169	0	0,2231
13	0,3551	0	0	0,3799	0	0
14	0,3754	0	0,0949	0	0	0
15	0,3278	0	0,0397	0,1568	0	0
16	0,3322	0	0	0,3554	0	0
17	0,4132	0	0	0,442	0	0
18	0,321	0	0,0389	0,1535	0	0
19	0,3072	0,0369	0,0171	0,0354	0,1353	0

3. Weight values in CRS-AR model

DMU	Production quantity	Net profit	Workers	Machine hours	Raw materials	Credit
1	0,2712	0,0678	0,0193	0,1932	0,0193	0,0193
2	0,3254	0,0813	0,0841	0,0084	0,0084	0,0084
3	0,2654	0,0663	0,0189	0,189	0,0189	0,0189
4	0,3079	0,077	0,0219	0,2193	0,0219	0,0219
5	0,304	0,076	0,0785	0,0079	0,0079	0,0079
6	0,3773	0,0943	0,0452	0,0452	0,0452	0,4524
7	0,3089	0,0772	0,021	0,2104	0,021	0,0756
8	0,3504	0,0876	0,0905	0,0091	0,0091	0,0091
9	0,2953	0,0738	0,0575	0,0057	0,0575	0,0057
10	0,2875	0,0719	0,0743	0,0074	0,0074	0,0074
11	0,3449	0,0862	0,0891	0,0089	0,0089	0,0089
12	0,3185	0,0796	0,0227	0,2268	0,0227	0,0227
13	0,2985	0,0746	0,0213	0,2126	0,0213	0,0213
14	0,3286	0,0822	0,0849	0,0085	0,0085	0,0085
15	0,2908	0,0727	0,0109	0,1089	0,1089	0,0109
16	0,2743	0,0686	0,0195	0,1954	0,0195	0,0195
17	0,3138	0,0784	0,0223	0,2235	0,0223	0,0223
18	0,2709	0,0677	0,0193	0,1929	0,0193	0,0193
19	0,2791	0,0698	0,0105	0,1046	0,1046	0,0105

A case of project-type education in Kosen:
Development of a Predicting System of Harvest Time and Tomato Yield

Mikiko Sode Tanaka
International College of Technology
Kanazawa, Japan

Conference Key Areas: New Complexity Quest in Engineering Sciences, New Notions of Interdisciplinary in Engineering Education

Keywords: Regional collaboration, System development, Software engineering, Extracurricular education

ABSTRACT

Kosen is an educational institution that provides professional engineering education for those aged 15 to 22. Kosen is a unique educational system in Japan and has a reputation for nurturing engineers that have the capacity to be useful in society.

In Kosen, it is difficult to educate the hand-on system development capabilities required by society at regular classes, because of the constraint of class hours. Teachers can explain the features of the software development method, and the development process, etc. However, the lecture can only convert knowledge. It is difficult for students who have not experienced software development to master the abilities required for actual system development. In addition, it is difficult to develop leadership skills, the ability to listen to the user's voice, and the ability to learn by oneself. To solve these problems and bring out the self-initiative, Kosen has many types of extracurricular education systems.

In this paper, we will explain the regional collaboration education at the International College of Technology, which is one of Kosen. We educate students through the system development method using project activity of the tomato production management system in collaboration with Komatsu City JA. By experiencing the development of the tomato production management system, students were able to master the system development method. By making use of knowledge and skills through project activities, system development along with regional collaboration enabled us to acquire attitudes such as independent learning, and listening to the opinions of users. It can be said that the proposed method is effective for nurturing the abilities required in society.

1 INTRODUCTION

Kosen is a five-year (or seven-year) education institution in which one can be enrolled after graduating from junior high school [1, 2] (Figure 1). Kosen is a unique educational system in Japan and has a reputation for nurturing engineers. The Kosen curriculum allows students to study both general subjects and specialized subjects in a wellbalanced manner. The goal is to acquire the rich academic and systematic expertise necessary for engineers. Kosen focuses on technical education that leads directly to employment. Its strength is that it is possible to construct an educational curriculum that can consistently train students for the five (or seven) years important for human development between the ages of 15 and 22 (or 24), including the major subjects in engineering.

In Japan, engineering education ordinarily starts when students enter university if they choose to go to university after graduation from high school. In the case of the information field, programming that is equivalent to addition and subtraction in mathematics is content that can be acquired in elementary schools, but it takes time to learn. In the case of Kosen, students can receive an engineering education from the age of first-grade high school students, so by first-year university, students have all the basics. This is one advantage of Kosen education. As a self-employed spirit developed in dormitory life and thorough technical education from the age of 15, Kosen produces many entrepreneurs in Japan, which is said to have few entrepreneurs.

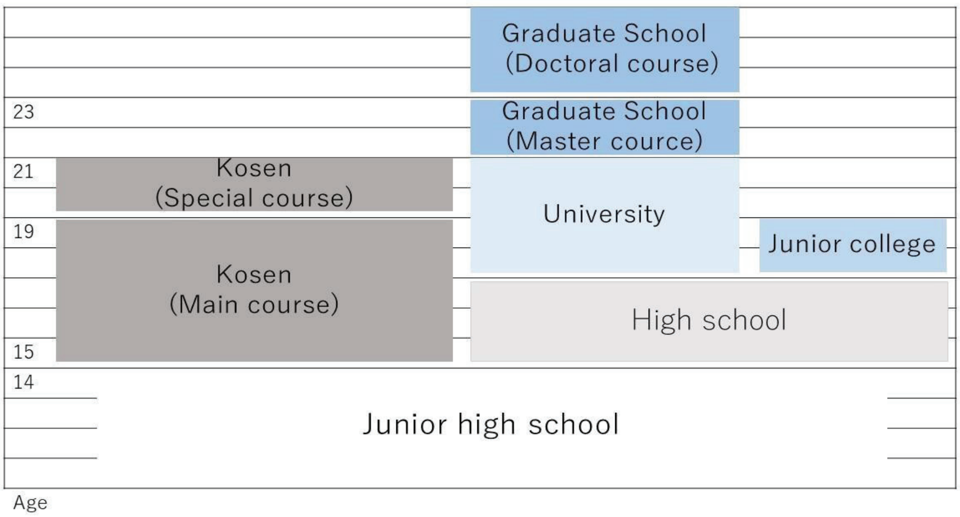

Fig. 1. Institutional relationship between Kosen and high school/university

The International College of Technology is one of the Kosen institutions. In Kosen education, it is difficult to teach the system development method in regular classes. Although it is possible to explain the types and features of software development methods, development processes, etc., the problem is that students who have not had experience in system development have only acquired knowledge and information. To solve this problem, students created the tomato production management system in cooperation with Komatsu City JA (an agricultural cooperative) as extracurricular education. In this paper, we report the whole image of education by regional collaboration and its results.

By experiencing the development of the tomato production management system, students were able to master the system development method. Students were also able to acquire practical system development methods. As the 4th and 5th graders of Kosen have been receiving specialized education for three years or more, they have sufficient “knowledge” and “skills.” However, by making use of knowledge and skills through project activities, the system development with the regional collaboration enabled us to acquire attitudes, such as independent learning, and listening to the opinions of users. It can be said that the proposed method is effective for nurturing the abilities required in society.

2 INFORMATION ENGINEERING EDUCATION IN KOSEN

In Japan’s high school systems, engineering education is not taught. In general, students who have graduated from high school usually receive engineering education after entering the university. On the other hand, Kosen is an integrated high school and university, where students receive engineering education from the age of 15. Moreover, the number of classes per week is greater than those offered in university. As far as engineering is concerned, Kosen can be said to be an environment where students can learn more extensive knowledge and skills than in university.

In Kosen, the basic contents of information engineering can be studied in classes. However, these are only some of the capabilities needed in society. There is a need for ability education that can transform knowledge into wisdom, and thereby help improve society. To achieve these aims, the following contests were conducted.

1. Kosen Robocon [3]
2. Kosen Programming Contest [4]
3. Kosen English Presentation Contest [5]

In addition, education through regional collaboration is conducted. By participating in the contests and the regional collaboration, students can learn skills that are difficult to learn in classes.

The major difference between the company’s work and the schooling is whether answers are available or not. In society, one has to set one’s own goals while thinking about what the answer is and clarifying the answer. Each type of contest and the regional collaborative education are places to practice in which one sets one’s own goals while thinking about what the answer is.

Kosen focuses on educating students in three elements: “knowledge,” “skills,” and “attitudes,” as these are the abilities that companies demand from employees(Fugure 2). “Knowledge“ is a theoretical idea that addresses whether it is possible to explain something in a well-documented, rational way. “Skill” is a practical matter in contrast to theory, and can be acquired by gaining experience. “Attitude” is an orientation toward things, such as attitudes toward learning, goal setting, and motivation. Not only “knowledge and skill” but also “attitudes” are used to discover problems by oneself, to search for solutions, and to identify the search for the abilities, such as thinking, judgment, and expressive power that are required. There is also a need for an attitude toward working with diverse people with a sense of independence.

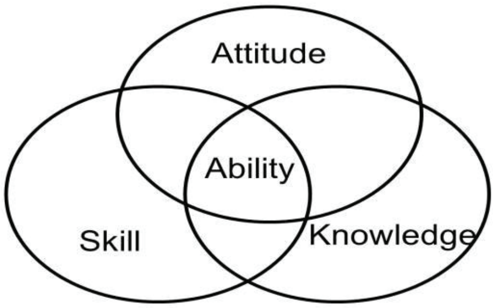

Fig. 2. Three factors that bring out the ability

In Kosen, knowledge and skills education that place the importance on experimentation and practice are carried out. In contrast, education that only strengthens the ability to set goals and act on one's own is less substantial. To address this problem, Kosen is carrying out the project activities through the regional collaboration education and the contests mentioned above.

3 POSITIONING OF PROJECT ONE!

Project One! is the project of the regional collaboration education in the International College of Technology; it was part of the Ministry of Education, Culture, Sports, Science and Technology's "Local Knowledge Base Development Project (COC Business)" [6]. The project was launched by students as a project to develop a rice growth management system with the goal of increasing the efficiency of agriculture by the power of ICT, and it has been working continuously with cooperation of local farmers [7].

The major goals of Project One! are to acquire the following abilities.

A) Awareness/Understanding to respond to social change

B) Ability to change one's interest and ability to take action

C) Mental and behavioral power to fully utilize one's own resources and solve social address issues

Society is constantly changing. In the information processing field, these changes are especially remarkable. We believe it is important to foster the ability to respond flexibly to change, create new value, and lead society in a more positive direction. We believe that we should actively tackle social problems and focus on developing human resources that can improve society. Under this philosophy, we are working on the development of a regional innovation system through regional collaboration as an extracurricular activity.

Another purpose of the project is to foster software development capability by developing an ICT system for agricultural support. We aim to improve the students' skills as information processing engineers by teaching them how to design a system while creating a system.

5 TOMATO PRODUCTION MANAGEMENT SYSTEM

5.1 Clarification of the problem

Komatsu City JA installs technology, such as temperature and humidity sensors, in the tomato green houses of farms that belong to it, and utilizes cloud services that automatically collect environmental data (temperature, humidity). By being able to confirm the numerical value of the work, which formerly depended on experience and intuition, the intention is to utilize improvements in the production process, challenge new agricultural techniques and productivity improvements, and train new talent. The challenge by the International College of Technology was a part of this; the quantity of tomatoes produced in the entire city was grasped, and the goals identified were to 'Eliminate the time that cannot be shipped' and 'Eliminate the rush of shipments'. The activity was to be undertaken by the 4th and 5th grades of the International College of Technology, and the activity was carried out after school and during holidays. Figure 3 shows the configuration of project members involved.

In the problem-solving process, the flow of problem-solving and improvement of activities were used. First, students identified and clarified problems, and created, selected, and implemented ideas. We discussed the details of the system with the tomato farmers in Komatsu City and Komatsu City JA. This was repeated many times, and their ideas were integrated into the process.

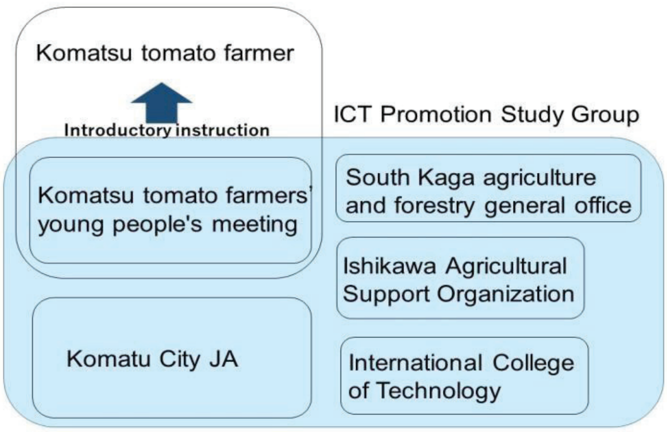

Fig. 3. Member structure of tomato production management project

To manage tomato production, it is necessary to predict tomato growth based on the acquired environmental data. In addition, it is necessary to forecast environmental data to estimate production volume. It is also important that Komatsu City JA can confirm the production forecast value of all farmers. Students summarized these system concepts, reported them to Komatsu City JA, discussed them, and examined the system concepts and what they should be. In addition, students also examined whether the functions needed to realize the system could be realized.

When the functions were clarified, students listed what was necessary to create a tomato production management system. Komatsu City farmers should be able to input the necessary data, and Komatsu City JA should be able to confirm the estimated tomato production by using the system. When the system was completed, it was time the farmers should input the data, but a problem occurred. Farmers were busy and it was difficult to enter the necessary data on the website's homepage. After all, Komatsu City JA collected and entered the data from farmers individually. This failure was however useful as a system development experience.

Although expert knowledge of students is sufficient for system development, the system that was completed at the beginning was difficult to use, because there was no experience in the system development process that assumed it could actually be utilized. Moreover, recognition of the importance of preparing the system to make it easy to use was low; it was also observed that only a technologically elaborate system was prepared. In class, it became clear that the trade-off between technology and usability was difficult to learn. We think students were able to learn the kind of design that is necessary to actually use the technology by working together with the Komatsu City JA. It was not simple, but students found that by being faced with the attitude that customers really wanted to utilize the technology, and by discussing this, their ideas changed.

5.2 Demonstration experiment by tomato production management system

The project was adopted as a measure to improve agricultural profitability in the fiscal year 2016, and a demonstration experiment was conducted jointly with Komatsu City JA and the Komatsu City tomato farmers from the spring of 2018. To make the project successful, students were required to have skills without learning experiences, such as the ability to develop multiple programs without bugs according to a schedule, and the ability to properly listen to user requests and to change specifications. The problem was that the activity time was limited because the International College of Technology was working alone. As there are classes from 8:30 to 5:00, it was not possible for students to engage with the activity frequently. Therefore, the time to listen to users' opinions was limited, and it was very difficult to fix the specifications.

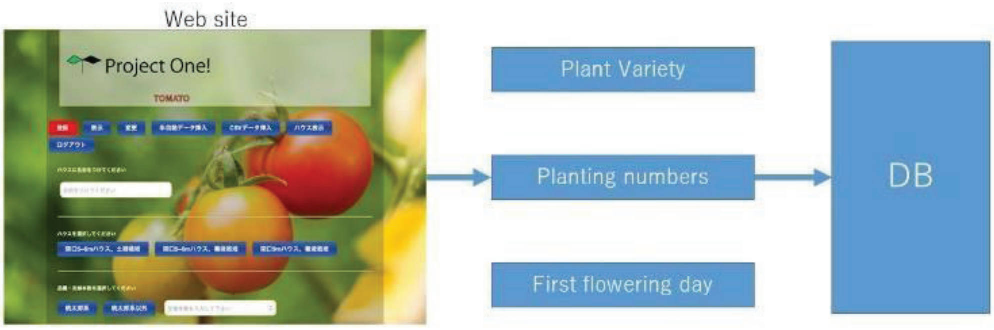

Fig. 4. Initial input screen

Figure 4 shows the input screen of the necessary information on the system constructed. The most difficult part of this activity was the creation of the input screen. It is easy to make it possible to enter the necessary information, but whether it is easy for the farmer to enter or manage it is another matter; whether it is easy to manage should be the result of testing it numerous times. However, it was difficult to match the schedule of the farmers and the schedule of the students, and we felt constrained by time.

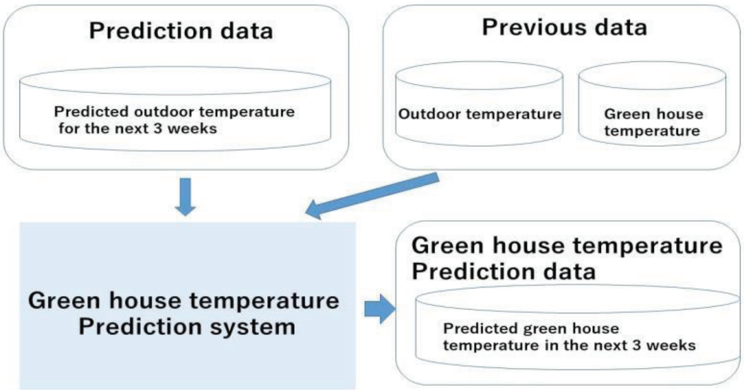

Fig. 5. Green house internal temperature prediction flow

In the tomato production management system, the temperature in the green house after about one month is predicted by machine learning, and the production quantity is predicted using the predicted temperature (Figure 5). It was possible to construct the system using techniques such as machine learning without any problems, because this had already been learned. Figure 6 shows the predicted production volume and the production volume, which shows that the trend is correct.

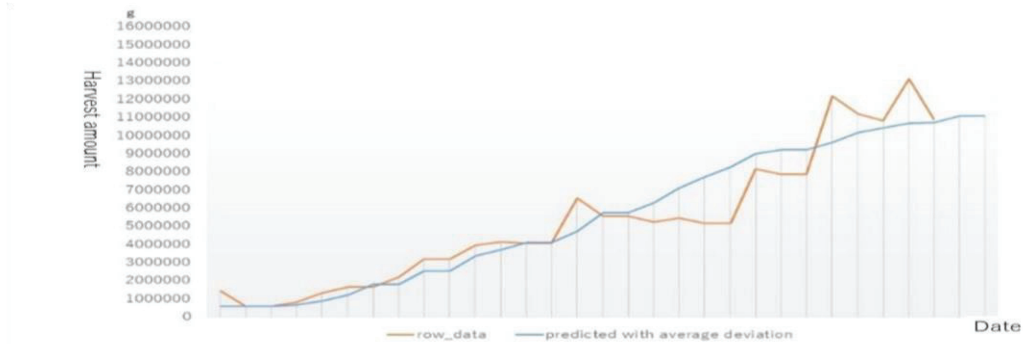

Fig. 6. Production volume and prediction volume

6 RESULTS AND DISCUSSION

Kosen focuses on educating students in three elements: “knowledge,” “skills,” and “attitudes,” as these are the abilities that companies demand from employees.

Therefore, the results of the activities of developing the system for predicting tomato production are summarized below from this point of view. ● Knowledge - Students already learned in regular classes

- Skill - Students learned while creating the system
- Attitude - Students take the initiative in participating in extracurricular activities

Students were able to develop the system for predicting tomato production using the knowledge learned in the International College of Technology. Knowledge in system development was sufficient as students have received specialized education for more than three years. On the other hand, students did not have knowledge about the growth of tomato, they learned while getting the help of JA Komatsu and Komatsu farmers. Through this activity students were able to gain new knowledge. Students did not have enough skills because students had little experience in system development, but students gained more necessary skills while creating a system utilizing the skills they hold. We think that students have gained enough skills since they were able to build the system. Because of the extracurricular activities, students voluntarily found free time and developed the system. Students took the initiative in developing a system by discussing with the community. From these things, sufficient growth was confirmed for “knowledge,” “skills,” and “attitudes”.

Students were able to transform knowledge into wisdom through the system’s development. Moreover, the system that was created was useful for the sale of Komatsu City’s tomatoes, and thus an activity which was useful to society was undertaken. In addition, the students themselves presented the results of their activities at international conferences [8] (see Figure 7). Thus, the major goals of the project activity were achieved. Given that a system that could actually utilize the knowledge acquired in class was constructed by students utilizing their spare time after school, we judged that they had acquired the abilities to fully utilize their own resources to develop their mental and behavioral powers.

Fig. 7. Presentation at an international conference

Through regional collaboration education, the students actually experienced software development, learned how to use the knowledge acquired in class in actual development sites, and eventually learned the development style that is being practiced in the company.

In the proposed method, the software development was carried out throughout the project, and students were required to complete the development with limited resources. The project members worked together with Komatsu City JA and Komatsu farmers to make prototypes that had actual development deadlines. Students improved their abilities to set goals and act on their own. The significance of conducting a regional cooperation education in Kosen is very promising.

Through the regional collaboration education, students comprehensively learn the system's development and the abilities required by a system engineer. As the program is an extracurricular activity, students do not have to worry about small mistakes, and have the advantage of being able to spend time trying different things and learning through trial and error. In the external and internal design phases, both the external and internal designs were repeated many times to complete the interface between modules. Such a learning method is regarded as difficult in regular lessons given time constraints. However, for Kosen students who have knowledge and skills but do not have the attitudes necessary to learn by themselves or the experience of working in a group, we think that the process of repeated failure and growth is important.

The above points also suggest that the proposed method is effective for system development.

7 CONCLUSION

Students experienced the development of tomato production management system with the cooperation of Komatsu City JA and Komatsu City tomato farmers, and thereby learn the system development method. In addition, they were able to acquire practical system development practices that could not be obtained through lectures alone. As students in 4th and 5th grade technical colleges have received over three years of specialized education, they have shown they have adequate knowledge and skills. By carrying out project development using these knowledge and skills, and by conducting system development in the regional collaboration, the students were able to acquire appropriate attitudes, such as an orientation to independent learning and willingness to listen to the opinions of users. It is clear that the proposed method is very effective for fostering the skills required in society.

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What elements of engineering curricula do graduates really value? – A reflective survey

G A Thomson[1]
Aston University
Birmingham B4 7ET, UK

Keywords: Curriculum design, graduates, employability

ABSTRACT

When designing a curriculum, engineering academics have a number of influencers shaping the process including student expectations, accrediting body requirements and the needs of employers in filling often very diverse graduate roles. They also consider modes of teaching which often balance best practice and resource constraints. Feedback from accreditation visits, module questionnaires and industrial advisory boards help iterate and revise the curriculum, etc. and while these are useful, they may often be indirect or inappropriate measures of the effectiveness of our programmes in the workplace.

An area the sector in general has less hard information on are reflections of graduates on specific elements of their undergraduate learning experience once in industry. The survey presented here is part of a wider mixed methods approach which will also involve initial destination data and interviews with graduates.

The work presented here is based on a survey of selected graduates from a particular degree family over the past decade. The curriculum has been broken down into five areas typical of many degrees; traditional engineering science, applied engineering skills (eg. CAD, Quality), internship, group design build and test projects and their individual thesis project with graduates asked to reflect on the impact and value of each of these on their subsequent working life as a graduate engineer.

[1] Corresponding Author
Dr G A Thomson
g.a.thomson@aston.ac.uk : https://orcid.org/0000-0002-7104-4348

1 INTRODUCTION

The development of curricula in engineering education is influenced or defined by a number of factors. These may include the need for professional body accreditation such as ABET [1] in North America or the Engineering Council [2] in the UK which typically define core academic competencies of professional engineers. Local and national employers will also influence academic teams in their construction of curriculum via the use of industrial advisory boards and graduate recruitment patterns [3,4]. In addition 'employability' – an umbrella term to help cover both the technical and personal qualities required of graduates into industry, together with sustainability has become of increasing importance to curriculum developers in recent years [5]. The students themselves are also naturally key influencers in ensuring that the programmes offered are competitive and attractive in the face of numerous alternative offerings [6,7]. These influencers together with the likes of external examiners will also act to scrutinise the suitability and operation of the programmes.

If however the aim of a degree is to equip graduates with the skills needed to transition into and develop once in their professional careers it could be argued that many of the commonly used measures to draw up and review degrees are indirect and do not close the loop on the effectiveness of programmes. Learning outcomes defined by accreditation, for example, may be quite generic and give a syllabus template which **should** deliver the competences the graduates are thought to need. Student surveys while offering a timely measure of contentment with teaching style and organisation are poorly placed to act as measure of the relevance of content.

An area which is not routinely used to develop and adjust programmes is the reflective experience of graduates of the programmes and how the degree they did supported their careers [8,9]. Arguably this is a key measure which truly closes the loop on the effectiveness of programmes.

The aim of the work presented here was to explore and compare how on reflection different elements of a degree are valued by graduates once in the workplace.

2 METHOD

2.1 Methodology

It was decided that an anonymous online survey of engineering graduates from a set of programmes at Aston University, UK would be carried out. This will form part of a wider study with the intention to follow the survey up with a series of interviews to consolidate and explore key points of the survey data. This further activity is beyond the scope of this current paper.

The online survey was chosen as a practical approach to ensure both the anonymity of the respondents and the efficient and consistent gathering of data for a geographically disparate group of individuals.

Approval for the survey and associated methodology were sought and granted by the Aston University Engineering and Applied Science ethics committee.

2.2 The Survey

While focussed on the experiences of a particular degree family at a specific UK University the survey was structured to draw on key components of many degree programmes to help offer the opportunity for lessons learned by this work to be more transferable.

The main content of the survey therefore looked at 5 elements which feature in many engineering degrees :

- Conventionally taught core engineering science and mathematics
- Applied engineering science *(CAD / Manufacturing / Quality / Society etc.)*
- Project based learning (PBL) *(Whole class projects with students working in groups)*
- Major final year project / dissertation (FYP)
- Industrial internship / placement *(Year long paid placement in industry)*

The survey had three sections.

- Demographics : This featured broad categorised basic information on when the individual graduated, industry sector and current role.
- Main content : for each of the 5 programme elements students were asked if they used the content taught directly, if it underpinned what they did even if not used directly and if the element developed transferable skills used in their current role. This was done via a 5 point Likert scale in each case and participants could add further comments if desired.
- Further comments : Participants were offered on opportunity to offer areas of curriculum they would have liked to have added, to have dropped or make any other comments.

2.3 Participants

The graduates recruited for this study were those sourced via the author, a former programme director's "Linkedin" network and were individuals who had graduated from the Mechanical Engineering family of undergraduate programmes at the parent University over the previous decade.

For the programmes involved, participants who graduated 6 or more years ago followed a relatively traditional curriculum, while a more project based learning (PBL) focus following CDIO principles was introduced for the more recent graduates. CDIO is an educational framework stressing engineering fundamentals set in the context of Conceiving — Designing — Implementing — Operating (CDIO) real-world systems and products. In addition to the projects embedded in the taught degree, the University also encourages students to undertake a year long industrial placement however this is not compulsory.

Around 80 former students were approached with 32 completing the study. 20 of the students graduated over the last 5 years and followed a programme with significant PBL content with 12 graduating 6 years or more ago and following a more traditional curriculum. 16 of the 32 total took a year long industrial placement.

Mechanical engineering graduates have a diverse range of careers, in highly varied industry sectors and this was reflected in the roles of those surveyed. A breakdown of the industry sectors in which the graduates operate can be seen in *figure 1.*

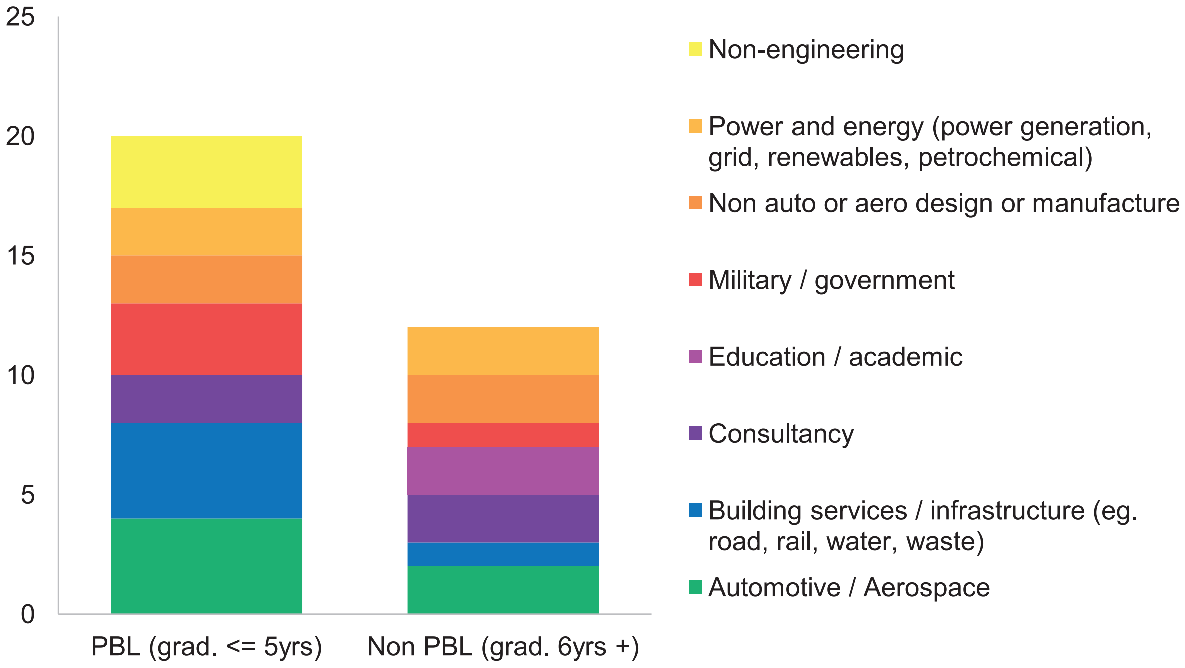


Fig. 1. Industrial Sectors of Graduates Participating in Survey

3 RESULTS

Figures *2* to *4* show the aggregated results from the survey where in each case the graduates were asked, for each of the five programme elements, whether in their daily work they used these directly, whether they underpinned what they did and whether the modules helped them develop the transferrable personal and professional skills needed in their role.

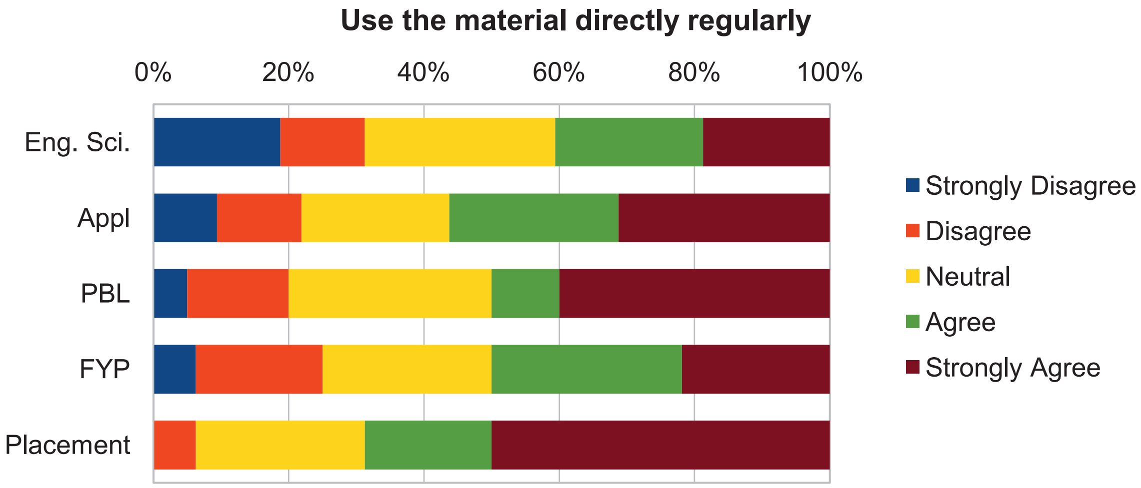


Fig. 2 : “I use some of the formally taught knowledge and skills gained in *(programme element)* directly on a regular basis”

Figure 2 shows the extent to which graduates directly used the material taught to them in each of the programme elements. Most notable is that for the classic engineering science modules which form a significant part of most degrees, relatively few students call on this first principles knowledge directly on a day to day basis. This element is not on its own however with the final year project, PBL and applied engineering sections showing hovering around 50% of responses clearly positive. This might not be unexpected given the range of diverse and specialist roles graduates find themselves in where the regular application of the basic broad fundamentals are more likely to be surpassed by industry specific tools and techniques. For some however, particularly those working in perhaps research areas, core skills will still be key as indicated by a comment from a graduate working in research and development in the power generation sector :

“I use the skills learned in Solid Mechanics, Thermofluids, Heat Transfer, Engineering mathematics, Turbomachinery on a daily basis.”

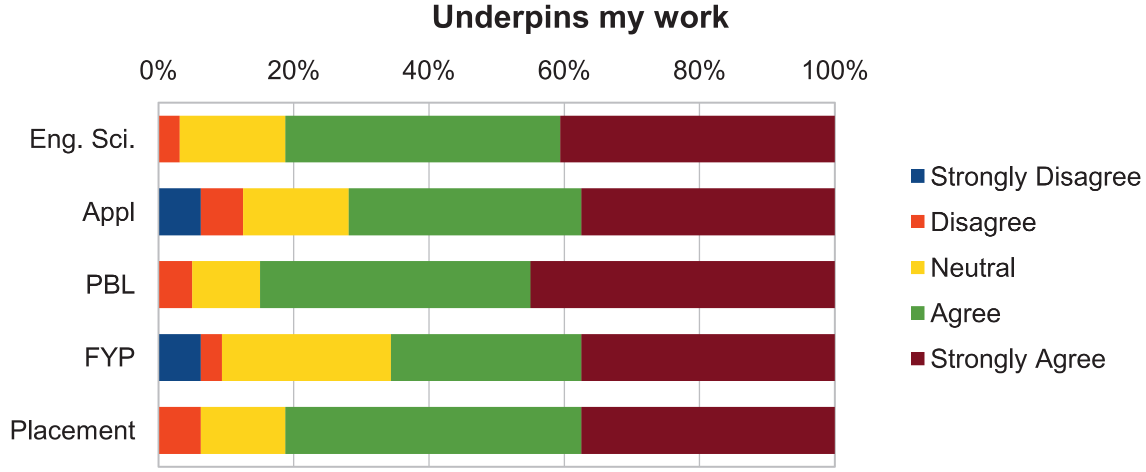


Fig. 3 : "Whether or not I use the knowledge formally gained in *(programme element)* directly, I feel it underpins much of my daily work"

Figure 3 shows that the graduates appreciated that even if they may not use the formal learning in a direct sense on a day to day basis they appreciated that derivatives from this work informed their role and adds to the depth of understanding of their current processes.

From a graduate working in the military / government sector :

"While I do not use all of the skills directly they have enabled me to become a CEng and allow me to retain a level of credibility when discussing technical subjects."

From another along the same vein

"The tacit knowledge, vocabulary and understanding is invaluable as an aid for working alongside engineers with a deep technical specialism and translating / facilitating their conversations with the business functions."

Figure 4 shows the impact of those transferrable skills elements embedded in degree programmes which help to develop the wider personal and interpersonal qualities of the individual. It was clear that graduates felt this was important and had been a positive support to their career. In particular the project based learning element and the placement appeared extremely strong in this area with in both cases around three quarters of graduates strongly agreeing that it had helped them feel comfortable with more general problem solving, organisational, investigation or personal and interpersonal skills in their daily work.

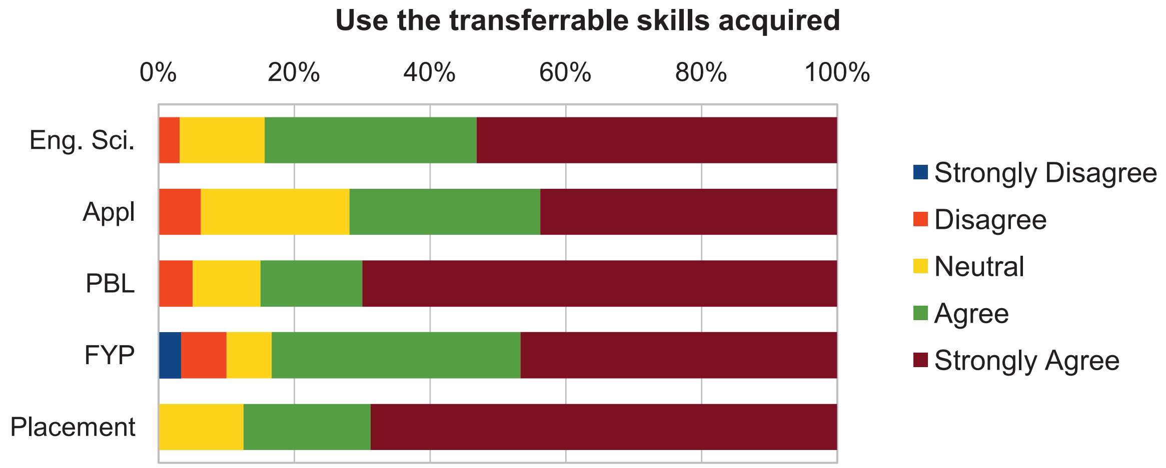
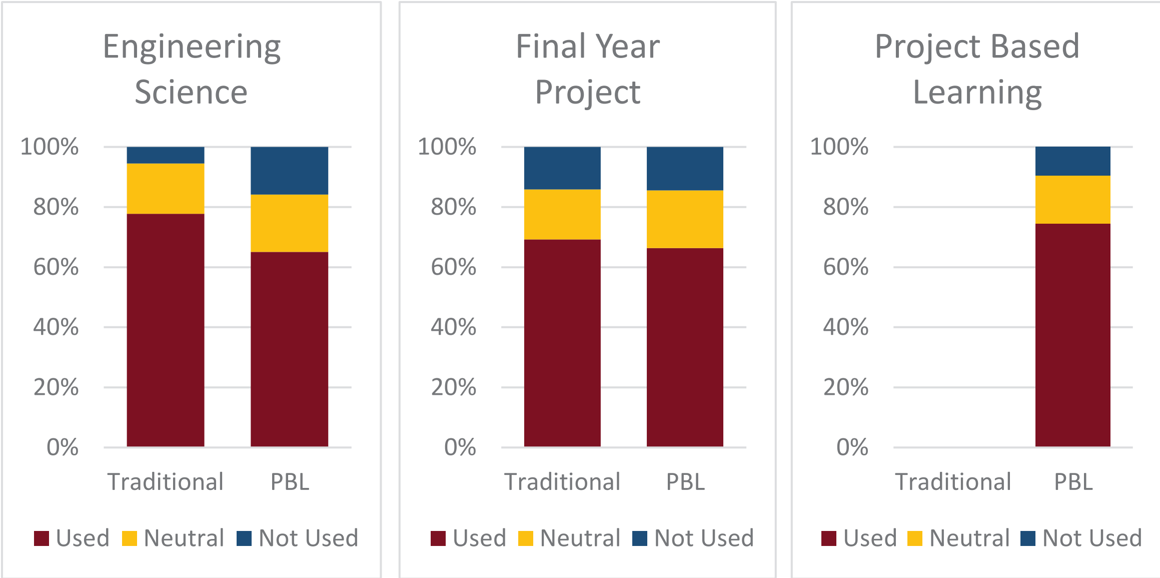


Fig. 4 : "The *(programme element)* helped me feel comfortable with more general problem solving, organisational, investigation or personal and interpersonal skills in my daily work"

In regard to the PBL elements some comments from surveyed graduates included :

"….provide a link into reality of engineering problem solving and team work. This section of the degree provided good foundation for project / schedule management skills, working within teams and general applied engineering" and "*The skills garnered in PBL have been a constant part of my tool set as I have progressed through my career."*

The students involved in this study graduated over the course of a decade. While the programme structure and detail content varied and evolved over this time, the core elements of engineering science, applied engineering topics, final year project together with the option of an industrial placement were constant. Midway through the decade a major change however was the introduction of project based learning elements designed to make the learning more effective and industry focussed. As part of this work we wanted to see if this element was valued ?



Engineering Science *(a)*   *Final Year Project* *(b)*   *Problem Based Learning* *(c)*

Fig. 5 : Aggregate comparison of reflections of three programme elements as featured in the traditional and PBL focussed degrees.

Figure 5 shows aggregated results for students on the older, traditional programme versus those on the PBL aided model. For each programme element a comparison has been drawn by aggregating all the Likert responses which indicated use / neutral / limited or no use for direct / underpinning or transferrable skills in the graduates current working role.

For the engineering science element *(Fig 5(a))* there does appear to be some slight dropping away of the use to which the more recent graduates place on this. A similar pattern was also observed in the applied engineering section. The follow up interviews will explore this issue to investigate whether this is a genuine trend, a statistical blip given the relatively small numbers surveyed or is related to the increased emphasis on PBL in the newer degree. This element has been well received and its relevance to graduates as can be seen in *Fig. 5(c)*. By contrast *Fig 5(b)* shows a very consistent appraisal of the relevance of the final year project.

4 DISCUSSION AND SUMMARY

Graduates are the key product of engineering programmes. Academic teaching teams work hard to try to deliver effective programmes, balancing constraints of resource with the demands of a range of influencers whether these be their own institutions policies, accrediting bodies, current and future students, external examiners and industrial boards. Graduates themselves the consumers of the programmes and those who have direct experience of taking the learning into industry are often not part of many formal review processes.

This work has taken some steps in this direction. It shows that, for the graduates participating in the survey, taking a degree has been important in preparing them for and supporting them in their work life. All components of a degree programme whether the conventional engineering science, placement or final year project deliver direct, underpinning or transferrable skills giving positive benefits to graduates in the workplace.

It does however also pose some questions.

While the results were generally highly positive there were some students who reported less than optimum and negative responses for some aspects of some elements. It may be that this may be inevitable given the broad range of sectors and roles to which graduate mechanical engineers may go to – a perfect course for a graduate engineer in the rail sector is unlikely to similarly suit an individual working in manufacturing or biomedical engineer sector.

For analysis and transferability, the programme used in the study was broken down into five programme elements common to many degrees. While this was an efficient way to segment the degree it also needs to be recognised that in doing so each element was characterised by a blend of both different content types and different learning modes. Isolating the effectiveness and relative importance of these two aspects of each element will be explored in future interviews.

It is intended that this work will be expanded. Potentially some further students are to be surveyed while semi-structured interviews will be carried out to explore and deepen the understanding of some of the issues raised. This will also look at longitudinal issues to reflect that over a decade, regardless of internal issues of content and format within a programme, the students embarking on their studies together with market and societal issues will also change and these could also be reflected in graduate views on the merits and suitability of their degree.

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On the Illusion of knowledge

T. M. Thorseth[1],
M. S. Kahrs
Department of Physics
Faculty of Natural Sciences
Norwegian University of Science and Technology NTNU
Trondheim, Norway

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ABSTRACT

Following principles derived from self-regulated learning and self-determination theory, good feedback practice should provide feedback on the subject and learning practice. However, large groups and lack of time prevents the teacher from providing individual written feedback. In a qualification course in mathematics, we have implemented an assessment practice with immediate feedback that aims to create a dialogue between the lecturer and the students. The feedback is combined with self-evaluation. We also ask the students to reflect on the learning process. Common challenges appearing in the written reflections are then addressed in a subsequent intervention.

Today, learners have access to online video lectures that can support learning or in some cases replace lectures. In these online videos, they can watch experts explain a subject and perform calculations with ease. However, watching these instructions or lectures alone might create the illusion of having acquired the skills without having spent the effort.

What we see from the students' self-evaluations and reflections is that they often fail to recognize the difference between understanding a subject and being able to apply the knowledge. Through these assessments, students experience the difference between doing calculations with a textbook or a guide available compared to working on their own. Using what the students write after such assessments are used to introduce what interventions are needed. "I don't know what happened today, because I know this!" represents an experience that was used to initiate a discussion with the students on the concept *illusion of learning*.

[1] Corresponding Author
TM Thorseth
Trond.M.Thorseth@ntnu.no

INTRODUCTION

"I don't know what happened today, because I know this!"

This comment appeared as a part of a student's written reflection after a formative assessment in mathematics. Clearly, the student was surprised by the actual performance compared to the efficacy beliefs held by the student. The experience expressed through this statement is not unique. However, the question is: How can we understand this and similar experiences? Of course, there could be numerous reasons for this experience – some of which are outside the student's control. He or she could have been surprised by an unusually difficult set of mathematics problems. It could be that the student had a bad day or problems concentrating. However, there is a self-reflecting message here. The student seems to judge the problems to be within what he or she expected to master, but there appears to be a mismatch between the perceived knowledge and the actual ability to solve the problems. What are the possible reasons that might cause this experience? Can we as teachers learn something from trying to interpret these short reflections?

The experience given in the comment above can also shed light on similar experiences. For example, students participating in regular lectures make comments like, "it is so easy when you do it!" This illusion of knowing the material after having seen others solve and explain problems may falsely give the students the impression that they have acquired the transferred knowledge. Some students even believe in the idea of an ideal student, for whom it should be enough to just show up for lectures, to achieve the necessary skills.

Adding to this, a part of the modern way of studying is to use online videos of skilled professionals solving problems and explaining. Students find video lectures online, some closely related to the curriculum in the Norwegian language, like "campus increment" and "matematikk.net". In addition, international pages like Kahn Academy and YouTube provides a lot of excellent presentations where professionals explain and show how a student can understand and solve problems. Merely watching others may create the illusion of having acquired the skill [1]. The students have limited knowledge about learning as active construction of knowledge and skills, and the amount of work needed to learn mathematics.

In this paper, we describe how the initial comment appeared in the context of a dialogic feedback process related to formative assessments. Finally, we will offer a theoretical interpretation of the initial citation which may be useful when addressing this and similar student experiences.

THEORETICAL BACKGROUND

It is a known problem that students have varying degrees of knowledge about how they learn. When we ask first-year engineering students at NTNU "*Would you say that you study the way you do because a teacher (or teachers) taught you to study that way?*" between 80-85% answer "no". Similar results are reported by Hartwig and

Dunlosky [2] and Kornell and Bjork [3], where 64% and 80% of the students (respectively) report that they have not been explicitly taught how to study. As stated by Bjork et al. [3], "*people often have a faulty mental model of how they learn and remember*" (p. 417). How to study and manage the learning process is probably the most important knowledge structure that we co-construct in a lifelong learner's mind.

Koriat and Bjork [4] define the illusion of competence as the "overestimation of one's future memory performance"(p.187). Koriat and Bjork point at the fundamental difference in conditions between learning and testing situations as a cause for the overestimation. Formation of a belief about future performance is made in a learning context, with social support from peer students and a teacher, textbooks, and the answer readily available. In contrast, in an exam (i.e. test) context, support and resources are strictly limited.

Carpenter, Wilford, Kornell, & Mullaney [5] has shown that fluent and well-prepared lectures give the students an illusion of having learned more than from an unprepared and disorganized version of the same lecture. However, the actual student performance as a result of participating in these lectures was shown to be equal in these two cases. The way a student makes a judgment of his or her learning is based on a system that might give rise to such illusions.

Koriat and Bjork [4] do not include the emotions involved in the learning context. Learning, attention, memory and decision making, in general, are influenced by emotions [6]. Recent theory links emotion as a cue for learning, and so people may be misled by recent emotional states to infer that they have learned more than they have [7].

Baumeister, Alquist, and Vohs [7] have investigated how emotions shape the way we make judgments of our knowledge. Their participants "*rated that they learned more after an emotion had been induced than in emotionally neutral control conditions*" (p.149). Baumeister et al. observe that the illusion of learning is caused by emotions in general.

THEORETICAL BACKGROUND FOR ASSESSMENT

To facilitate a formative assessment, we have to create conditions where we generate feedback on performance in a way that improves the learning process [8]. It is a goal to develop the students' ability to self-regulate their learning. The term self-regulated learning refers to the degree to which students can regulate their thinking, motivation, and behavior during learning [9].

Literature on self-regulated learning has long been concerned with higher-order information processing and metacognition, and only recently have emotions been included as a factor [10]. In this context, we claim that a metacognitive perspective of the emotions observed is one of the important skills that should be included in formative assessments. However, finding the form, the language and conditions to discuss emotions in a mathematics class, is a challenge. Providing feedback in an interactive dialog with the students might be one solution.

Nicol and Macfarlane-Dick [11] suggested seven principles for feedback practice that we have used as the main guide to developing the situations where we provide feedback. Good feedback practice:

1. helps clarify what good performance is (goals, criteria, expected standards);
2. facilitates the development of self-assessment (reflection) in learning;
3. delivers high-quality information to students about their learning;
4. encourages teacher and peer dialogue around learning;
5. encourages positive motivational beliefs and self-esteem;
6. provides opportunities to close the gap between current and desired performance;
7. provides information to teachers that can be used to help shape teaching.

In the next section, we will describe the didactical procedure that was used during formative assessment sessions in mathematics. We will also specifically describe how we addressed the 7th principle from Nicol and Macfarlane-Dick [11] using the students' written reflections as a source for subsequent interventions.

METHODS

We are developing ways of providing feedback, where the students' learning processes are explored and challenged in a qualification mathematics course. The mathematics covered is typically precalculus with an introduction to calculus. The "class" consist of approximately 60 students, where most students are from 19 to 25 years old. Most of the students have a vocational background and participate in the qualification course to start an engineering education. Previous knowledge in mathematics within the group is varied. The described feedback practice has been implemented in a qualification course in mathematics for the last five years. There are five parallel classes. However, written reflections focusing on self-regulated learning, which in turn informs subsequent interventions have been carried out in only one parallel for the last two years.

We introduced formative tests where the students are given problems similar to the level they will encounter at the final exam. Each student must participate in 10 of 14 assessments to be allowed access to the final exam. The assessments are not graded except for two larger ones that last for 5 hours. Assessments are given one week after the material has been taught. Each test lasts for two hours. In the first hour, the students must solve 4-6 problems with the same aids that are allowed at the final exam. The tasks are handed out on paper and students work with the problems on paper as they would on an exam. In the second hour, after a short break, the problems are reviewed. This provides the students with immediate dialogical feedback. As part of the review, students are asked to judge and reflect on their performance.

Information from students is gathered in two ways: written reflections related to the assessment conditions, and feedback in subsequent interventions where students respond using a text-based response system. In the final part of each assessment, students are asked to judge and reflect on their work. To guide the students, they are encouraged to answer questions about the experience, reasons for the experience, and the learning process in general. The question “What is the biggest challenge in learning this subject for you right now?” generated a lot of information about what students face or experience when learning the subject. Selected responses to this question are used to initiate interventions to create a dialog around learning.

The interventions aim to create an understanding for and at the same time challenge the learning strategies that the students use. Based on the reflections, an intervention consists of a session lasting approximately 20 minutes, taken from the regular lecture time. The text-based student response system iLike [12] is used to interact with the group. Students respond to questions, either multiple choice or open-text-questions and students respond using their mobile phone or PC. Text-responses provided by the students are used immediately and in subsequent interventions and such address principle 7 from Nicol and Macfarlane-Dick [11].

When students answer open text questions, anonymity makes it possible to discuss questions that student often perceives as private. Text responses often contain much information and can give insight into the variability in the student’s perceptions, which sometimes is difficult to comprehend when the subject is discussed in class. The perceived degree of trust in the room is essential to get this process going. The information given by the students is an essential part of the 7th principle of Nicol and Macfarlane-Dick [11] “good feedback practice provides information to teachers that can be used to help shape teaching”.

DISCUSSION

The statement “*I don’t know what happened today because I know this!*” can be interpreted as a problem associated with the illusion of knowledge. A citation like this, taken from a student, provides an opportunity to start discussing the phenomena. A part of this way of working is that it is the students’ initiative, reflection or comment that trigger the intervention. The intention is that the intervention can provide a deeper understanding of how learning works, in a context where the students experience a need for such information.

Two possible reasons might cause the illusion of knowledge; the difference in context during learning and assessment, and how emotions may be misinterpreted when we learn.

When we make judgments about the world around us, we tend to do this from a momentary active state or the emotions as an important source of information [13]. However, we see that in a learning context, this might lead to false judgments of own learning. Learning how to use these emotions from the learning context, which rarely are explicitly noticed or reflected upon, and to develop a sound metacognitive perspective of the learning situation is important.

Developing students’ metacognitive skills in interpreting and acting upon emotions is important. According to the theory of constructed emotions [14], emotions are seen as learned idiosyncratic interpretations that the brain has constructed. This means that it is impossible, even in principle, for a teacher to provide concise, constructive feedback to the individual student. Hence, we can argue that students need to, and in fact, can learn to recognize and interpret the small signals gained from the experience of insight. The students should, however, recognize that this is only a step towards gaining knowledge and not be misled by the emotion.

CONCLUDING THOUGHTS

Working actively with dialog-based feedback where the current level of performance is assessed, should be combined with ways to challenge the students' learning strategies [15].

The main challenge is time, and the feeling of psychological safety in the room in such a way that students dare enter the subject of reflecting on their own learning experience. We recognize that response technology where students can respond to questions anonymously is an essential element in creating the dialog.

Having the metacognitive skills to reinterpret experiences with learning as a step towards gaining knowledge, and not as a signal of having achieved knowledge is important. More importantly, when these emotional signals appear while learning from an online video, these emotional impressions might be uncorrected since there are no one around to adjust or correct the reactions. If these learning conditions are left untested, this might lead to false judgments of own learning. However, finding occasions and the language to discuss emotions in a mathematics class is challenging.

In a search for ways to expose the students to experiences and later focus on how to challenge the students' individual experiences, this way of working is interesting. So far, the exam results compared to parallel mathematics courses, suggest that this way of working towards the students seems promising, but it is too early to state any conclusion.

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An Automatic Assessment System for CAD Education

T. K. Tiainen
Doctoral Candidate
Aalto University
Espoo, Finland
E-mail: tuomas.tiainen@aalto.fi

K. Jaakma
University Teacher
Aalto University
Espoo, Finland
E-mail: kaur.jaakma@aalto.fi

P. J. Kiviluoma
Senior University Lecturer
Aalto University
Espoo, Finland
E-mail: panu.kiviluoma@aalto.fi

R. A. A. Viitala
Postdoctoral Researcher
Aalto University
Espoo, Finland
E-mail: raine.viitala@aalto.fi

P. O. Kuosmanen
Professor
Aalto University
Espoo, Finland
E-mail: petri.kuosmanen@aalto.fi

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ABSTRACT

Computer aided design (CAD) is widely used in mechanical engineering to create models of part geometry. Current CAD education at Aalto University relies heavily on course assistants assessing exercises manually. This paper presents a novel system for automatically assessing mechanical engineering parametric CAD modelling exercises. A review of different possibilities for automatic assessment was conducted and a prototype online automatic assessment system for parametric 3D CAD modelling exercises was developed. The system used an interface found in a commercial CAD tool to compare submitted modelling exercises to correct reference models or known values. The system was tested with 102 students on a course and a user experience survey was conducted. Results of the survey indicate that students generally approve of the possibility to use an online service to submit exercises independent of time and place and to get immediate feedback. Automatic assessment systems also reduce the

amount of human work required. Future plans at Aalto University include extending existing e-learning platforms with newly developed automatic assessment tools to create MOOC-style basic CAD courses.

1 INTRODUCTION

In mechanical engineering, computer aided design (CAD) tools are used to create 3-dimensional models of parts. In parametric CAD tools, the model geometry is created with features, which can have references to other features or model geometry. Designing efficient models in requires both technical skills with the tools and strategic skills to structure the model so that it is versatile and can be re-used. The aim of CAD education is to teach both of these skills [1].

At Aalto University, all mechanical engineering students take a basic course in CAD. The assessment of the course exercises has relied on manual assessment by the course assistants, which poses a significant amount of work for a large course. Consistent grading of CAD exercises is challenging, since small errors can lead to large differences in the end result. An automatic online assessment system for CAD exercises could aid in solving these problems.

Automatic exercise assessment systems have been used in other fields, such as the education of computer programming. Literature on automatic assessment systems reveals several benefits of using such systems. An online automatic assessment system reduces manual work by course instructors and ensures grading each submission in a consistent manner [2]. In addition, benefits of an online system include having the system always available, which gives students the possibility to progress on the exercises at any pace. Another benefit of using automatic exercise assessment tools is that students receive immediate feedback after submitting an exercise, which enables learning from failures [2].

The authors of the paper are not aware of previous automatic assessment systems for parametric CAD exercises. A possible explanation for such systems not existing is that CAD software packages are commonly commercial and closed source; programs from different manufacturers also have differing tools and differing ways to access them programmatically. The aim of this research was to create and test an assessment system for parametric CAD modelling exercises.

The current study presents a novel system to assess parametric 3D CAD exercises automatically by using software to extract information from models with tools already found in a commercial CAD software package. The paper also presents evaluation of experiences and survey results of using the system on a basic technical university CAD course.

2 FEATURE BASED PARAMETRIC CAD IN MECHANICAL ENGINEERING

In mechanical engineering, feature based parametric CAD programs are used to design parts and assemblies. These modern 3D CAD systems can describe objects with solid models, which use a combination of surfaces and boundaries to define the volume inside and outside an object [3]. In feature based CAD systems, the part models consist of feature trees and the features can have references to parameters, other features or geometry, such as edges or surfaces. When a feature or a parameter is changed, the change is reflected to the geometry down the feature tree. [4] An example of a parametric model is presented in figure 1.

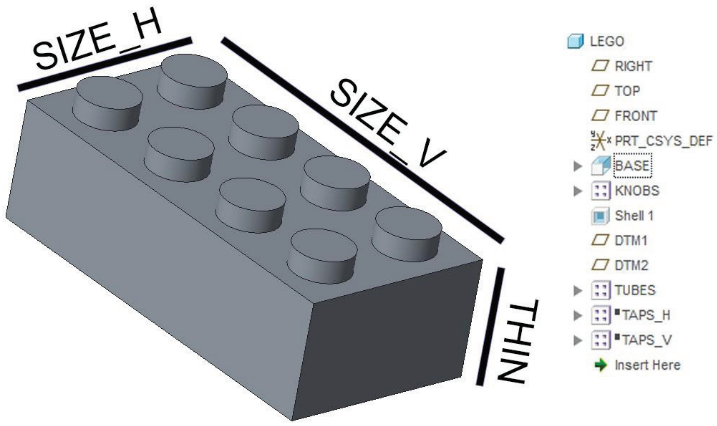

Fig. 1. A parametric CAD model of a Lego block and its feature tree. Three parameters control the shape of the block: width (SIZE V), length (SIZE H) and if its thickness (THIN).

Parameters are non-geometric features in a CAD-model [5]. Defining a CAD model with parameters, constraints and features improves efficiency by enabling the re-use and reshape models [5]. Relating model features to parameters enables regenerating the part in different shapes. A good practice is to construct the model around a parametric skeleton, which contains centralized design information and conveys *design intent* about the part [5]. For example, when altering a skeleton model, the more detailed geometry in a model follows changes in major dimensions.

Commercial CAD software packages contain application programming interfaces (API) which can be used to drive the software programmatically without user interaction in the graphical user interface. In industry, the APIs are used for model automation, but they can also be used to drive tools necessary for the automatic assessment of exercises. [4]

CAD education Successful and productive 3D CAD requires declarative (3-dimensional perception, technical competence with the tools) and strategic skills (building and structuring the whole model) [1]. On basic courses the objective is to give a fundamental understanding of how the software and tools work and how geometry is created [4]. The aim of more advanced CAD courses is to teach both declarative and strategic skills. Advanced CAD education can focus on upper-level concepts, such as conveying design intent in the structure of the CAD model, by parametrizing the most important features of a model [4].

A typical master's degree in mechanical engineering in a Finnish university includes from 5 to 10 ECTS credits of CAD courses. Most CAD courses in Finnish universities consist of using commercial CAD tools to complete different types of 3D modelling and

2D drawing exercises. The courses typically rely on course assistants checking and assessing the work of students. University curricula are not limited to CAD education only; collaborative tools and simulation tools are often taught together with CAD. [4]

3 AUTOMATIC ASSESSMENT OF EXERCISES

Automatic assessment tools

In software engineering, automatic tests are used to discover faults in programs and to inspect whether programs meet specified requirements [6]. Assessing any other exercises addresses the same problem; the assessment method must inspect whether the returned exercise has faults and measure how well the returned exercise meets a given set of conditions. In the education of computer programming, automatic exercise assessment tools have established a foothold and many educational institutions have successfully used automated assessment systems. [7]

The use of automatic exercise assessment in programming education is based on practices used in software testing, where industrial testing frameworks exist to test the functionality of written code. Some systems used for programming exercise assessment work by applying tools found in testing frameworks on the submitted code. Other possible approaches include comparing input and output of the code or comparing graphs of the submitted solutions to known correct answers. [8]

Using automatic assessment effectively requires considering the limitations of the automatic assessment method when designing the exercises [7]. For example, assessment tasks easy for a human mind may not be easy for software-based assessment systems. Limiting the number of submissions can be used as a tool to prevent trial and error type solutions [8]. It is also possible to parametrize the exercises to generate varying exercise instances separately for each student and resubmission [8].

E-learning systems as user interfaces for automatic assessment tools

E-learning systems can be categorized into automatic assessment systems and learning management systems, of which the letter are used to manage courses and assignments [9]. A review of automatic assessment systems [9] shows that it has been common for learning systems to have been implemented for a very specific use case and to have incorporated features from both system types. Furthermore, previous studies suggest that this fragmentation was due to the tools having been developed in separate thesis projects and by individual teachers to support specific teaching requirements on their courses [8].

Recently e-learning environments have been developed, which separate different distinct features into modules communicating between each other via documented interfaces [9]. For example, the A-plus system at Aalto university separates different layers of the systems: the user interface and authentication is handled separately and there are external synchronous, asynchronous or static methods available for the assessment [4][9].

4 AUTOMATIC ASSESSMENT SYSTEM FOR PARAMETRIC CAD EXERCISES

The research aimed at developing an automatic assessment system and to test it on a basic CAD course at Aalto University. The course *computer aided tools in engineering sciences* is common for all mechanical engineering bachelor students in Aalto University School of Engineering. The course consists of modules where students learn to use different CAD programs for a typical set of tasks.

The system was developed for the course's Creo Parametric module. Creo Parametric is a 3D CAD software developed by PTC. The software includes tools for solid and surface modeling of parts, sheet metal and weld modeling and technical documentation [10].

4.1 Assessing CAD exercises automatically

All exercise assessment is essentially measuring how well the solution of the exercise meets a given set of requirements and then grading the submission based on predefined a set of criteria. There are several approaches to automatically assessing exercises, but for all cases it is necessary to specify the requirements for assessment and criteria for grading. The concepts presented in this section can be applied to automatic assessment of any CAD exercises, but the implemented system is specific for Creo Parametric.

To automatically assess CAD exercises, it is possible to use APIs in CAD software packages to compare data from the submitted CAD files to known values or data from another file. The APIs can be used to programmatically regenerate the model with different parameter sets and then check if it matches to a reference model. The APIs also provide access to other sources of information (such as the volume, surface area and center of gravity) that can be used to check if a model is correctly constructed.

Proxies for the correctness of geometry include the feature tree and mass properties of a model. Comparing only the feature trees is not always enough, because the same geometry can be constructed with different features; having correct geometry does not necessarily mean having a matching feature tree. The mass properties of a model contain information of the total volume, mass, surface are and centers of gravity of the model, which can be compared with the respective information from a correct model. Commercial CAD software packages also have tools which can be used to compare and visualize differences the geometries of two models (figure 2).

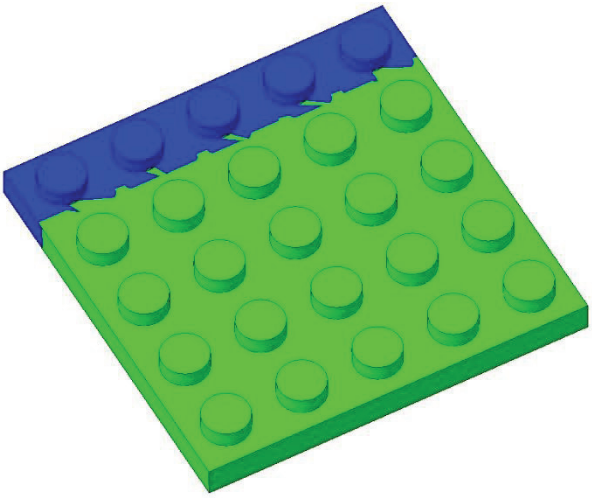

Fig. 2. The *Compare geometry* tool in Creo Parametric 3.0 can be used to visualize differences in two models. A similar tools exists in Solidworks [4].

Several standard exchange formats exist to transfer 3D geometry information between CAD systems of different manufacturers. Examples of these neutral file formats are STEP and IGES. Parametric features are not supported in these formats and they do not store information of the history of the part in the same way as proprietary file formats [3][4]. A manufacturerindependent CAD exercise assessment system could make use of neutral file formats, but the assessment would be limited to geometry only.

4.2 CADVER: Automatic exercise assessment system for Creo Parametric

After a review of available options for automatic assessment of parametric CAD models, the prototype system CADVER was developed.[1] The system had an online interface, through which students could submit the exercise and view the assessment results.

The system uses the VBAPI available in Creo 3.0 and can be used to regenerate models with different parameter sets (example of a parameter set for the Lego block exercise in figure 3). When the part has been regenerated, the system uses the API functions to compare information from the model to predefined values or a known correct model. The system supports comparing mass properties (e.g. volume and mass), feature trees, and checking if the model successfully regenerates with given parameters.

When a file is submitted to the system, the system runs the appropriate check tasks based on check templates configured in the system. Checks were implemented for matching surface area or volume of the models to given given values or values read from a reference file. A check was also avaiable to check for a matching of feature types present in the model's feature tree. An admin panel for the system was also implemented to display information of passed and failed check tasks user by user.

[1] The developed automatic assessment system (CADVER) is open source and available at https://github.com/tuomastiainen/cadver

```
[{"SIZE_V": 1, "SIZE_H": 5, "THIN": true},
{"SIZE_V": 2, "SIZE_H": 1, "THIN": false},
{"SIZE_V": 1, "SIZE_H": 2, "THIN": false},
{"SIZE_V": 3, "SIZE_H": 5, "THIN": false}]
```

Fig. 3. Example of a parameter set used to test the parametric Lego block exercise. The system regenerates the model with all parameter combinations in the set and compares the result to a reference. The reference can be another model or predefined values.

Automating the use *compare geometry* tools for assessment proved to be difficult, and the implemented system did not utilize these tools. The tools can directly produce visual feedback, which would be useful because the feedback can convey information of how the part is incorrect, not just that it is incorrect.

4.3 Evaluating the performance of the developed system

The developed system was evaluated in two ways:

- The CADVER system was tested on a basic CAD course at Aalto University and a survey was conducted. The survey was originally conducted as a part of a master's thesis [4]. Students were required to submit the Lego exercise (figure 1) modelled on Creo Parametric 3.0 to the automatic system and answer to a survey assessing the background of the students, user experience and the learning experience with the automatic system.
- A collection of exercises from was run through the automatic assessment system to check if they pass or fail the assessment

5 RESULTS

The system was successfully deployed and tested, both manually and online on a university basic CAD course. Analysis and visualizations of the conducted survey results are presented. The results indicate that students generally approved of the system.

102 students returned the exercise (95 accepted, 7 failed) and 91 answered the survey. The scale in figures 4–9 is the number of answers, the options for the survey questions are displayed in Table 1.

Table 1: Options for the survey questions

1	Disagree
2	Somewhat disagree
3	Neither agree nor disagree
4	Somewhat agree
5	Agree

Overall, the results of the survey were similar to results from previous studies concerning e-learning and automatic assessment. The main result was that the possibility to submit exercise independent of time and place is viewed positively among the students. Most students generally approved of the exercise instructions and the instructions on how to submit them to the automatic assessment system.

The results suggest that students felt that the system supported their learning (figure 8) Most students answered that they prefer using automatic assessment systems compared to submitting the work to course staff 9. Majority of the students also trusted that the system assessed their work correctly (figure 6). Most students did not see the feedback of the system as sufficient (figure 5). For each submission, the system only displayed the checks applied to the exercise with their results; the system could benefit from more visual feedback.

Almost half of the students completed and submitted the exercises without assistance from course staff (figure 7). The reasons for this might be that the students already had some experience with parametric CAD modelling. The exercise was not the first exercise on the course, and due to rearrangements made in Aalto University courses, over a third of the students had completed the exercise before. 40% of the students had previously used automatic exercise assessment systems.

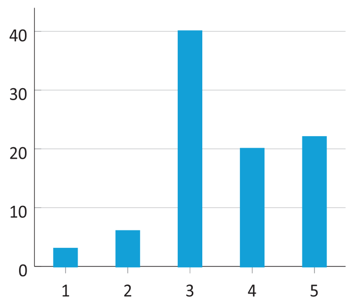

Fig. 4. The automatic assessment system supported my learning.

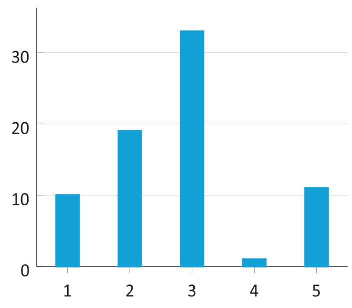

Fig. 5. The feedback provided by the automatic assessment system is sufficient.

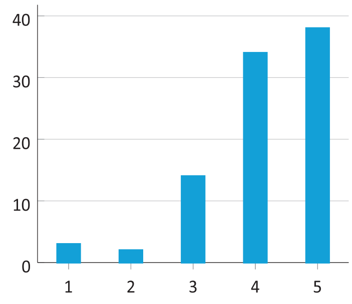

Fig. 6. I trust that the automatic assessment system assessed my work correctly.

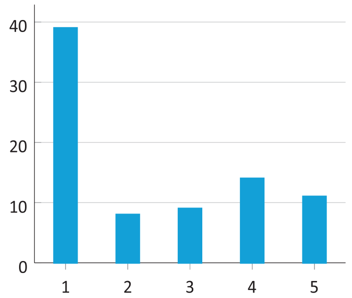

Fig. 7. I needed assistance from course staff to complete the exercise.

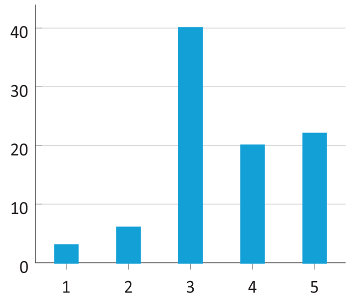

Fig. 8. The automatic assessment system supported my learning.

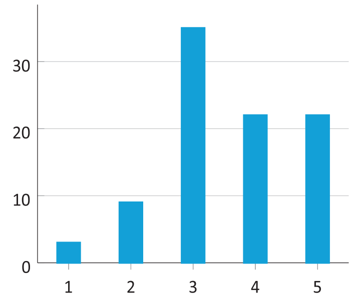

Fig. 9. I prefer using automatic assessment systems compared to submitting the work to course staff.

The system was also tested on an archive of old exercise submissions by students on courses in the past. It successfully identified several incorrectly constructed models, where a certain parameter sets produced a faulty output. This is probably because human assessment had failed to catch certain edge cases; for a human it is not possible to check a high number of parameter combinations in a reasonable time.

In some studies, the amount of false positives (exercises which are not correct but are reported correct by the system) in automatic assessment has been investigated. In this study, the amount of false positives was not evaluated, but the majority of students were confident that the system assessed their exercises correctly. When using automatic assessment systems, which compare input and output, it is important that the exercise and task are unambiguous and that the assessment is not dependent on how the output was achieved.

6 DISCUSSION

Students generally give positive feedback about online automatic assessment systems on courses. Especially students value the possibility to make progress on courses independently of time and place. The generally positive feedback received from students in the survey was along the lines of previous research.

Based on these results, further conclusions cannot be made about how the utilization of automatic assessment systems actually affect learning. It is possible, that automatic assessment does not have positive effects on learning. Completing exercises independently without interaction between a course assistant reduces feedback and in class, students get an understanding of their own skills, when they get to see the work of others. A potential positive effect is that more students in total might take courses which do not require attendance. The amount of required human resources per student is also significantly lower on courses with automatic assessment.

For the assessment of many exercises an approach where only inputs and outputs are compared can be sufficient. Similar methods that have already been in use in programming and mathematical education can be applied to exercise types specific to mechanical engineering, such as 3D parametric CAD modelling. More complicated exercises which include the evaluation of actual design choices will require human assessment in the foreseeable future. When using automatic assessment, the suitability of the exercises for automatic assessment must be taken into account in the design phase of the course.

Many other types of exercises in the domain of mechanical engineering would be suitable for implementing automatic assessment using simple methods, such as comparing the output of a simulation model to a known output of a correct model with the same input. The use of automatic assessment in the education of mechanical engineering can be further expanded and new automatic assessment tools will be needed to assess new types of exercises.

Since automatic assessment tools have been used in other fields, and service-oriented system already exist, duplicate work could be avoided if new assessment systems are integrated directly into existing e-learning systems.

During the last few years, several universities have opened Massive Open Online Courses (MOOC). The courses are typically free of charge, the materials are available online, students can progress on the course at their own pace and the exercises may be assessed automatically. The development of automatic assessment tools opens possibilities to create MOOC courses for new domains, such as mechanical engineering. MOOC courses have received criticism from the pedagogical viewpoint. MOOC courses should be used as tools to create a higher learning impact with the available resources, not as tools to minimize the effort put into teaching.

To conclude, in this research a novel system to assess mechanical engineering parametric CAD exercises was developed and successfully tested. Work continues at Aalto University to extend the functionalities of such systems and to establish MOOC style introductory level courses for mechanical engineering.

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Introductory Engineering Physics as Learning Environment for Engineering Skills

J.A. Tiili[1]
Tampere University of Applied Sciences
Tampere, Finland

Conference Key Areas: Fundaments of Engineering Education: Mathematics and Physics, New Notions of Interdisciplinarity in Engineering Education

Keywords: Engineering skills, Engineering physics, Active learning methods

ABSTRACT

Successful engineering profession requires substance skills in natural sciences and engineering but substance skills only are not enough. It is recognized that successful engineering professional needs a large variety of other professional skills like critical thinking, communication skills, problem-solving skills and interpersonal skills. Skills grow from students' learning environments and their methods to study.

By tuning the methodology in introductory engineering physics theory and laboratory courses, they can be tuned towards learning environment of these skills that future professional engineers need in their professional life, not forgetting physics. Overall, the use of active engagement learning methods enhance the adaptation of the skills.

The paper presents a short review of engineering professional skills, needed for success in working life today and in the future. The paper also presents shortly a development process of elementary physics courses (theory and lab) towards an active engagement of students.

It is also important that students recognize the skills and their importance of the skills they adapt. On basis of a survey, students see the importance of the skills quite similar to engineering academics and professionals. Survey also shows that important non-technical skills develop on engagement introductory physics courses.

[1] Corresponding Author
J.A. Tiili
juho.tiili@tuni.fi

1 INTRODUCTION

Stereotypical profile of an engineer among large population could be characterized as highly or purely technologically oriented male whose abilities and interests are purely concentrated in technological aspects. The community of engineering educators fortunately knows that the description does not represent the truth. Nowadays a global change and a change in working-life is so rapid that the adaptation to changing surroundings and the ability to work with people with different educational and cultural backgrounds are a part of every expertise, also engineering. But still, engineer is not an engineer without strong technological and scientific background. How to equip our engineering students with both high technological skills and all other non-technical but important working-life skills? is a challenge to engineering educators.

Engineering students are at the very first steps of growing their expertise. It is also important to help them to see the importance of non-technical skills and give them a possibility to grow into the skills that they will need during their future career as engineers. Technological expertise is mostly expertise of knowing or doing. Non-technical working-life expertise is in addition to these expertise of being, that needs a proper learning environment and time to grow. Therefore it is important that engineering students have a possibility to grow into these skills from the beginning of their studies. The importance if these non-technical working-life skills may not always be crystal clear to beginning engineering students.

2 ENGINEERING SKILLS AND ACTIVE ENGAGEMENT LEARNING METHODS

2.1 Engineering skills

European EUR-ACE accreditation criteria declares program outcomes that are minimum requirements in an engineering program [1]. Learning outcomes under EUR-ACE criteria include eight categories, which are:

- Knowledge and understanding
- Engineering practice
- Engineering analysis
- Making judgements
- Engineering design
- Investigations
- Communication and team-working
- Lifelong learning

From these categories, knowledge and understanding, engineering practice, engineering analysis and engineering design are considered more as technical and scientific knowledge that form the basis of engineering. Remaining four categories, making judgements, investigations, communication and team-working with lifelong learning include skills that are necessary among wider range of professions and areas of expertise.

European Society of Engineering Education (SEFI) has published a position paper in engineering skills in 2016 [2]. According to the position paper, engineering skills include deep technological knowledge but also beside it the ability to adapt in the changing surroundings. The adaptation means ability to work in rapidly changing world and working environments. Engineering curriculum should support this ability by including innovative, entrepreneurial and social skills. Paper also declares that engineering profession should broaden from deep technical knowledge towards critical thinking, creative thinking, reflective thinking, systems thinking, and synthesis capabilities of novel solutions. Engineering graduates should also develop a deep understanding of ethics and sustainable development. The position paper also declares that from the first cycle, engineering student has to learn how to learn, and the learning is for life. [2]

Recent survey from Ireland recognized 17 engineering skills from systematic literature review. Their importance was also ranked by academics and engineering professionals. Six most highly ranked skills by the professionals were also most mentioned in the literature survey. They were problem solving, communication, critical thinking, practical focus, self-direction and teamwork and collaboration skills. [3]

The skills mentioned above are not only limited in engineering profession. They are also more widely recognized in working-life. In 2011, Institute for the Future for the University of Phoenix Research Institute declared ten skills needed in working-life of 2020's. [4] The skills are:

- Sense making
- Social intelligence
- Novel and adaptive thinking
- Cross-cultural competency
- Computational thinking
- New-media literacy
- Transdisciplinarity
- Design mindset
- Cognitive load management
- Virtual collaboration

How to include these important skills in engineering curriculum? The most efficient way is not to arrange a lecture series of each mentioned topic but integrate the skills in teaching and learning methods of engineering education. The growth of these skills could be a part of everyday life of university community including teaching professionals. Many of skills mentioned above can be considered as skills of modern working-life. In a teaching and learning point of view, many of these skills are somehow present in active teaching and learning methods like Peer Instruction [5], Just in Time Teaching [6] and interactive lecture demonstrations [7].

Engineering physics courses are usually in the beginning of engineering curriculum and so at the hotspot to start the development of important skills. By including the development of suitable soft skills in introductory physics theory and laboratory courses, the courses themselves may change to more attractive to students.

2.2 Methods to study introductory physics in Tampere University of Applied Sciences

Since 2010, introductory engineering physics courses have been developed towards active engagement on both, theory and laboratory courses. The origin of the development has been a feedback from students and a pressure to develop teaching and learning towards more modern teaching and learning methods in which students take more responsibility of their own learning. The development of non-technical engineering skills comes as a side-effect of pedagogical development.

The development of introductory engineering laboratory courses have included the idea of students' self-designed laboratory work that students design, implement and report themselves, not under specific worksheet or detailed instruction. During years of implementation, students have reported their self-designed laboratory works using formal written report, poster presentation [8] or video presentation [9]. The development of introductory physics laboratories also includes the development of a course "Basics of measurement and scientific reporting", which is an integrated course in physics, mathematics and communication that supports the basic skills measuring, data processing and reporting [10]. The integrated method supports the skill development as a whole, not as separate subjects. The integrated method is visualized at fig. 1

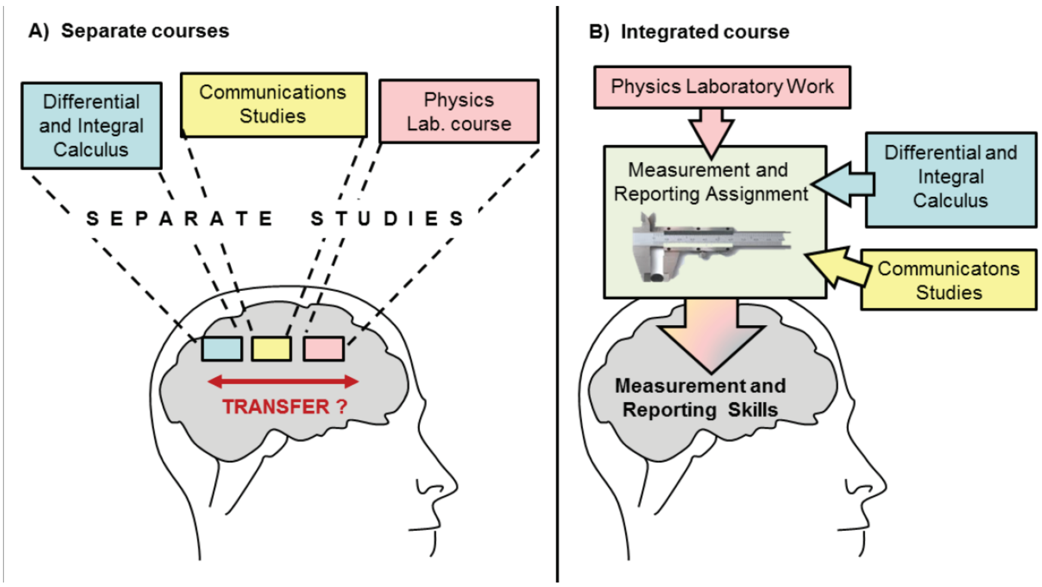

Fig. 1. A) Separate courses, B) integrated course [10]

Theory courses in Tampere UAS have also been under development process. The main direction in development has been the active engagement of students, inspired by Hake [11]. The implementation of active engagement includes following methods.

- Peer Instruction
- Continuous assessment with week exams
- Assessed group measurement assignments in theory classes
- The use of pre-lecture assignments
- Flipped classroom

The development process of the teaching and learning methods of physics theory courses have been documented in [12-14]. Overall the methods listed above include that students need to explain their own thinking to peers and actively progress with their studying during the course, not only at the final exam.

The aim of the study is to find out

- How students see the importance of non-technical engineering skills?
- How the students see non-technical engineering skills have developed in
    - Physics theory courses studied in active engagement methods
    - Physics laboratory courses using non-traditional methods

3 METHODOLOGY AND DATA GATHERING

On basis of [1] – [4], a questionnaire was built with a set of important non-technical skills. Chosen skills were problem solving skills, critical thinking, systems thinking, practical focus, synthesis of novel solutions, team working skills, creative thinking, co-operational skills, self-directional skills, sustainability, learning how to learn, communicational skills, cognitive load management, innovation skills, social skills, ethical skills, cross cultural competency and entrepreneurial skills. Students were asked their opinion of an importance of a skill on a scale 1 (not at all important) to 5 (very important). They were also asked how much each skill has developed during introductory physics theory courses and laboratory courses on a scale 1 (not at all) to 5 (very much).

A link to Google Forms questionnaire was emailed to 188 first and second year bachelor level engineering students studying electrical engineering, ICT engineering or laboratory engineering during April 2019. All of these student groups had just finished their introductory physics studies with similar study methodologies but different teachers. The courses aimed only to introductory physics and laboratory skills as described before. Either students or teachers did not know that development of non-technical skills will be asked at the end of the course.

54 (29 %) of students filled the questionnaire anonymously and answers are analysed as one group. From the data, means and standard deviations are calculated.

4 RESULTS AND CONCLUSIONS

The averages and standard deviations of students' answers are presented in *Table 1*. In the table, skills are presented in the order of their importance among students.

Table 1. Skills, their importance and development in introductory physics

	Average and standard deviation		
Skill	Importance	Development in physics theory courses	Development in physics laboratory courses
Problem solving skills	4.76 (SD 0.37)	3.46 (SD 0.76)	3.52 (SD 0.72)
Critical thinking	4.54 (SD 0.55)	3.44 (SD 0.89)	3.44 (SD 0.91)
Systems thinking	4.51 (SD 0.56)	3.39 (SD 0.76)	3.40 (SD 0.77)
Practical focus	4.43 (SD 0.57)	3.06 (SD 0.81)	3.06 (SD 0.82)
Synthesis of novel solutions	4.31 (SD 0.58)	3.13 (SD 0.96)	3.18 (SD 0.94)
Team working skills	4.30 (SD 0.65)	3.50 (SD 0.85)	3.48 (SD 0.85)
Creative thinking	4.28 (SD 0.62)	2.81 (SD 0.85)	2.88 (SD 0.82)
Co-operational skills	4.24 (SD 0.65)	3.31 (SD 0.88)	3.28 (SD 0.89)
Self-directional skills	4.17 (SD 0.56)	3.06 (SD 0.81)	3.06 (SD 0.82)
Sustainability	4.13 (SD 0.64)	2.46 (SD 0.85)	2.44 (SD 0.84)
Learning how to learn	4.11 (SD 0.66)	3.15 (SD 0.94)	3.14 (SD 0.94)
Communicational skills	4.02 (SD 0.47)	3.09 (SD 1.03)	3.06 (SD 1.05)
Cognitive load management	3.89 (SD 0.67)	2.57 (SD 0.85)	2.58 (SD 0.86)
Innovation skills	3.80 (SD 0.71)	2.08 (SD 0.81)	2.10 (SD 0.81)
Social skills	3.70 (SD 0.70)	2.74 (SD 0.87)	2.78 (SD .86)
Ethical skills	3.50 (SD 0.83)	1.94 (SD .77)	1.98 (SD 0.77)
Cross cultural competency	3.22 (SD 0.96)	1.61 (SD 0.75)	1.64 (SD 0.75)
Entrepreneurial skills	3.07 (SD 0.59)	1.50 (SD 0.69)	1.54 (SD 0.70)

Three most important skills scored by students were problem solving, critical thinking and systems thinking, which scored an average of over 4.5 of 5, which means that they are considered as very important. These skills were followed by practical focus, synthesis of novel solutions and team working skills. Result is quite similar to [3], in which the importance of skills were rated by academics and engineering professionals. Three of the top five skills in [3] are among six top ranked skills of students in this study. Only self-direction and communicational skills were ranked clearly less important than professionals and academics.

None of the skills' importance in questionnaire scored an average value of less than 3, which means that all skills included in the study were considered at least as neutral or important. Three less important skills were entrepreneurial skills, cross cultural competency and ethical skills, which all scored an average of 3.5 or less. So overall non-technical skills that were included in the study were considered as important or at least neutral among students.

How skills were developed during introductory physics courses? The most developed skills were problem solving skills, team working skills, critical thinking, systems thinking, co-operational skills, synthesis of novel solutions and learn how to learn. At the scale 1 (not at all) to 5 (very much), seven most developed skills scored averages between 3.14 and 3.52. This can be interpreted as the development of these skills is above average in students' opinion.

Among the top six most important skills, only practical focus was not among the most developed skills. This is a bit surprising because the practical focus was also assessed in laboratory courses.

Students were asked to assess the development between theory courses and laboratory courses separately. Averages in *Table 1* show that skill development between different types of courses are almost the same.

Three less developed skills were entrepreneurial skills, cross cultural competency and ethical skills. The skills are the same that were assessed as less important skills. The developments of these skills were assessed between 1.50 and 1.98 meaning just very little development.

As a conclusions it can be said that engineering students rank the importance of non-technical skills in a similar way to academics and engineering professionals. It is also noticeable that students see these non-technical skills developing already in the beginning of their studies in studying scientific subject that is usually felt difficult to study, if methods chosen are supporting the skill development.

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Developing Innovative Interdisciplinary Engineering Education with IoT Technologies

H-P Tsai
C-Y Wen

Department of Electrical Engineering
Graduate Institute of Communication Engineering
Innovation and Development Center of Sustainable Agriculture (IDCSA)
National Chung Hsing University
Taichung, Taiwan

Conference Key Areas: New notions of interdisciplinarity in engineering education; New complexity quest in engineering sciences

Keywords: creative thinking, internet of things, interdisciplinary engineering education.

ABSTRACT

As we know, incorporating artificial intelligence (AI) into the Internet of Things (IoT) already revolutionizes the world with the capabilities of improving operational efficiency and helping avoid unplanned system downtime. Therefore, on the basis of the previous project (focusing on conducting project-oriented learning and using the application development training as a concrete embodiment of the interdisciplinary engineering education), the current project aims at achieving cultivation of creative thinking and conducts two representative trainings: (A) Proposing AI-powered application proposals with IoT technologies and (B) Implementing the proposed projects with embedded systems. Essentially there are four major steps involved in this project: (1) Do: developing applications of IoT, (2) Check: performing capture, storage, and data analysis, (3) Adjust: executing data-based learning, and (4) Plan: revealing insights that redefine the problem. On the topic of education training, we plan to arrange cross-presentation of creative thinking techniques and experience sharing in the field, which allows the students to leverage AI-powered IoT technologies. This paper presents the preliminary results of this project, which emphasizes on human-centric design process and aims to develop an architecture model for problem solving and application service. On the theme of creativity and design thinking workshops, several lectures and experience-sharing group discussions will be arranged. Related Topics cover: the technology and concept of creativity and design thinking, training procedures, tools, and the need and importance of creative thinking in engineering education. Hope that through this workshop activities and thoughts training, students can cultivate the ability to think creatively in engineering education.

1. INTRODUCTION

With the developments of networked sensing technologies, significant breakthroughs have been made for the Internet of Things (IoT) applications. In order to successfully implement the IoT applications, smart solutions linked to the cross- cutting issues will be an important subject in future engineering education. For achieving cultivation of creative thinking and the realization of interdisciplinary engineering education, two representative trainings are conducted: (A) Proposing human-centric application proposals with IoT techniques and (B) Implementing the proposed projects and assessing the system complexity. Fig. 1 shows the roadmap of the IoT technologies, which suggests that the ability to monitor and control remote objects is essential for IoT applications in the next three years.

On the basis of our current project, essentially there are four major steps involved: (1) Integrating creative and design thinking with local infrastructures and services (e.g., efficient parking space management, design of a smart environment),
(2) Developing IoT applications (proposing a specific problem statement), (3) Embedded system implementations, and (4) Validating the system design via user feedback.

On the topic of education training, we plan to arrange cross-presentation of creative thinking techniques and experience sharing in the field, which may allow the students to leverage IoT techniques and describe general issues of people-oriented problems through observation and discussion. This paper will present the preliminary results of this project, which emphasizes on human-centric design process and aims to develop an architecture model for problem solving and application service.

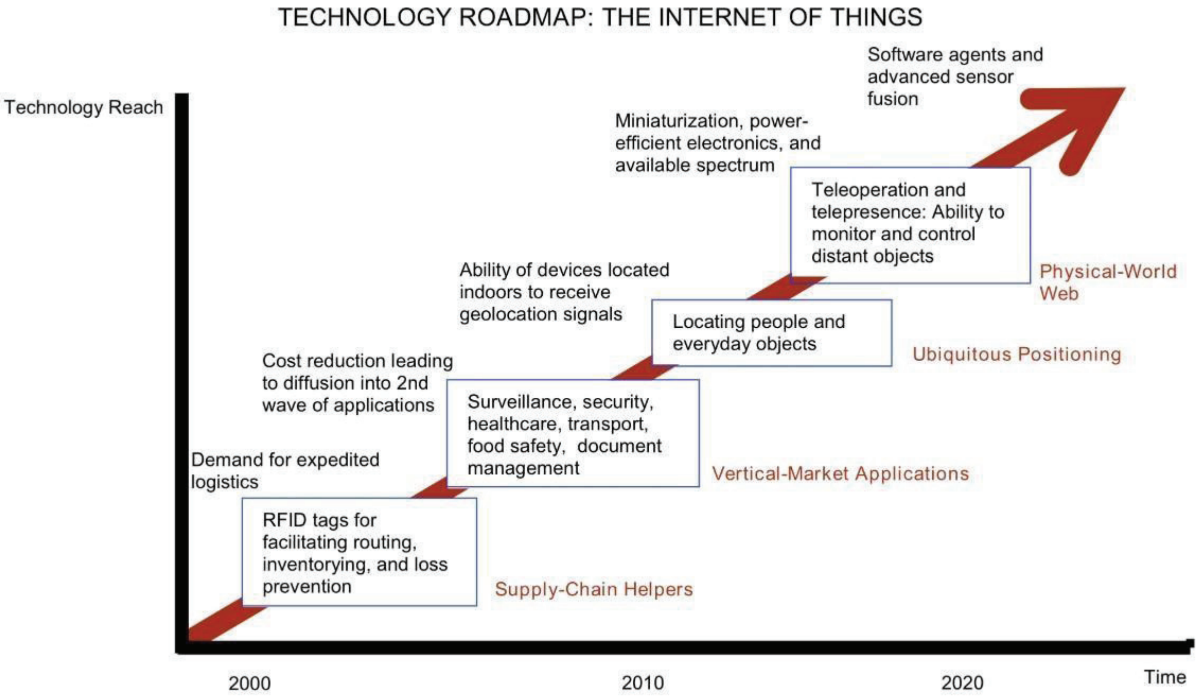


Fig. 1. Roadmap: IoT technologies [1].

2. COMPLEXITY OF AN IOT SYSTEM

An important source of complexity within the IoT paradigm comes from the great amount of data collected. In most cases, the data also need to be processed in order to be converted into useful knowledge. Fig. 2 describes the basis of managing the complexities of an IoT system, such as domain expertise, sensing and networking, infrastructure, flexibility, and security [2]. Referring to [3], in view of the recent proposals on how to handle the complexity of Big Data, there are three general approaches to carry out the ensuing very intensive data processing: (A) local processing; (B) edge computing; and (C) cloud computing. Fig. 3 shows a schematic overview of these approaches for handling the complexity of the intensive data processing.

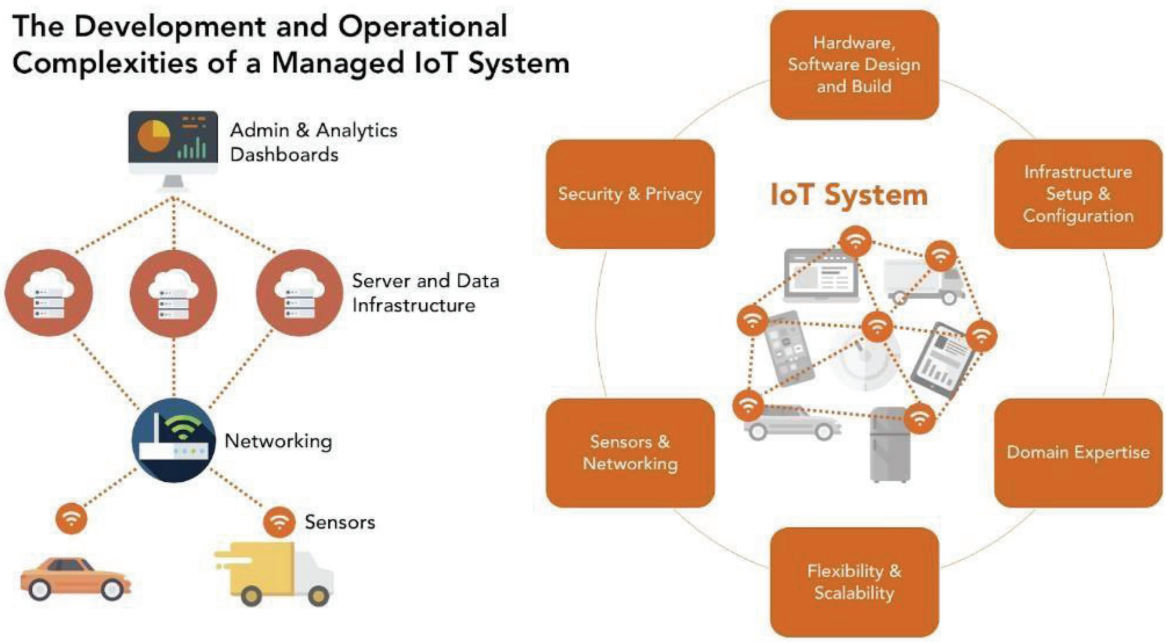


Fig. 2. The Complexities of a Managed Internet of Things System [2].

2.1. Local Processing.

This approach basically consists of processing the data where the data is collected. In this way, no raw data need to be communicated to remote servers. Instead, only the useful and relevant information is centralized to make smart decisions [4]. In addition, deploying the first level intelligence closer to the sensors produces an increase in the overall energy efficiency and significantly reduces the communication needs of many IoT applications, which develops the concept of 'smart sensor' with computing and communication capabilities. Nowadays, smart sensors are becoming integral parts of intelligent systems for the corresponding development of advanced applications.

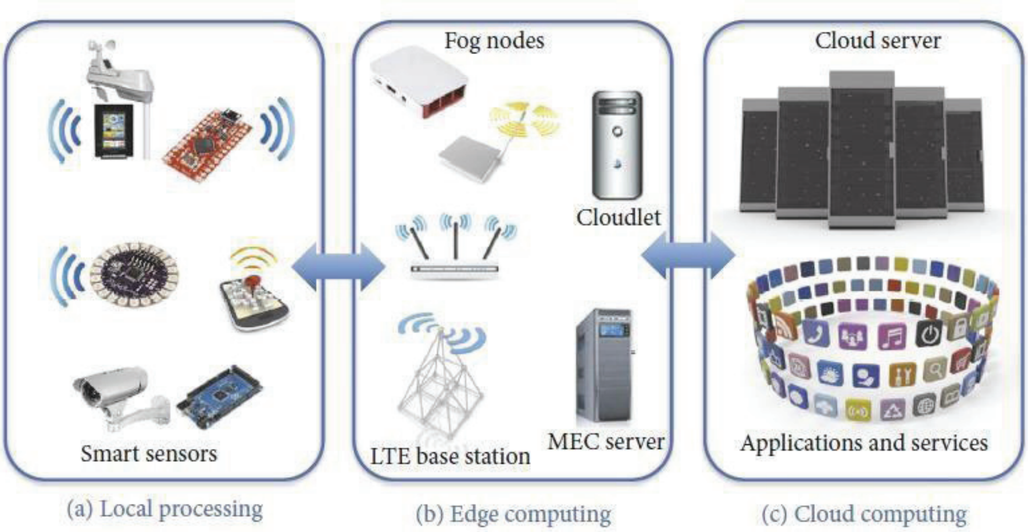


Fig. 3. A schematic depiction of the approaches to handle the complexity of the intensive data processing (modified and reproduced from [3]).

2.2. Edge Computing.

Edge computing consists of the deployment of storage and computing capabilities at the 'Edge' of the Internet. The 'Edge' of the Internet can be defined as the portion of the network between sensors or data sources and cloud data centers [5]. The edge computing paradigm aims at deploying computing, storage, and network resources in this portion of the network such that lower end-to-end latency, high bandwidth, and low jitter to services can be achieved.

2.3. Computing.

The cloud computing technology gives the IoT applications the possibility to work in different environments in a very agile way using the same infrastructure [6], which favors the development of large-sized data centers where the resources are optimized through virtualization and efficient management systems. and an IoT system is considered as a service.

2.4. From the Design and Engineering Education Perspectives

As mentioned above, the system design can take several aspects into account, such as power consumption, communication networks, and the availability of computing platforms. Therefore, dynamic solutions can easily adapt to the more favorable approach to better handle the complexity and meet the operation constraints. The research lines in this field aim at reaching a smooth engagement with the IoT ecosystem, mainly by reducing the management complexity of dispersed edge resources and developing mechanisms to maintain the security perimeter for the data and applications [7]. In this project, students are guided to explore the application design from engineering education perspectives.

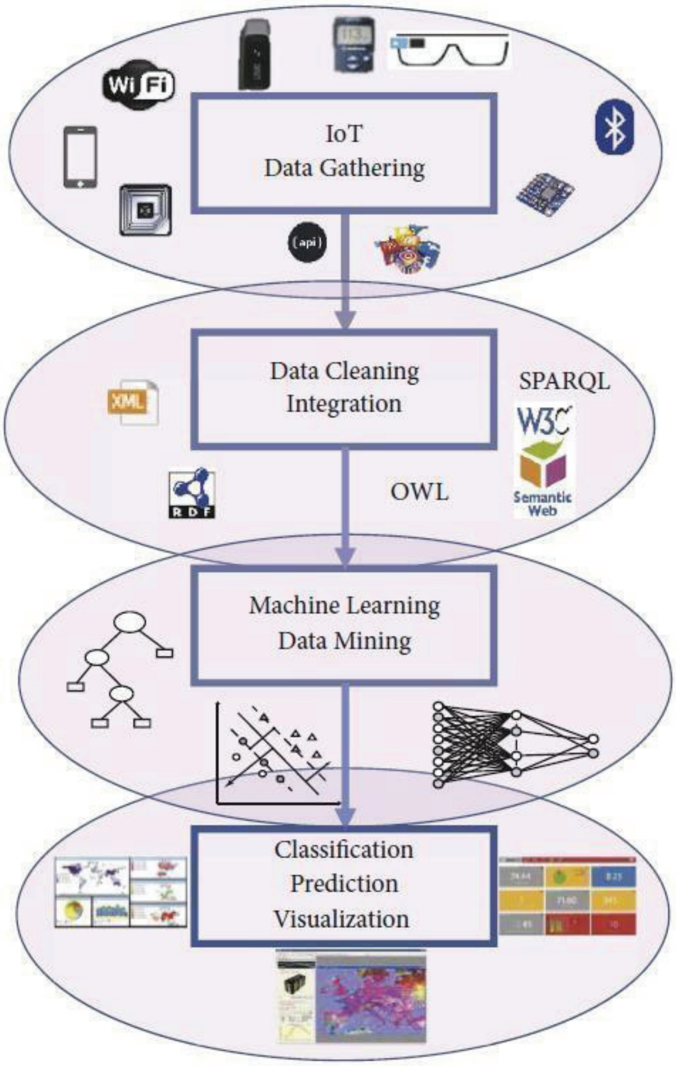
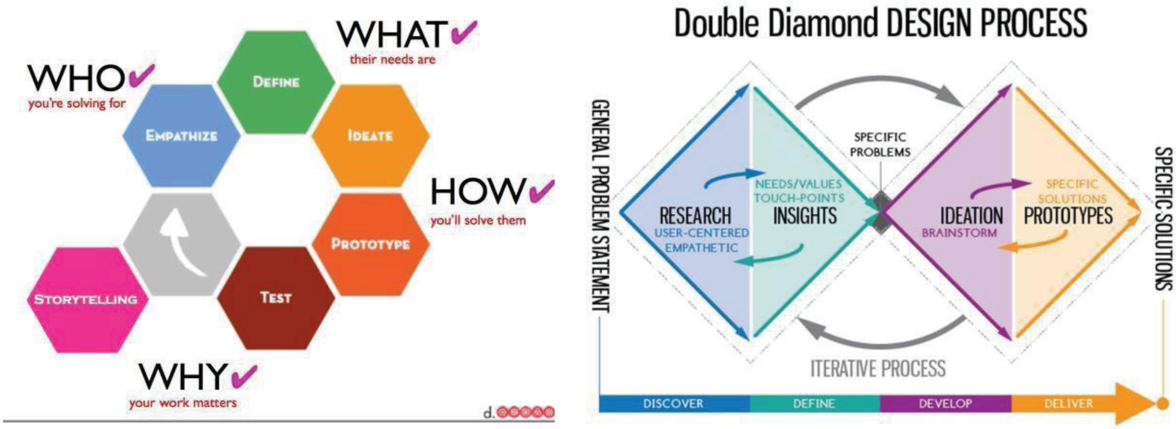


Figure 4. A classical procedure for the discovery of knowledge based on data gathered from a large number of diverse devices [3].

3. CREATIVE AND DESIGN THINKING PROCESS

In Figure 4, a classical procedure of discovering knowledge from the data gathered from a large number of diverse devices is depicted. Our project explores the learning experience by integrating creative and design thinking with local infrastructures and services. Using the process of design thinking presented by Stanford (Fig. 5 (left)), learners can translate their observations into insights, products and applications that can improve human life. Note that although the thinking process of is human-centred, it is a system design viewpoint. Furthermore, the industrial mentor may be consulted to guide the learners from discovering problems, defining issues, proposing possible solutions, and finally finding the best solution by using the Double-Diamond Thinking mode (Fig. 5 (right)). It is to be hoped that through the idea of the concept of creativity training, students can gain experience and skills for proposing general issues, which may provide a basis for defining specific problems (Empathy and Define). Then, through the combination of creative thinking training and engineering education, an appropriate solution may be explored to solve the problem (Ideate, Prototype, and Test).



(a) (b)

Fig. 5. (a) Design thinking process [8] and (b) Double-diamond thinking model [9].

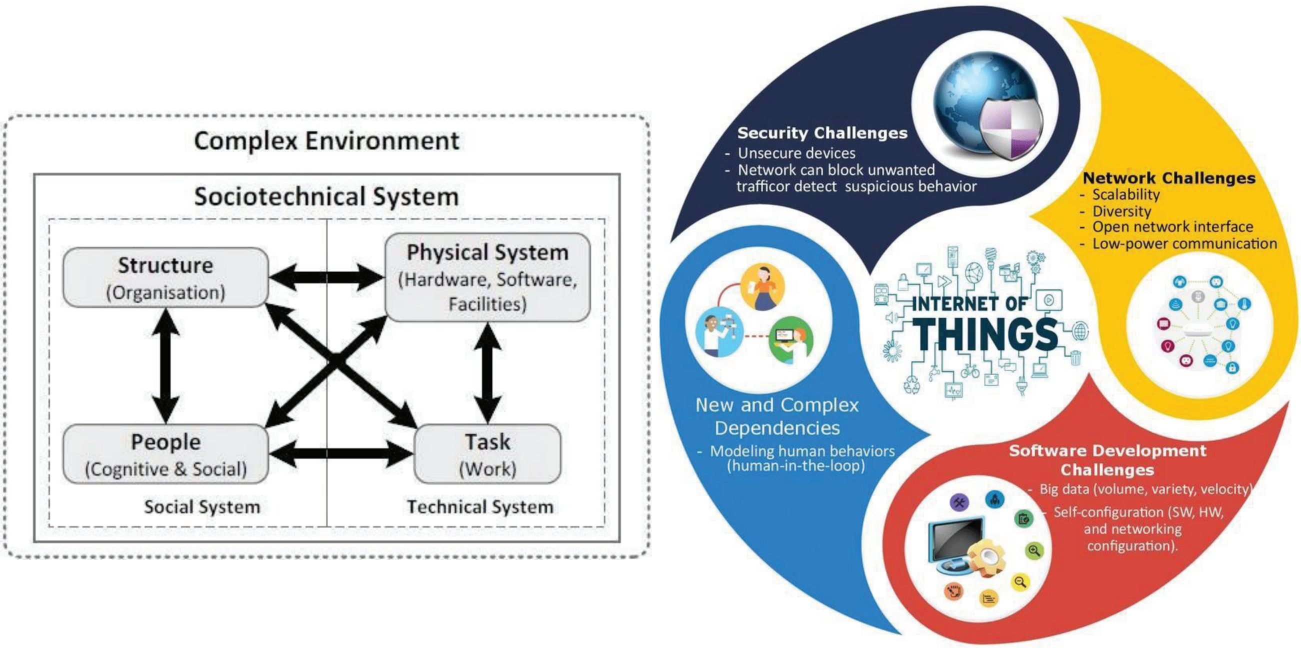


Fig. 6. A sociotechnical system designed in a complex environment [10]; the challenges of an IoT system design [11]

Therefore, on the basis of our previous project (focusing on conducting project-oriented learning and using the application development training as a concrete embodiment of the interdisciplinary engineering education), the current project aims at achieving cultivation of creative thinking (Fig. 6 (left)), where a sociotechnical system is designed in a complex environment, and conducts two representative trainings: (A) Proposing application proposals with IoT technologies and (B) Implementing the proposed projects with embedded systems and exploring the design challenges of an IoT system, as depicted in Fig. 6 (right). Essentially there are four major components involved in an IoT system: (1) Physical System (Software/Hardware): developing applications of Internet of Things (proposing a specific problem statement), (2) Structure/Organization: performing capture, storage, and analysis of data (finding insights in data), (3) People/Social System: executing data-based learning (validating and modifying the system design via feedback), and (4) Task/Technical System: revealing insights that redefine the problem.

3.1 Application Proposals

On the theme of creativity and design thinking workshops, several lectures and experience-sharing group discussions will be arranged. Related Topics cover: the technology and concept of creativity and design thinking, training procedures, tools, and the need and importance of creative thinking in engineering education. Hope that through the activities and thoughts training, students can cultivate the ability to think creatively in engineering education. For instance, guide students to think about the intelligence and complexity in the design of IoT applications (Fig. 7), considering sensing and recognition, knowledge processing, decision and support, and learning, which may lead the students to consider the design issue from cross-domain perspectives and may further provide a better solution for the social service.

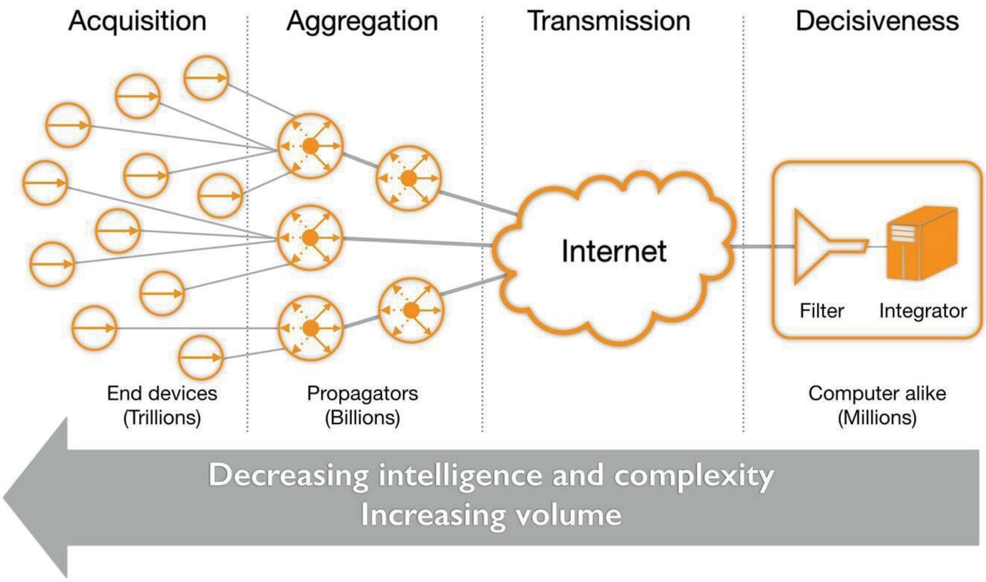


Fig. 7. The intelligence and complexity in the design of IoT [12].

3.2 Intelligent System Implementations

Under the architecture of an IoT application as shown in Fig. 7, we detail on I/O interface, interrupts and control mechanism, process operation w/wo OS, and data flow and storage. In addition to setting up a development environment, students will conduct the labs on building a basic IoT device to sensing data, integrating multiple sensors and performing a complex sensing task, interacting IoT device with IoT gateway, processing data among IoT device, IoT gateway, and the sever end. Fig. 8 tracks the IoT applications and depicts possible wireless technologies for achieving smart cities. To validate the system design, the users as well as domain experts are invited to give suggestions on the ideas and the proposals based on student's demonstration, which provides an opportunity for students to review their idea and proposals. The suggestion of the users, the degree of accomplishment, and the discussion among the students are helpful feedbacks to revise the content of the program.

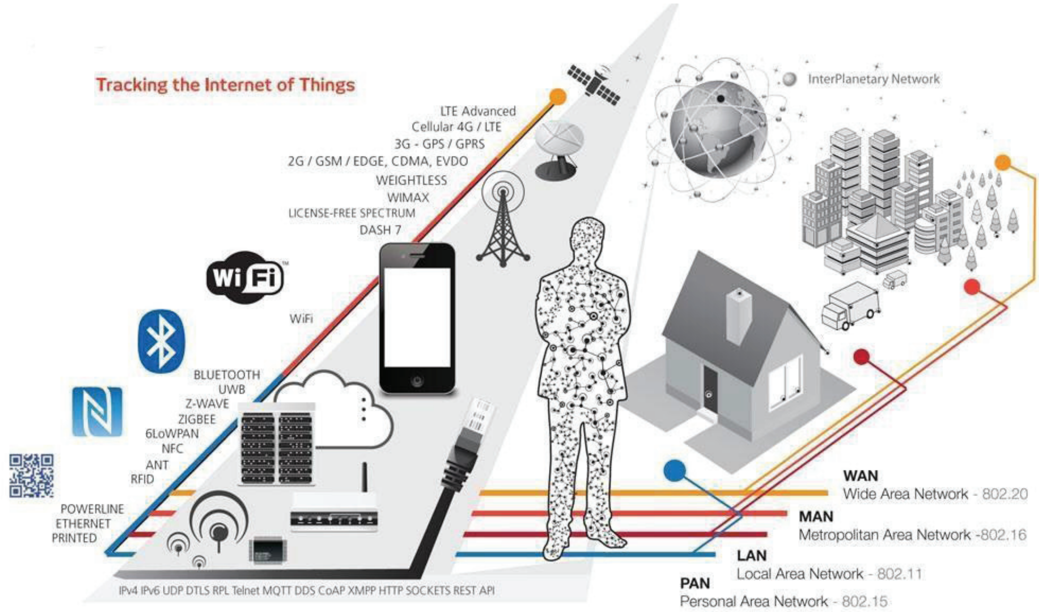


Fig. 8. possible wireless technologies for achieving smart cities [13].

4. CASE STUDY

A course project is applied to develop a practical application using IoT technologies. The students are grouped into teams to discuss application architectures from cross-disciplinary perspectives and propose their problem statements, project deliverables, system descriptions, project setups, prototype implementation, test and feedback. Here, we use a smart parking system as an example to describe the design issues.

4.1 Problem Statement

This paper explores the system design and the efficiency of parking space allocation in urban environments, where drivers make their decisions by drawing on various levels of information about the parking demand (number of drivers), and perfect knowledge of the parking supply (capacity) and the applied fees on the parking facilities. Referring to [14], the questions that arise in this respect are as follows:

- How do different amounts of information on the parking demand affect drivers' parking choices?

- Could this be controlled by the parking service operator to minimize the cost that drivers incur and the redundant cruising cost?

4.2 Design Goal

Parking has become an important issue that many modern cities need to deal with. Studies show that, the average time to find a parking spot is varying from 6 to 14 minutes for major large cities in the world. Knowledge about travellers and their behaviour is the key to influencing mobility. Parking policy is one of the most effective forms of influencing mobility behaviour. Since exact knowledge about parking and mobility behaviour is lacking and effects of parking policy are difficult to calculate, existing research is not always well translated into usable knowledge for practitioners. Moreover, parking violation is also a big problem for city traffic. Many drivers tend to park their cars in prohibited areas, which can cause traffic jam and lead to car accidents. Therefore, the design of parking lot occupancy tracking system is an important issue. This case study focuses on using sensors (e.g., ultrasonic sensors, PIR human body infrared sensors), Lora devices and a web server to achieve real-time monitoring of the parking spots, which may help on reducing the time for drivers to find parking spots. Fig. 9 shows a typical parking detection system.

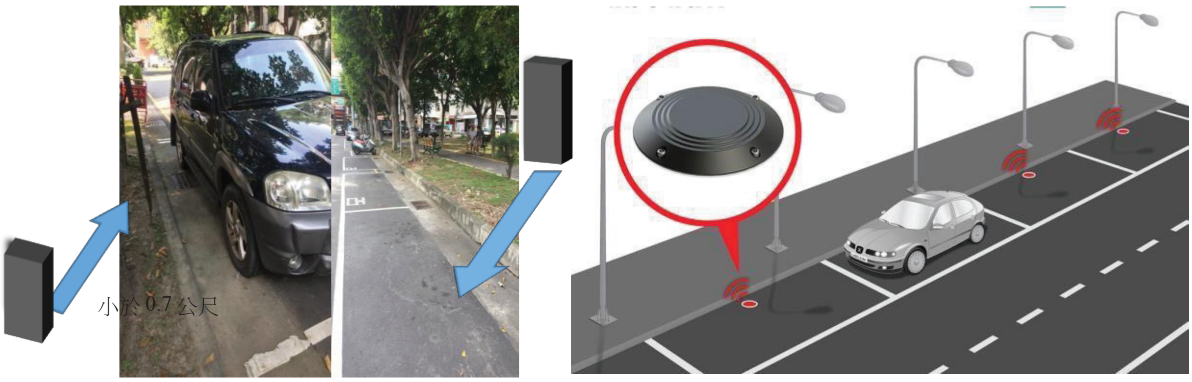


Fig. 9. The parking detection system.

4.3 Key Features and Contributions

In this case study, students explored parking space selection issue from strategic and psychological points of view. In the strategic method, they manipulated the costs and found out the optimum number of drivers in the competition. The studies show that the effect on total efficiency of system is significant and considerable. As shown in Fig. 10, by including drivers' personal characteristics in the type of decision making, the students managed to design a model which is much more efficient in information of available parking space. Possible scenarios are depicted in Fig. 11, where students may design a parking lot occupancy tracking system from inter- disciplinary perspectives for environmental monitoring, including parking detection, monitoring and control, parking guidance, and parking payment, which are explored to demonstrate the project concept.

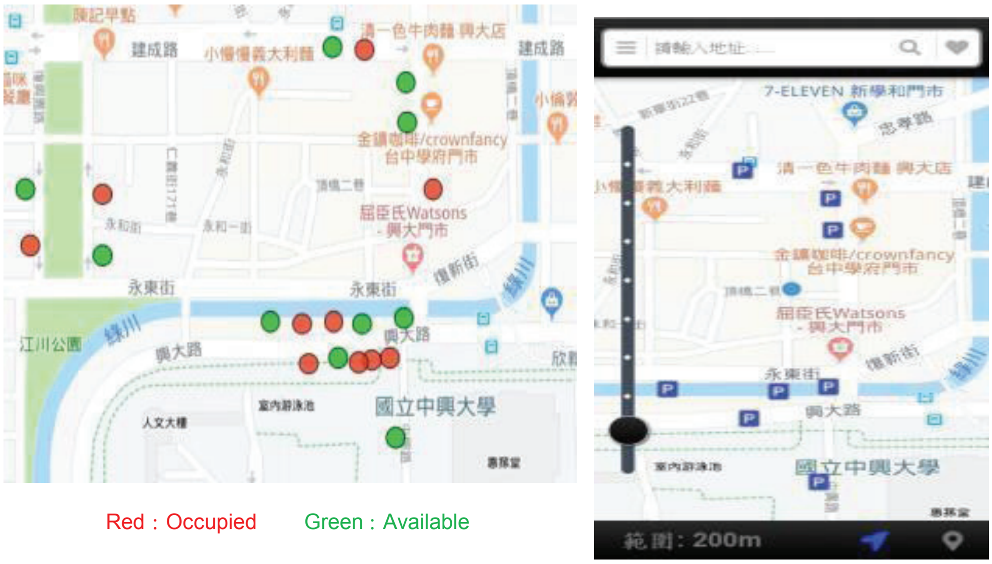


Fig. 10: Neighboring parking information (left)；information of available parking space (right).

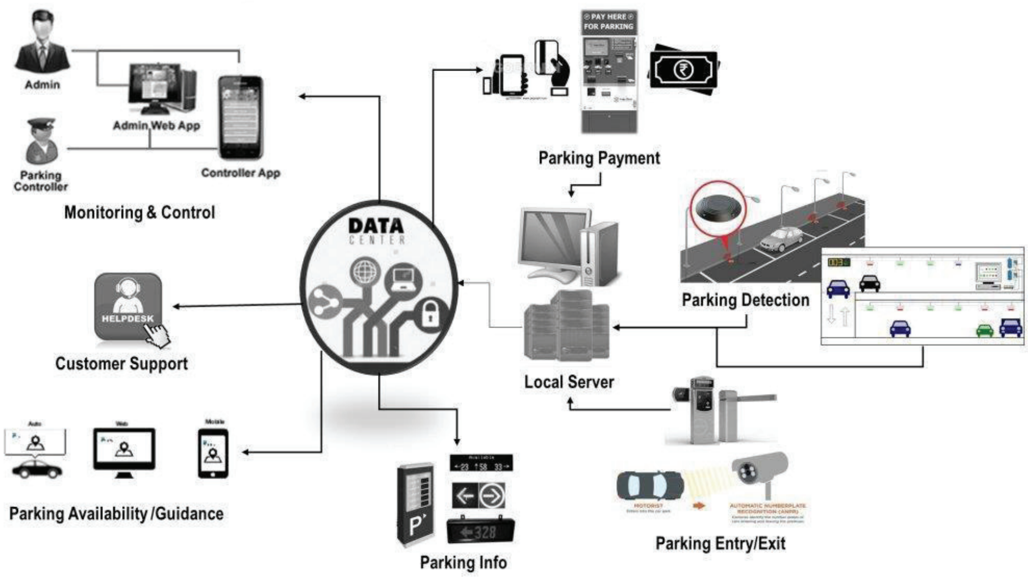


Fig. 11. A typical parking application with the IoT technologies [15].

5. CONCLUSION

This work presents the preliminary results of this project, which emphasizes on human-centric design process and aims to develop an architecture model for problem solving and application service. Hope that through the activities and thoughts training, students can cultivate the ability to think creatively in engineering education and think about the intelligence and complexity in the design of IoT applications. As shown in Fig. 12, top 3 skills in 2020 are “complex problem solving ability”, “critical thinking”, and “creativity”, which are essential to handle the complexities of an IoT system and provide an example to echo with the conference theme: “Complexity is the new normality?”.

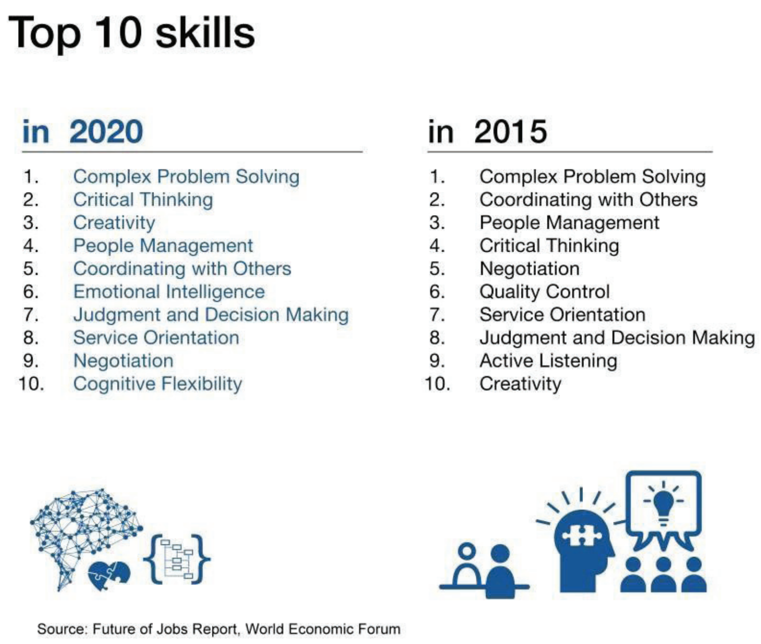


Fig.12. The top 10 skills you need to thrive in 2020 [16].

5. ACKNOWLEDGMENT

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Lifelong learning is a (self) complex: monitor; reflect; directed learning situation

Tun Zaw Oo*
*Doctoral School of Education, University of Szeged

Dr. Anikó Kálmán**
** Budapest University of Technology and Economics

(Department of Technical Education),

ABSTRACT

Nowadays, the world is changing rapidly. According to Schwab (2017)1 from the World Economic Forum, the convergence of digital, physical, and biological technologies has immense potential to be a source of world economic growth. Furthermore, many professionals said that new knowledge is rapidly being developed and disseminated, demanding that students/engineers acquire a wider range of skills and knowledge in these areas (Sopdek, Bernard & Oliva, 2007) 2. In learning that new knowledge, Kalman (2016) 3 said that learning should take place as close to application as possible. And in her lifelong concept, education must comprise all learning, not only formal but also informal and non-formal learning. These concepts are very important for the engineers and the methods of teaching. The formal learning is not enough for them, they also need to learn for life and not for the school report, and need new competencies, innovation and creativity in learning. Thus, there is a must not only for the students but also for the teachers to self-manage, self-monitor, and self-reflect on what they did to know whether they are effective or not. This paper aims to clear the dust from the ideas of lifelong learning for helping the engineers to acquire new technologies and new competencies for their lives. Therefore, the first section provides an account of the lifelong concept and its importance for facing new challenges in 21st century. In the second section are provided two key elements of lifelong learning such as self-directed learning and reflective practices for engineers.

Key words: lifelong learning, self-directed learning, reflective practices

1. INTRODUCTION

"The 21st century can be rightly regarded as a century of transformation, economic and cultural globalization and rapid technological development. In this context, it is vital to form a society which can adapt to the changes occurring in the environment, by always acquiring and updating knowledge and skills, necessary for everyday life and beyond" Due to the globalization and the growth of the fast-changing knowledge economy, people require upgrading their skills throughout their adult lives to cope with modern age, both in their work and in their private activities.

According to the above statements, we are not able to lead our lives without continuing to learn or updating our knowledge to adapt with the changing world. In the lifelong learning for adults, educational media and technology have evolved to the extent that there must be a paradigm shift in the way education and the working and learning processes are presented, conducted, and extended, changing these 'educational' norms in the context of lifelong learning. Thus, while we can't control much of the world changing around us, we can control how we respond. Our world is changing in such a frantic pace that if we do not continue to grow and develop; we will soon be left behind.

To update knowledge, people become aware on the importance of ongoing learning. Whilst the concept has been known since 1960s, most people are hardly involved in actual practices. They merely know about the lifelong learning is for the whole life of individuals (from the cradle to the grave). The essence of lifelong learning is meanwhile deeper and more beneficial for everyone. Lifelong learning's core values: exploring, and serving, coupled with benefits for the mind, body and spirit make it an incredibly powerful tool for personal transformation and enhancement. Actually, lifelong learning is a (self) complex: monitor; reflect; directed learning situation. If we know this concept well enough that may be useful for acquiring new competencies and skills.

In this paper we explain the lifelong learning concept is, how to self-monitor, self-reflect, and self-direct oneself; and how the teacher can help the students develop these interrelated situations.

2. HOW IS LIFELONG LEARNING (SELF) COMPLEX?

2.1 The Lifelong learning concept

There are various kinds of definitions for lifelong learning. According to UNESCO, *"lifelong learning is about acquiring and updating all kinds of abilities, interests, knowledge and qualifications from the pre-school years to post retirement which promotes the development of knowledge and competences that will enable adaptation to the knowledge-based society and also valuing all forms of learning*.

As the next concept, lifelong learning refers to "*the activities people perform throughout their lives to improve their knowledge, skills and competence in a particular field, given some personal, societal or employment related motives"*

The European Lifelong Learning Initiative also defines lifelong learning as *a continuously supportive process which stimulates and empowers individuals to acquire all the knowledge, values, skills and understanding they will require throughout their lifetimes and to apply them with confidence, creativity and enjoyment, in all roles circumstances, and environments.*

These basic concepts encourage people to update their knowledge to be able to adapt with the changing world.

Furthermore, Lifelong learning is viewed from the lifewide perspective. In the contemporary perspectives of lifelong learning as a lifewide dimension; it refers to the fact that learning takes place in a variety of different environments and situations, and is not only confined to the formal educational system. Actually, lifewide learning covers formal, non-formal and informal learning. Life-wide learning involves a breadth of experiences, guides, and locations and includes core issues such as adversity, comfort, and support in our lives. Then, as the another perspective of lifewide learning is the experience in management of ourselves and others, of time and space, and of unexpected circumstances, turns of events, and crises. This learning brings skill and attitudinal frames for adaptation for how to adapt, to transport knowledge and skills gained in one situation to another, and to transform direct experience into strategies and tactics for future use.

However, in Kalman's book, "Learning – in the new lifelong and lifewide perspectives" she states that the term 'lifelong' does not refer to only one dimension of lifelong, but it signifies these two (lifelong and lifewide) dimensional learning process itself, which is as 'long' and as 'wide' as life itself since it is an inseparable part or constituent of life, which the phrase 'lifelong' wishes to capture. According to her, the terms 'lifelong' and 'lifewide' are actually involved in the process of lifelong learning process. The most importance is how to increase the lifelong long learning more for all individuals. The most important thing is how to increase lifelong learning for everybody.

In my opinion, however, the term *'lifelong'* education does not refer to the longitudinal or temporal dimension of continuous learning or education, but it signifies *the concrete two-dimensional learning process itself*, which is as long and as wide as life itself since it is an inseperable part or constituent of life, which the phrase 'lifelong' wishes to capture. 'Lifelong' has been two-dimensional from the beginning; simultaneously meaning the vertical integration of the consecutive levels of education, the requirement that higher and higher levels be built upon each other, and horizontal integration, that is, the harmonisation of learning activities with one another and other activities such as cultural activities, work, family life and public-civic activities. The so-called integrated curricula or cooperative educational programmes have been designed with this perspective.

If we merely want to refer to one dimension of lifelong learning, the vertical dimension, we use the terms lifecourse, lifetime, lifespan or life prospect. If we refer to the other, horizontal dimension or integration, we can use the term 'lifewide'

For lifelong and lifewide learning to function well, there is an urgent need to view afresh at the current trends of the technological landscape and learning paradigms impacting on education in order to formulate the most appropriate strategies for an integrated approach. Thus, the core to help the learning paradigms change is to know how the lifelong learning is a (self) complex; monitor, reflective, directed learning situation, and how it can be improved to all. Like the Edwards et al.'s (2002) 4 belief, "self-directed learning (self-managing & self-monitoring), and reflective practices (self-reflecting) are the key tools for the lifelong learning process", how the self-monitoring, the self-reflective and the self-directing are important for individual's lifelong learning is described in the following.

2.2 Self-monitoring learning situation, a part of lifelong learning process

As described in several studies, the self-monitoring can be categorized into two groups: namely behavioral and academic self-monitoring.

Individuals, who monitor themselves behaviorally are much more likely to monitor themselves academically as well. When it comes to academic self-monitoring, it is also necessary in order to use the metacognitive strategies in academic learning. Likewise, self-monitoring is also a vital skill for the individual who can use learning strategies, regulate their own learning; that is to say, the individual has learned to learn.

About behavioral self-monitoring, self-monitoring is an evidence-based strategy that involves systematically observing one's own behavior and recording detecting whether or not the target behavior occurs. Furthermore, self-monitoring is claimed to be a main component of self-management, providing an opportunity for collaborative diagnosis and treatment evaluation, and forming the starting point for self-insight and initiation of change in patterns of experience and behavior. In few studies, the self- monitoring was highlighted as a two-stage process involving (a) discriminating the occurrence/non-occurrence of a target behavior, and (b) self-recording some aspect of the target behavior.

About the cognitive self-monitoring, it may be part of the cognitive process by which indeterminate zones of practice are identified in that it leads trainees to realize the problem initially, and then to actively respond by engaging in reflection-in-action. Moreover, self-monitoring refers to students' efforts to observe themselves as they evaluate information about specific personal processes or actions that affect their learning and achievement. By depending upon this information, students can assess their progress and make necessary changes to ensure goal attainment. They exclaimed that self-monitoring can serve as a tool for self-improvement by enabling students to direct their attention, to set and adjust their goals, and to guide their course of learning more effectively.

Therefore, today's youths should know how to self-monitor themselves for their lifelong learning. In 2012, McDougall, Morrison and Awana (5) pointed out some procedures for self-monitoring. They said that self-monitoring refers to behavioral self-control and it was mentioned as the self-assessment followed by self-recording. In the behavioral self-control process, three steps for all individuals for their continuous learning are presented. These steps are (a) self-determination of reinforcement and self-administration of reinforcement (procedures in which individuals decide how and when to reward themselves contingent upon successful performance of predetermined tasks); (b) self-evaluation (whereby individuals judge the quality of their performance or products); or (c) self-graphing (whereby individuals chart their behaviors on graphs which display an on-going record of the frequency, duration, rate, or accuracy of those behaviors). These three steps are useful for the learners in the self-monitoring process.

Moreover, the teachers should also know how to help their students self-monitor their progress which can lead to their lifelong learning process. Lane et al. (2011; p. 148) 6 outlined the following steps for implementing self-monitoring of life-long learning process:

1. Establish prerequisite conditions
2. Identify and operationally define the behaviors

3. Design the self-monitoring procedures, including a monitoring form
4. Teach the student the self-monitoring procedures
5. Monitor student progress
6. Consider maintenance and follow-up

To think further the statements of the above authors, we can find three groups such as definitions of self-monitoring, procedures for self-monitoring, and teacher's roles to help students implement their self-monitoring process. First, to conclude the above definitions of self-monitoring, there are two groups of self-monitoring; behavioral and academic. And self-monitoring can be interpreted as the self-insight and initiation of change in both behavioral and academic self-monitoring. It is because we can find some words similar in meanings such as *self-insight in patterns of experience and behavior; discriminating the occurrence or nonoccurrence of a target behavior; self-recording some aspect of the target behavior; identify to realize the problem; observe themselves to direct their attention*. Second, in the part of self-monitoring procedures, the students can do self-monitoring very well by following these procedures, especially, first self-assessment, and second, followed by self-record. Third, the teachers can also help their students by using the above six steps for implementing their self-monitoring. Actually, this monitoring stage is the most basic part for all individuals.

2.3 Self-reflective learning situation, a part of lifelong learning process

Self-reflective learning is another situation of individuals' lifelong learning process. Reflective *practice is the ability to reflect on one's actions so as to engage in a process of continuous learning*. Therefore, self-reflective practice is important for the lifelong (continuous) learning. Actually, this idea of reflective practice is originally used by Dewey and its meaning is *assessing the grounds (justification) of one's beliefs*, *the process of rationally examining the assumptions by which we have been justifying our convictions*. To become lifelong learner, the individual needs to rationally justify his/her own beliefs about the actions. In some explanations of reflective practice, they highlighted that a person which reflects throughout his or her practice is not just looking back on past actions and events, but is taking a conscious look at emotions, experiences, actions, and responses, and using that information to add to his or her existing knowledge base and reach a higher level of understanding. According to their explanation, the learner needs to make conscious look (not mere looking) at the past events; only then can the learning improve more and more. If we have a look to John Dewey's definition of reflective practice, it is *the active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends*. Thus for the learners, they need to learn with careful consideration for their continuous development.

Reflective *practice is probably the most valuable tool in one person's box of resources and enables him to think both backwards and forwards*. Thus, reflective practices are of great importance for the lifelong learning process. In lifelong learning, the learner has to reflect on his past and present events (in studies) and move towards his/her further progressive development. Without this kind of reflection, he/she will not become a successful learner. Then, if we have a look at the definitions of reflective practice, their main point is that *reflection is a process of viewing an experience of practice in order to describe, analyze, evaluate and to inform learning about practice*. Thus reflective practice can be useful and even called lifelong learning process – to describe and analyze the current studies and to progressively change to another step of studies.

Reflective practices can help in both present and past events effective learning. There are two kinds of reflective practices such as *reflection-on action* and *reflection-in action*. Reflection-on-action is perhaps the most common form of reflection. It involves carefully re-running the events in mind that have occurred in the past. The aim is to value the strengths and to develop different, more effective ways of acting in the future. Reflection-in-action is the hallmark of the experienced professional. It means examining the own behavior and that of others while in a situation.

There are many available reflective practices for their students, some of which can be used for our lifelong learning development. They are; personal journals, dialogue journals, highlighted journals, key phrase journals, double-entry journals, critical incident journals, three-part journals, free association brainstorming, quotes, quotes in songs, reflective essays, directed writings, experiential research paper, directed readings, ethical case studies, class discussion, students' portfolios, it's my bag, express yourself, small group week, email discussion groups and class presentations. These reflective practices can be done not only by the students themselves, but also can be encouraged by their teachers. Apart from these practices, based on Dewey, Oluwatoyin (2015) 7 described some questions for reflective practices that can be used in thinking process of lifelong learning.

- What was I aiming for when I did that?
- What exactly did I do?
- How would I describe it precisely?
- Why did I choose that particular action?
- What theories/models/research informed my practice?
- What was I trying to achieve?
- What were the reasons for doing that?
- How successful was it?
- What criteria am I using to judge success?
- What alternatives were there?
- Could I have dealt with the situation any better?
- How would I do it differently next time?

In one concept about lifelong learning, it is actually that *lifelong learning focuses on the accumulation of skills and qualifications as a means of coping with changes and uncertainty in professional practice – they believe that lifelong learning is an important tool for developing a habit for reflective practice*. Thus, for these two options (reflective practice and lifelong learning), one is necessary for the other. And we can even say that lifelong learning is the self-reflective process for individuals. Furthermore, Pollard, et al., (2014) 8 said that the teachers can ask the following questions to encourage the students to make self-reflection:

1. How might you find this out?
2. What skills did you use?
3. How did your group function?
4. What worked and what didn't?
5. What connections did you make?
6. How was your thinking pushed?
7. Why did you choose the approach you did?

8. What did you enjoy and why?
9. How could you have done it differently?

To conclude the above authors' findings, three main parts can be found like *definitions of reflective practices, the time events in which reflective practices can be done,* and *reflective tools*.

In the part of definitions, we can notice that the reflective practices (described in different ways; *to reflect*, *rationally examining*, conscious look, *careful consideration*, *think both backwards and forwards*, *viewing an experience of practice*, *recapture their experience*) lead to the lifelong learning (described in different ways; *continuous learning, justifying our convictions,* adding information to his or her existing knowledge base, *the further conclusions to which it tends,* move to his further progressive development, learning about practice, working with experience). Thus, we can conclude that lifelong learning is the (self) reflective process. For all individuals' lifelong learning development, these above mentioned reflective practices are of great importance. Only when they can reflect on their own behaviors can they lead to their successful lifelong learning.

As the third conclusion on reflective tools, we can find many kinds of reflective practices for supporting individuals' lifelong learning practices. Finally, some reflective questions are presented to both students and teachers to encourage the students' reflective practices in their lifelong learning, which is important point in the process.

2.4 Self-directed learning (SDL) situation, a part of lifelong learning process

Lifelong learning is also a self-directed learning situation. Learners' self-directed learning has been defined and described in various ways such as autonomous learning, independent learning, student-initiated learning, student-centered learning and all these terms *carry the meaning of becoming less and less reliant on the teacher or tutor; while the students take on more responsibility for their own learning*. Thus, to become lifelong learner, the students can achieve self-directed learning by monitoring and reflecting themselves whether they had prior higher-order understanding or not.

Then, from the point of lifelong learning, the acquisition of self-directed learning skill (SDL) equips students to be lifelong learners and referred to *a process in which individuals take the initiative in diagnosing their learning needs, formulating learning goals, identifying human and material resources, choosing the appropriate learning strategies, and evaluating learning outcomes*. To diagnose, formulate and identify the learning needs, the reflective practices are therefore of great importance for the students.

For self-directed learning, the individual has to decide about the learning goals and strategies, make decisions on how to use the resources and how to evaluate the success, sustain his/her motivation and make appropriate evaluations on learning process. In self-directed-learning, the control is gradually transferred from the teacher to the learner and learners in the learning goals and how to carry out a task have greater independence. Self-directed learning emphasizes the role of motivation and determination of learners at the beginning and continuation of efforts to achieve the goals. In their studies, they described that self-directed learning is controlling and directing the process consciously and constantly to understand any situation-concept, solve problems, having or strengthening any skill.

Actually, the self-directed learning is a teaching method that can be defined based on the learner's responsibility. Then, to dawn upon the lack of teacher's direct participation on student's self-directed learning, self-directed learning can include various types of individual and group activity of students that they have undertaken in the classroom and extracurricular activities at home without the direct participation of the teacher. In student's self-directed learning, there is no need of teacher' participation; however, the student cannot lead his lifelong process without reflective practice.

Richards and Lockhart (2005) 9 described some reflective questions for the students' self-directed learning. These questions can be self-reflected by the students. They are as follows.

- What am I learning?
- Why am I learning it?
- How am I learning it?
- How am I using what I am learning?
- What are my strengths and weaknesses in learning?
- What must be my learning priorities?
- How can I improve and build upon my learning process?
- How well can I work towards my short-, medium- and long-term goals.

Although teachers cannot directly participate in student's self-directed learning, in the schools, they can teach students by emphasizing self-directed learning skills, processes, and systems rather than content coverage and tests. For the individuals, self-directed learning involves initiating personal challenge and developing the personal qualities to pursue them successfully.

Kalman (2016) highlighted the teachers' roles for helping the students to become self-directed learners. In these roles, the teacher should:

1. Serve as a resource for the individuals or small groups, with certain parts of the learning content,
2. Help learners assess their needs and competences so that everyone can plan their individual study schedule,
3. Provide feedback about each learner's subsequent draft plans or ideas,
4. Specify the resources available and provide new information in the topics specified in the survey of needs,
5. Compile a collection of resources about the information, media and models related to the specific fields or topics of study,
6. Organize how to establish contact with people who function as resources in specific topics,
7. Work with the learners as mock audience or in order to provide stimulus outside regular classes and group activities,
8. Help students develop an approach to learning which promotes independence,
9. Encourage debates, asking questions and small group activities in order to arouse interest in the learning experience,
10. Help learners develop a positive approach to learning and self-directed interest,
11. Control the learning process including such activities as the continuous recognition of needs, the obtainment of continuous feedback and promoting learner participation, and

12. Provide confirmation or assessment of student performance both during the process of obtaining the learning experience and at the end of it.

To conclude the above statements on self-directed learning, we can often find terms which are similar in meaning; *individuals take the initiative in diagnosing their learning needs, individual has to decide the learning goals and strategies, the control is gradually transferred from the teacher to the learner, based on the learner's responsibility, and activities without the direct participation of the teacher*. These terms dawn upon the students' self-directed learning. Thus, we can conclude that lifelong learning is also self-directed learning process. The reflective practices can increase the individuals' self-directed learning process. These reflective processes are interrelated with individuals' self-directed learning. By following the above suggestions of students and teachers' roles for self-directed learning, not only the teachers can encourage their students for their continuous learning process, but become the students empowered to develop their lifelong learning themselves.

CONCLUSION

Actually, lifelong learning is self-directed learning. To make self-direction, the learners need to do self-monitoring first, based on self-assessment, and self-reflecting on present and past actions to find out which are their strengths and weaknesses. After completing these basic learning situations systematically: self-monitoring and self-reflection, can they self-direct own successful lifelong learning.

This paper intends to be a concept paper of lifelong learning which is a (self) complex; monitor, reflective, directed learning situation. In the literature cited, the three parts are systematically described such as how to do self-monitoring, self-reflecting, and self-directing; and how the teacher can help their students to improve these three scenarios. If these steps are carefully followed, today's learners can lead their successful lifelong learning process and may become productive citizens for future.

According to the European Lifelong Learning Initiative (which defined lifelong learning as a continuously supportive process which stimulates and empowers individuals to acquire all the knowledge, values, and skills), we can acquire knowledge, values, and skills if we understand the learning process in its entirety and complexity and apply it lifelong.

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Analysis of the significantly improved results after the implementation of a major pedagogic reform in an engineering degree programme

H. Valmu[1], E. Kupila, R. Kallio
Metropolia University of Applied Sciences
Helsinki, Finland

Conference Key Areas: Adaptive learning, revolution of assessment

Keywords: Curriculum design, pedagogical reform, drop-out rate, course integration

ABSTRACT

All the engineering curricula of the Metropolia University of Applied Sciences were renovated in 2014. The teaching and learning has since been based on larger course entities and collaborative pedagogy. The most thorough reform was conducted in the department of electrical engineering where all the courses are now organized in 15 ECTS entities, which are given by a larger number of professors integrating their subjects and assessing the course with one single grade. It has been already previously shown that the reform is extremely successful with respect to student progression and drop-out rate, and the improvement has been much more significant in this department compared to the other engineering departments making only minor pedagogical changes. A student feedback survey was completed in 2017 and the student satisfaction has been greatly improved in the student groups following the new curriculum. The first group of these students graduated after the spring term of 2018. Previously only 40% of the graduates graduated in due time (60% later). Due to the modular structure of the curriculum as well as other key elements of the new pedagogy the programme made its record ever in the number of graduates in 2018 (67% in due time or earlier; 33% later). The drop-out rate is as well significantly improved (decreased). This paper presents the new pedagogy, the significantly improved metrics as well as the actual process of implementing a revolutionary pedagogic paradigm shift in an engineering degree programme discussing as well the major challenges of the implementation

1 INTRODUCTION

Traditionally one of the common challenges in the engineering degree programmes of the Finnish Universities of Applied Sciences (UAS) has been the high drop our rate as well as the students' slow progression in their studies. In 2014 the Finnish ministry of

[1]H.Valmu
heikki.valmu@metropolia.fi

education decided to base the funding of the universities on two key factors: the number of graduates as well as the number of students completing more than 55 ECTS yearly (of nominal 60 credits). Before the implementation of the new funding scheme only 30 - 40% B. Eng graduates completed their studies in the nominal 4 years (8 semesters). *Fig.1* shows the percentages of the graduates of the degree programme in Electrical Engineering and Automation Technology (EE) of Metropolia UAS of four consecutive years of intake. In 2015 40% of the graduates (year of intake 2011) got their degree in due time and this result was the second best of the engineering programmes of the university. The results were improved for student groups starting in 2012 and 2013 because by then the new funding scheme was published and minor steps of improvement were taken. As seen in *Fig. 1* the results were significantly improved for the 2014 group (graduation in 2018). This is due to the new pedagogical methods and the modular curriculum implemented in 2014. This paper discusses the methods of the pedagogical reform and shows the results in detail. The improvement is significantly better in this programme compared to the other engineering degree programmes of the university due to the more thorough implementation of the pedagogical reform.

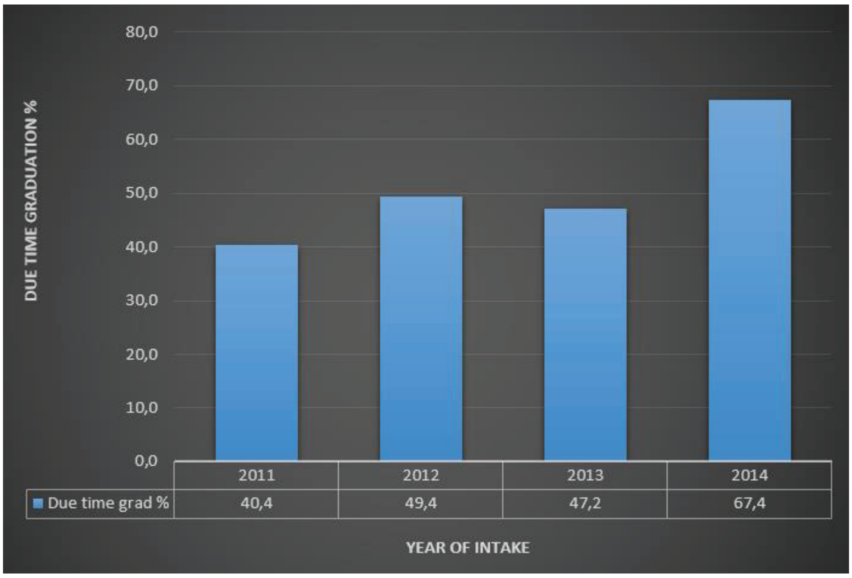

Fig. 1. The percentage of the graduations in nominal time in the degree programme in Electrical Engineering and Automation Technology for four consecutive years.

1.1 The degree programmes and study groups

The EE programme is the second largest engineering degree programme in Metropolia UAS having a yearly intake of 160 full-time (daytime) engineering students as well as 50 part-time students. The nominal duration of studies is four years (8 semesters) in both cases. The same department runs as well a parallel programme in electronics in which tuition is completely in English as well as a post-graduate program with a yearly intake of 30 students. The English electronics programme and the post-graduate programme are not included in the analyses because their results may not be clearly compared to other degree programmes of the university. The results of the electronics programme have been as well analysed and the trend is similar to the results presented here but a detailed analysis of the post-graduate programme is still to be done.

1.2 Different approaches for improvement

Before 2014 all the engineering curricula of the university were based on relatively small courses (typically 3 ECTS) and one of the main reasons for the poor metrics was the traditional way of organizing lots of small theoretical courses of mathematics and physics in the beginning of the studies thus increasing the number of drop-outs during the first four semesters and forcing the students to retake these courses over and over again during the final years complicating the completion of the professional studies and thus prolonging the graduation. During the curriculum design process in 2013-2014 it was decided on university level that the size of each individual course should be at least 5 ECTS and in the field of engineering a specific package of basic mathematics and physics was specified for all the engineering programmes. The size of that package is only 10 ECTS and different programmes may then increase the amount if needed. It was as well suggested that the basic studies should be integrated more deeply to professional studies to focus on the applications of these studies to practical engineering subjects instead of pure theory.

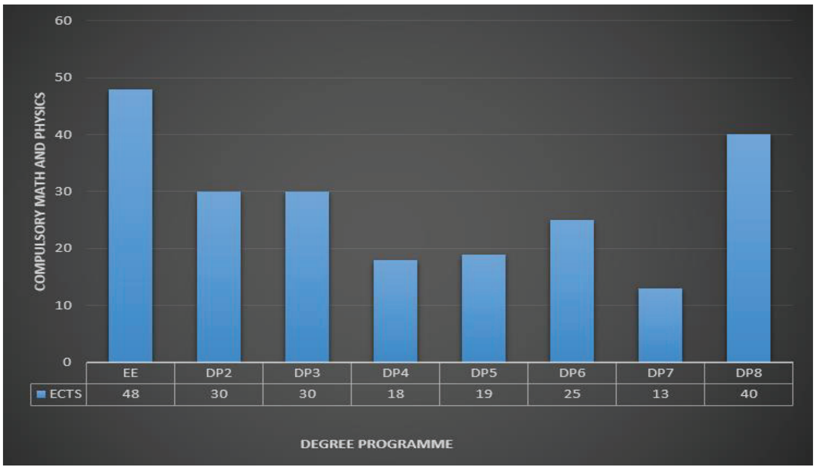

Fig. 2. The amount of compulsory mathematics and physics in eight different engineering programmes after the curriculum reform.

Different programmes chose different approaches to improve their metrics and some programmes did reduce the amount of these difficult subjects to minimum while some programmes such as the EE and electronics programmes chose a completely another perspective by having the amount of these subjects at the same level as before by integrating the contents. *Fig. 2* shows the amount of compulsory mathematics and physics in 8 different degree programmes of the university after the curriculum reform of 2014.

2 THE REFORM

2.1 Course integration and modular curriculum

A more detailed description of the modular structure of the curriculum on the degree programme in Electrical Engineering and Automation Technology is found in [1], [2] and [3]. The curriculum is based on courses of 15 ECTS in which different contents are integrated. One such course is given by three to five different teachers who plan, organize and assess the course together. The duration of one such course is typically 8-10 weeks covering one study period (each semester is divided to two consecutive periods). Only one single grade is given for one course and all the courses are based on continuous assessment (i.e. different tasks for students to be completed throughout the course and assessment as well as feedback of these tasks given instantly).

The first year of study consists of four consecutive courses compulsory for all the students in the EE programme and the four consecutive modules of the second year are major specific (at this stage one of the majors is merged to the parallel electronics programme). The last two years consist of optional modules, some electives, internship periods, the innovation project and the thesis project. The students find the modular structure very clear and the student feedback of the model has been very good otherwise as well [4]. According to the feedback survey of the graduating students in 2018 the electronics programme is ranked as #1 of the engineering programmes of the university and the EE programme as one of the best as well.

2.2 Initial implementation and first results

The new curriculum was launched for the first year students in late August 2014. The teachers for the first year courses were carefully selected among the most cooperative staff members and different methods to integrate the contents and different assessment schemes were encouraged. All our teachers have completed a compulsory pedagogical training and thus most of them are able to adjust well to new methods of teaching. After the first semester the student progression was analysed [2] and the best integration and assessment practices were selected. The content integration of the first year courses is more difficult (physics, maths, professional studies, programming, communications, etc.) compared to the more subject specific courses later. The results were however very encouraging and it was then easier to motivate all the academic staff members to apply this model.

The results after two semester did show [2] that more than 80% of the first year students were able to complete all their compulsory first year studies (previously 40 - 50% only). A similar analysis was just completed for the first year students of the academic year 2017-18 and those results may be seen in *Fig. 3.* This graph shows the percentage of the first year students of five different engineering programmes completing all the compulsory first year studies in due time. The large difference between the EE programme (86%) and the others may be explained by two benefits of the integration: 1) the students are basically “forced” to complete all the subjects in due time, otherwise they would fail a larger course entity, 2) in other programmes the courses of mathematics and physics are still mostly organized traditionally and their failure rate remains too high.

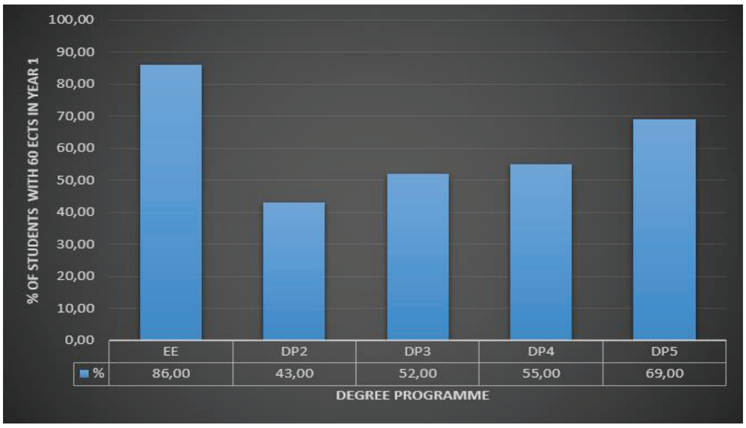

Fig. 3. The percentage of students completing all first year courses in due time in five different engineering programmes (academic year 2017 - 18).

2.3 Challenges

The number of academic staff members teaching in the degree programme is approximately 30. During the first year of implementation (academic year 2014 - 15) only 40% of them were teaching the first year students according to the new model. The feedback from these staff members was generally very positive even though they faced many transition phase problems in accreditation of prior learning, finding suitable platforms for common assessment etc. After the second year of implementation most teachers and after the third year all the teachers were involved. The results of the employee satisfaction survey in 2017 (the third year of implementation) were much worse than expected and the reasons may be tracked to the implementation of the collaborative pedagogy, the course integration and the continuous assessment in the new model.

Some staff members are more willing than others to design common tasks, share materials and cooperate otherwise with their colleagues and that is quite understandable. Some teachers also heavily criticized the continuous assessment schemes preferring to give only larger exams at the end of the course after which they have four weeks for assessment. Many teachers also did complain about the fact that in some cases students may compensate their lack of knowledge of certain difficult subjects by their knowledge (and points) from some other not so difficult subjects within the same course. These topics are still constantly discussed and some staff members still have problems in following the common rules of assessment etc., which then leads to student complaints. The main points of criticism (of some professors) (together with the authors’ comments are listed below:

- all the study material delivered to the students is open to all other teachers of the module (true; some teachers avoided this by using external moodle-pages)
- continuous assessment finally leads to more assessment work by the teachers (partly true, but improved pass-rates minimizes the resit work)
- the assessment schedule is more strict (true, but generally the students should always have feedback of their learning asap, not many weeks after the final exams only)
- within one module the students may compensate the tasks of the “difficult” subjects by the tasks of the “easy” subjects (partly true; our analysis shows that there’s only a few cases of such behaviour; this is as well the case in more traditional assessment since in order to pass a large end exam the students may collect points from the easy problems of the exam without being able to complete the most difficult ones)
- some colleagues do not perform well enough or work hard enough in teaching the modules (true; that’s however the case as well if the teachers give separate courses; here it’s at least visible; unfortunately some people do not want to cooperate with some of the others; in the academic world these problems are very difficult to solve)

To overcome these challenges the assessment requirements are now made more flexible for the teachers. Also minimum pass level of each topic within a course were introduced. This is quite an unfortunate compromise because after these adjustments the actual integration of different topics is more difficult. However fortunately still today most teacher groups do follow the original guidelines. The teachers of the basic studies (maths, physics, languages etc.) are the most willing to follow them as well as all the teachers of one of the three majors. On the other hand one of the majors totally abandoned this scheme and will be organizing all their courses of the last 6 semesters on 5 ECTS non-integrated course basis.

3 THE RESULTS

The first student group started their studies according to this curriculum in autumn 2014 and their nominal graduation date was in May - June 2018. After that it has been possible to analyse the graduation percentages as well as the drop-out rates of the first student group. The nominal time graduation percentages as well as the drop-out rates for both the full-time and part-time students are presented in the graphs below for five consecutive years of intake (nominal graduation 4 years later).

Two versions of drop out-rates are calculated and both versions are also taken into account in the calculations of the graduation percentages. In version 1 the drop-outs with no credits completed are not included in the drop-out rate. The reason for this is that in the total number of drop-outs (from the university statistics) also the accepted students who did not even start their studies are included. However in this case there might be some students excluded who had tried their best without any success. Such students should be included in the analysis, thus the truth lies somewhere between the two versions.

3.1 Graduation percentages

The percentage of full-time students graduating in nominal time of 4 years is presented in *Fig. 4* and the same percentage of the part-time students in *Fig. 5*. It may be seen that these metrics have improved by approximately 20 percentage points after the implementation of the new curriculum. As expected the percentages of the part-time students are lower than that of the full-time students (and the drop-out rates are higher correspondingly) due to the fact that the part-time students tend to prolong the studies even though all their project courses etc. are directly linked to their work and their prior learning is accredited in the beginning of their studies.

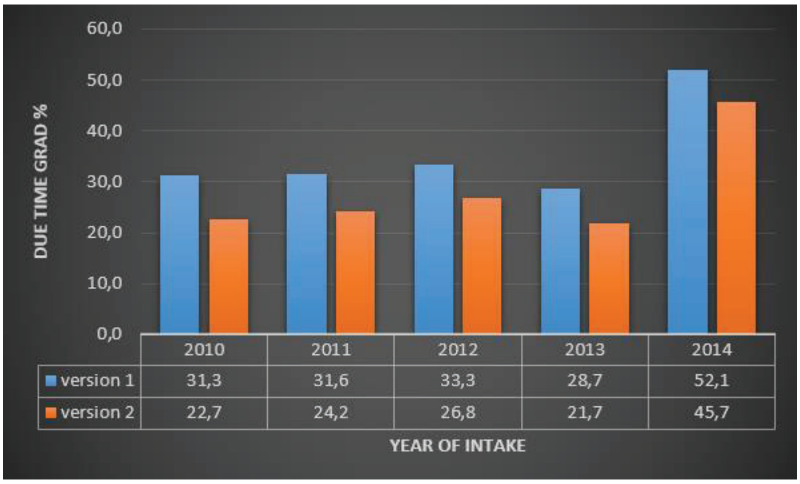

Fig. 4. The percentage of full-time students graduating in nominal time of 4 years (version 1: drop-outs with no credits completed not taken into account)

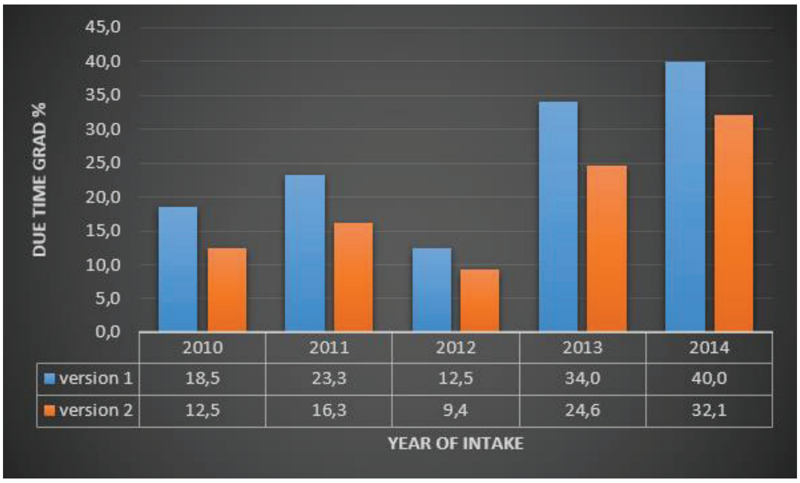

Fig. 5. The percentage of part-time students graduating in nominal time of 4 years (version 1: drop-outs with no credits completed not taken into account)

3.2 Drop-out rate

The drop-out rate of the full-time students is presented in *Fig. 6* and the drop-out rate of the part-time students in *Fig. 7*. It can be seen that the drop-out rates for all the students before the implementation of the new curriculum have been alarmingly high. It may as well be seen that the implementation of the new model has been improving (decreasing) the drop-out rate significantly. It has to be admitted that the drop-out rate for the part-time student group graduated in 2018 (intake 2014) is somewhat too optimistic, because there is still active students in the group and a significant number of part-time students tend to drop out after 10 semesters (one additional year after the nominal 4 years is automatically given).

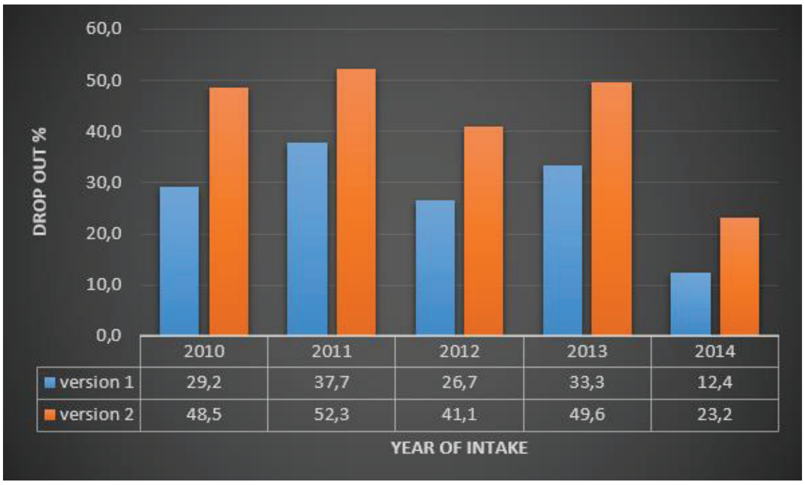

Fig. 6. The drop-out rate of full-time students
(version 1: drop-outs with no credits completed not taken into account)

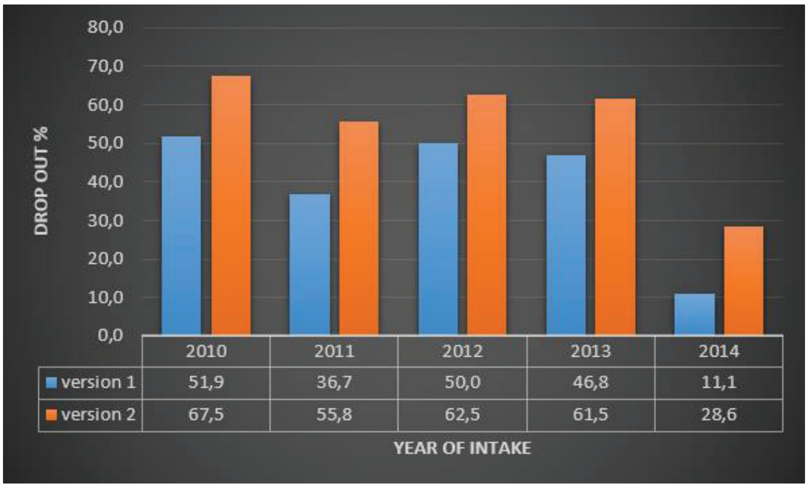

Fig. 7. The drop-out rate of part-time students
(version 1: drop-outs with no credits completed not taken into account)

3.3 Comparison to other degree programmes

Fig. 8 and *Fig .9* show some comparisons between different degree programmes of the intakes of year 2015. This data is from April 2019 when the students are just completing their eight semester before their nominal graduation date. *Fig.8* shows the averages of the credits completed by the eight semester students in different degree programmes and *Fig. 9* shows the drop-out rates of the same students thus far. Only full-time students are taken into account in these analyses and all the drop-outs are included in the drop-out rate (as version 2 in *Figs. 4-7*).

The data presented in Fig.8 is somewhat less reliable, since the students are still completing their last courses and some students already have their final year projects registered and some do not. However the trend is very much the same as in *Fig. 3* where only the five first programmes are analysed.

It is clear that many other engineering degree programmes have as well improved their results after the curriculum reform in 2014. This is very good news and the EE programme does not even rank as #1 in neither of these metrics. However the overall improvement is best in this programme and these results are achieved without reducing the amount of the basic studies as can be seen in *Fig. 2*.

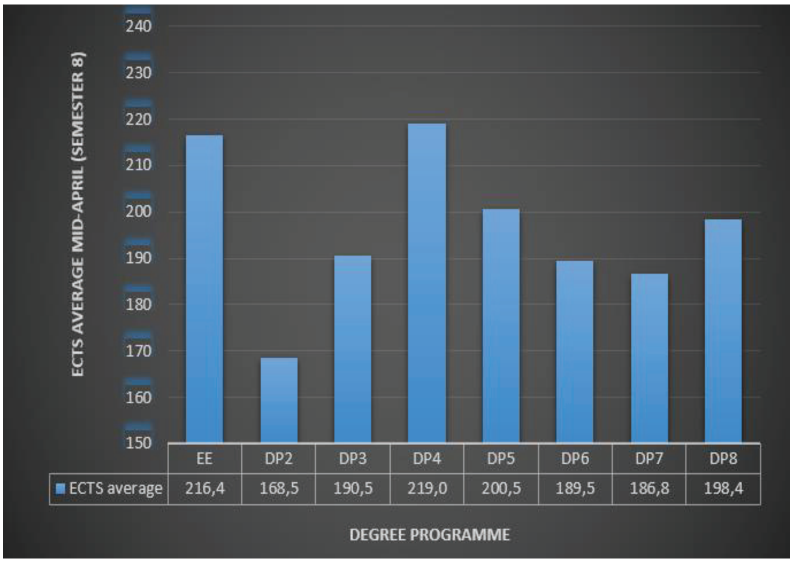

Fig. 8. The average of the ECTS credits of students in their 8^{th} semester
(8 engineering programmes; year of intake 2015)

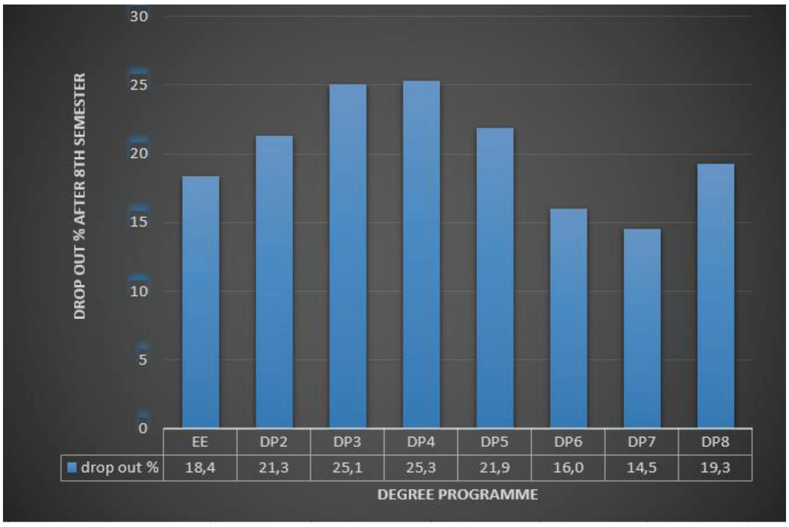

Fig. 9. The drop-out rate after 8 semesters in eight engineering programmes (year of intake 2015)

4 CONCLUSIONS

The implementation of the new curriculum based on collaborative learning, modular structure, continuous assessment and course integration in the degree programme in Electrical Engineering and Automation Technology in Metropolia UAS has significantly improved the most important metrics of the programme (student progression, drop-out rate, etc.). Additionally it also has a positive impact on the funding of the programme.

Besides these analyses the student feedback of the first student group has been analysed in two occasions, during the second year [2] and after graduation. The student feedback of the new model is very positive. The degree level learning outcomes of the graduates has not been analysed at all. Many teachers have compared the learning outcomes of their subjects to previous years by organizing larger tests within the new courses and the result are positive since in the continuous assessment scheme in the new model encourages student activity throughout the courses instead of focusing on larger end exams only.

The student feedback has been very good but it has been relatively difficult to implement the model completely because some academic team members have felt that they have lost some of their academic freedom by following detailed assessment system and deadlines. Therefore some basic guidelines of the model have been made more flexible in order to be suitable for all staff members. This however makes the implementation of the model more difficult. Most academic staff members are very satisfied with the model but currently some courses (within one major of the EE programme) are already being transformed to the old traditional way of teaching and learning.

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Enriching learning experiences for students to enhance their engineering competences across cultures and nations

Wim Van Petegem
KU Leuven, Belgium)[1]

Dena Lang

Penn State University, US[2]

ABSTRACT

Engineers nowadays should be able to live and work in a global community across cultures and nations. Therefore they need to have broad engineering skills and know-how, be flexible and mobile, and be able to communicate, collaborate and interact in an international environment. But, where, when and how do they acquire these competences? This paper presents an example of a course, offered jointly by the Engineering Leadership Development Program at Penn State University (US) and the Postgraduate Program on Innovation and Entrepreneurship for Engineers at KU Leuven (Belgium). This course, entitled 'Engineering Across Cultures and Nations' at PSU and 'Professional and Cross-cultural Skills in Engineering' at KU Leuven, runs now since 2015. The course material is fully available online. Based on a flipped classroom model, each week the students have to study one of the online modules and come prepared to the face-to-face sessions. These joint sessions are held synchronously both in KU Leuven and in PSU once a week via a webconferencing tool. Each week students rotate responsibility for leading this classroom discussion. The course also incorporates substantial project work, that students work on in mixed virtual teams, using proper communication and collaboration tools, tackling challenges of different languages, time zones, engineering backgrounds, etc. Over the years the course components (learning approach, materials and activities) have been improved, in order to enhance and enrich the intercultural and international learning experiences for the students (and for the teachers).

INTRODUCTION

Engineers nowadays should be able to live and work in a professional, agile way in our contemporary global community, across cultures and nations. They not only need to have broad engineering skills and know-how, but should also be flexible and mobile, and be able to live and work internationally. In today's global marketplace,

[1] Faculty of Engineering Technology, University of Leuven, Belgium, wim.vanpetegem@kuleuven.be, ORCID: 0000-0002-4553-4407
[2] Faculty of the School for Engineering Design, Technology, and Professional Programs, College of Engineering, The Pennsylvania State University, University Park, PA 16802, btcl133@psu.edu

successful engineers must combine their technical expertise with an understanding of how professionals in different cultures define problems and develop solutions.

To prepare future engineers for these new professional challenges, engineering educators are integrating genuine learning experiences in the curricula for engineering students to develop their intercultural competences. At The Pennsylvania State University (PSU) these skills and experiences have evolved since 1995 into a critical part of the undergraduate minor in the Engineering Leadership Development program (ELD). Over the past years the ELD program at PSU has been developing a Master of Engineering program to provide a graduate degree in Engineering Leadership and Innovation Management. The program developers recognize the importance of these global competencies at the graduate level as well as the undergraduate levels, and decided to incorporate an international virtual teaming course as a requirement in the program. In 2013-2014 they contacted KU Leuven in Belgium to establish a partnership in this endeavor. At KU Leuven the Faculty of Engineering Technology is organizing an annual Postgraduate Program on Innovation and Entrepreneurship in Engineering. This one-year program aims at developing entrepreneurial, managerial and innovation skills and offers the students an opportunity to gain a unique work experience through innovative projects in a stimulating working and learning environment. The match with the ambitions of the ELD program was obvious, and this led to the development of a common course, called *Engineering Across Cultures and Nations* at PSU and *Professional and Cross-cultural Skills in Engineering* at KU Leuven. This course is offered for students at both sides, since the academic year 2015-2016.

COURSE CHARACTERISTICS

General description

This graduate-level course focuses on the primary knowledge areas and essential competencies required for successful engineers to live and work in today's global marketplace. The course examines individual and cultural differences and how they impact business practices, communication and team dynamics when solving engineering problems in global contexts. These topics are central to international and multicultural engineering teams. The course takes the students on a journey from personal professional skills introspection and development towards intercultural and team competencies development. Students that complete the course will be able to understand sources of conflict that can arise in multicultural teams and effectively use the tools and resources learned in class to manage individual and team motivation and minimize or effectively deal with conflict, while harvesting the benefits of diversity as they work on a real world virtual team project, producing effective solutions to challenging engineering problems.

Course objectives

Upon completion of this course, students will be able to:

- Demonstrate a proficiency in team-building, leadership, and service in the context of cross-cultural engineering teams.
- Construct creative solutions to engineering issues incorporating cultural differences among team members and external stakeholders.
- Critically analyze personal and team-member competencies and biases.
- Formulate and apply strategies to improve engineering team dynamics.
- Provide effective feedback, recognition, motivation, and corrective guidance for international/intercultural team members.
- Evaluate engineering business opportunities or strategies for the diffusion of ideas within international and cross-cultural markets.
- Examine moral, ethical, and legal dilemmas in cross-cultural engineering environments.

Course contents

The top five most important attributes identified by industry leaders and engineering educators for global competence in engineering graduates are [1]:

1) An appreciation of other cultures,
2) Proficiency working in or directing a team of ethnic and cultural diversity,
3) Able to communicate across cultures,
4) Experience practicing engineering in a global context, whether through an international internship, a service learning opportunity, a virtual global engineering project or some other form of experience.
5) Effectively deal with ethical issues arising from cultural or national differences.

In addition, the qualities of an inter-culturally competent person include an open minded attitude, the acquisition of culture sensitive knowledge, and appropriate and effective interaction skills [2].

The course contents and related learning activities are selected, structured and developed to foster these important attributes and qualities in our students. They are centered around five themes: Understanding Yourself and Others, Developing Effective Teams, Cultural Differences, Dealing with Conflict & Team Motivation, and Cultures in Organizations. Throughout the semester students are invited to enlarge their view on the subjects by reading two text books: *Cultures and Organizations*, by Hofstede, Hofstede, and Minkov provides knowledge content on dimensions of culture, cultures and organizations, and the evolution of culture [3] and *Kiss, Bow, or Shake Hands* by Morrison and Conaway provides additional content related to conducting business in 60 countries and serves as a reference book for future travel [4].

The course incorporates a major experiential learning project, in which the students link the course contents with a concrete engineering problem in the global world. The students, in mixed teams across the ocean, encounter virtual, cross-cultural challenges of different languages, time zones, engineering backgrounds, etc. and resolve them while applying several course concepts. In this interdisciplinary project students combine their engineering knowledge and entrepreneurial spirit with their professional and intercultural skills in order to find innovative and feasible business opportunities.

Gradual improvements on the course format

We describe hereafter a process of continuous improvement of the course since its first run, based on (yearly) feedback from the students and our own reflections as teachers. This process could be linked to recurrent cycles of using the ADDIE[3] instructional design model, although the different steps are not always taken explicitly.

First run

A first edition of the course was offered in the Fall 2015 term [5]. The course format consisted of synchronous videoconference lectures twice a week given by faculty from both institutions and by guest speakers from the corporate and academic world, complemented by readings, case studies, individual assignments and group discussions. A limited number of students participated in this edition, i.e. six students at both sides.

At the end of the course, an informal student evaluation was performed. Students felt that the course material was relevant to their future work as an engineer, that the assessment methods were fair and that the course material (text books, lesson notes, and online materials) helped them understand the course contents (although a better job in organizing and presenting the material could have done). Students indicated that there was a need for less material covered in class. They were a bit frustrated about the group work done in the virtual class time, and would have rather preferred more time for discussions. Nevertheless, students loved it: “The interaction between the two universities made the class a great learning environment. By far the best experience.”, and called it an intensive, but rewarding ‘real life’ learning experience across several borders.

Also the teaching team had to cope with intercultural challenges due to different educational settings and paradigms, e.g. dealing with staggered time-zones and academic calendars (semesters are misaligned by about 4 weeks), with assessing students on a level playing field (marks are interpreted differently in the two academic worlds), with solving occasional technical hiccups, etc. One of the actions that helped the instructor team to overcome some of these difficulties was a face-to-face meeting prior to the start of the first edition of this course, where we could work out the schedule, lecture content, learning activities, and other administrative items. Such a face-to-face meeting was unfortunately not possible with the students.

Second run

A second run of the course was offered in the Spring 2017 term, again with a limited number of students (11 at KU Leuven, of which 3 Italian exchange students, and 5 at PSU).

[3] ADDIE is short for Analyze, Design, Develop, Implement, and Evaluate.

In order to free up class time for more in-class interactivity and discussion, the PSU teaching team, especially the second author of this paper, managed to develop a fully online course, complete with online learning materials, activities and assignments. In this exercise more emphasis was put on globalization and its impact on engineering, and on examining differences between stereotypes and generalizations applied to personality type as well as cultural dimensions. Care was also taken to make sure learning activities and assignments were tied more closely with the course project, in a coherent way to meet the course objectives.

At PSU, the students were engaged only in online learning, while the students at KU Leuven were offered a combination of face-to-face and online learning (i.e. blended learning) in a flipped classroom model. Students at KU Leuven met now for only one session a week. Each week they were supposed to study the online material (kindly made available to them through the PSU learning platform) and one student in particular prepared the face-to-face class discussion about the topic. They were free to organize themselves for the discussion: some prepared several statements based on the course contents that could spark a discussion, some prepared a role play to let their peers experience the concepts, some prepared a short quiz as basis for a debate, etc.

The students, at KU Leuven, were very enthusiastic about the online material and the flipped classroom model. They loved the variety of preparations and discussion formats, especially because that allowed them to be more creative and helped them to better grasp the different course topics. They were a bit less happy with the instructor (first author of this paper) taking over from the student who prepared for the session and leading the discussion himself.

As no changes were made on the substantial project work as part of the course, and since the PSU students were all online students (they did not participate in the class discussions), students at KU Leuven strongly recommended at the end of the course to include a couple of formal webconferencing sessions in the beginning in order to get to know each other, and to establish better bonds between the KU Leuven and PSU students.

Third run

The third edition of this course was offered in the Spring 2018 term, now with 8 students at KU Leuven (of 5 nationalities, speaking 6 native languages), and 6 students at PSU (of 5 nationalities).

This time we adopted the flipped classroom model at both sides, i.e. students were supposed to study the online material on a weekly basis and each week one student prepared the class discussion, now set up as a webconference (using Skype for Business). Due to the different academic calendars, students at PSU already started 4 weeks ahead of the students in Leuven, and had no Easter break: that were the weeks that they prepared their class discussions only for them. The KU Leuven students prepared for the webconferencing sessions in the common part of the course, i.e. for the other weeks in the term/semester.

An interesting aspect of this run of the course was with regard to language. As it is widely accepted throughout the world in international business practice the common language in our joint class is English. Already in the first edition, students from PSU, for whom English is the official language of education (and in most cases also their mother tongue), found this in unbalance with their peers from KU Leuven. To bridge that gap, they asked to learn a few words in Dutch (the mother tongue of the majority of the students in Leuven). Therefore we started the common sessions always with a short ‘language lesson’. In this third run, we continued this exercise, but because this time there was a huge diversity of students in terms of nationalities and hence languages, it was not possible to teach Dutch to the American students. Instead we ended up with short introductions to the different cultures of the students, rather than real language lessons. Students were keen to prepare a presentation about their country and were curious to learn about the cultures of others. However, we were spending quite some time on this, and the real language lesson was, as could be expected, rather limited: one could wonder whether students were learning anything about the language at all. More information on this language issue in this course has been reported in [6].

As with regard to assignments and the project work, no changes were made for this edition of the course, except that clearer instructions were given to the KU Leuven students about ‘homework’. In previous editions students at KU Leuven were complaining about weekly deadlines for (small) assignments to be submitted. Although this brings added value to the course, especially when studying the online learning material, this is a not so common practice at KU Leuven, where graduate students are exposed to more autonomous learning, i.e. they take their own responsibility on how and when to study. A compromise with the PSU approach needed to be elaborated, and boiled down to mandatory assignments affecting the team work, and optional (but strongly recommended) assignments for individual learning.

Fourth run

The fourth run of this course is offered in the Spring 2019 term, with 8 students at KU Leuven (2 nationalities, and 2 native languages), and 5 students at PSU (5 nationalities, and 4 nationalities). No worth mentioning changes have been made to the course format, assignments nor project work. The only alteration made was the integration of the language lessons in the online environment, linked to the countries studied in the modules of the course, rather than to the student backgrounds. We now also use Zoom as technology for the webconferencing sessions.

Content wise some improvements were made in this edition. We added the IDI (the intercultural development inventory) and an IDI plan, where students developed a plan for their own intercultural development. At the end of the semester they (will) write a reflection paper on this activity. We also added four (new) online journal entries with cultural scenarios that required students to apply what they learned to make a recommendation in a work setting.

As this edition is still running at the time of submission of this paper, no evaluation can be provided yet.

CONCLUSION

This paper presents an example of a course that gives engineering students an opportunity to acquire the competences they will need when living and working in a global community across cultures and nations. The course is developed jointly by the Penn State University (US) and KU Leuven (Belgium). It enables future engineers to have broad engineering skills and know-how, be flexible and mobile, and be able to communicate, collaborate and interact in an international environment. This course runs now since 2015, and in consecutive editions we have fine-tuned its contents, the learning activities and its format, based on the (informal) student evaluations and feedback. In the paper we describe how we currently apply a flipped classroom model, in which each week the students study one of the online modules and come prepared to the face-to-face webconferencing sessions. Each week students rotate responsibility for leading such a virtual classroom discussion. The course also incorporates substantial project work, that students work on in mixed virtual teams, using their own choice of communication and collaboration tools, tackling challenges of different languages, time zones, engineering backgrounds, etc. All these elements contribute to the goal of enhancing and enriching the intercultural and international learning experiences for the students (and for the teachers).

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Developing an instrument to monitor educational quality culture

The Quality Assurance Barometer

J. Vermeersch[1]
Quality assurance coordinator
Faculty of Engineering Technology, KU Leuven
Leuven Engineering and Science Education Center (LESEC)
Leuven, Belgium

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ABSTRACT

Quality assurance (QA) is experiencing a paradigm shift worldwide. The traditional emphasis on stakeholder satisfaction and compliance to external frameworks is increasingly being replaced or supplemented by a fundamentally different outlook, where institutional ownership, engagement to take responsibility for quality management, and trust are key [1,2]. Internal reflection is gaining importance, involving stakeholders such as management and lecturers. In this context the construct of quality culture is gaining importance. Monitoring whether a healthy quality climate is in place implies identifying and measuring different parameters such as perceptions, practices, attitudes, needs and ideas [3,4,5,6]. As a consequence, higher education institutions (HEIs) are faced with the challenge to develop new formats and tools for QA, and are looking for good practices.

This paper reflects on the Quality Assurance Barometer developed in 2018 by the multi-campus Faculty of Engineering Technology at KU Leuven university. The instrument was approached as an anonymous online survey. Its questionnaire was based on scientific literature on QA as well as input by faculty advisory boards. It measures attitudes towards QA in general, attitudes towards specific tools and practices, perceived impact of tools and structures, stakeholder needs, perceived priorities and opinions on potential new initiatives.

The barometer was filled in by n=167 academic staff members. Statistical analysis yielded useful feedback to strategic and middle management. Interestingly, some aspects of quality culture do correlate with other variables such as staff seniority and campus context. By sharing insights on the development of a quality culture monitoring tool, this paper may encourage other HEIs as well to take QA to the next level.

1 INTRODUCTION

The Faculty of Engineering Technology of KU Leuven is a multi-campus faculty organising (Bio)Engineering Technology programmes at seven campuses in Flanders,

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[1] Corresponding Author
J. Vermeersch
julie.vermeersch@kuleuven.be

Belgium. As an entity the faculty comprises about 600 staff members and close to 6,000 students.

The faculty introduced its quality assurance barometer in 2018 for two reasons:

1. Internal process optimisation. Since its establishment five years earlier the faculty had implemented a wide scale of QA tools. The time was ripe to review current practices and to let staff signal needs and suggestions related to QA.
2. External reporting. A new QA decree in 2015 had allowed the HEI to transition from external program evaluations to institutional reviews. This evolution has made internal monitoring highly relevant as faculties are expected to take more responsibility for QA and to report periodically to central services as well as external peers on their QA system. Stakeholder feedback provides useful information to assess the faculty's processes and climate as well as to check whether existing tools are fit for this new context.

2 QUALITY ASSURANCE AND QUALITY CULTURE

2.1 Trends in quality assurance

Quality assurance (QA), in essence, is a means to provide reliable information to stakeholders so as to allow optimal decision-making [8]. Quality is and will remain a culturally sensitive and relative concept [1] with criteria which moreover depend on the stakeholder's own perspective [7]. Perspectives on quality and quality assurance moreover change over time.

In the 1990s, quality was mostly considered as fitness for purpose or value for money [6]. In most countries, QA was introduced as a way to deal with growing concerns about the quality of higher education in response to expanding student numbers, rising awareness on dropout rates, and demands for accountability about public spending. As a result, higher education institutions (HEIs) increasingly had to demonstrate compliance with (minimum) standards, provide transparent information, and build trust. Many QA models from the start had features in common [2]. In past decades QA could typically be equated to quality control by means of structured action guidelines (e.g. DIN EN ISO 9000/9001 standards) or continuous quality development approaches (e.g. Total Quality Management) [3].

Later on, quality was in some contexts redefined, for example as a search for excellence [6]. Changes in QA follow in response to new insights, critique and changes in contexts [2,9]. Current trends include a growing consideration for self-improvement, taking into account institutional diversity, and stronger stakeholder involvement. Many agencies are indeed opting for lighter, formative procedures in favour of HEIs' own responsibility for QA [1,9,10]. Understanding of QA is moreover being extended to include informal and non-structural aspects of quality as well [3,5]. In this context, assessing quality by means of hard facts no longer suffices. Discerning the extent to which values are subscribed to and lived by members of the HEI becomes at least equally relevant [4]. As a result the concept of quality culture is gaining importance.

2.2 The quality culture concept

The exact meaning of quality culture (QC) is subject to debate as it is a complex social-constructivist phenomenon [5,6]. Still, the definition originating from the European University Association (EUA)'s network meetings is generally accepted [3,4,5,6]:

> *"Quality culture refers to an organizational culture that intends to enhance quality permanently and is characterised by two distinct elements: on the*

one hand, a cultural/psychological element of shared values, beliefs, expectations and commitment towards quality and, on the other hand, a structural/managerial element with defined processes that enhance quality and aim at coordinating individual efforts." [1 p. 10].

Quality culture is often considered the answer to challenges, while in reality, its strength is to help identify challenges. QC monitoring is first and foremost a means to ask questions about how institutions function and how they see themselves [6]. Follow-up of results should likewise differ fundamentally from traditional approaches. The culturally sensitive and relative construct of quality means there are no intrinsically right or wrong answers, on the contrary: diversity in perspectives is in fact desirable as a starting point for dialogue, as this stimulates internal QC [1].

Recent years have shown growing appreciation for the QC concept. Yet there are a limited number of empirical studies on its operationalisation [3,5]. Moreover, those that can be found focus on the point of view of students and not as much on academic staff [3].

2.3 Quality culture frameworks

The following three frameworks illustrate different perspectives on QC.

The framework stemming from the heiQUALITY Cultures Project was specifically designed to explore and operationalise the concept in the higher education setting [3,4].

The EUA definition was its main inspiration. This model correspondingly describes QC as consisting of two interrelated components (*Fig. 1*): a structural-formal one (comprising normative, strategic and operative aspects, i.e. goals, principles, responsibilities, tools and measures) and an organisational-psychological one (individual and collective dimensions, i.e. commitment, sense of responsibility, engagement, leadership, communication, participation, shared values and trust).

The framework was subsequently translated into the Quality Culture Inventory, an umbrella term grouping two questionnaires: a structural-formal questionnaire to assess an organisation's QA and quality management, and a survey on the organisational-psychological component [3,4].

Fig. 1. Assessment model of quality culture [3 p. 49].

A second model reflects on the interconnectedness of context, working mechanisms and outcomes as depicted in *Fig. 2* [5]. According to these authors, subcultures play a major role in individual and collective behaviour. Top-down and bottom-up approaches need to be balanced for quality management efforts to succeed. The structural-managerial and cultural-psychological elements must therefore be linked through elements such as leadership and communication [5].

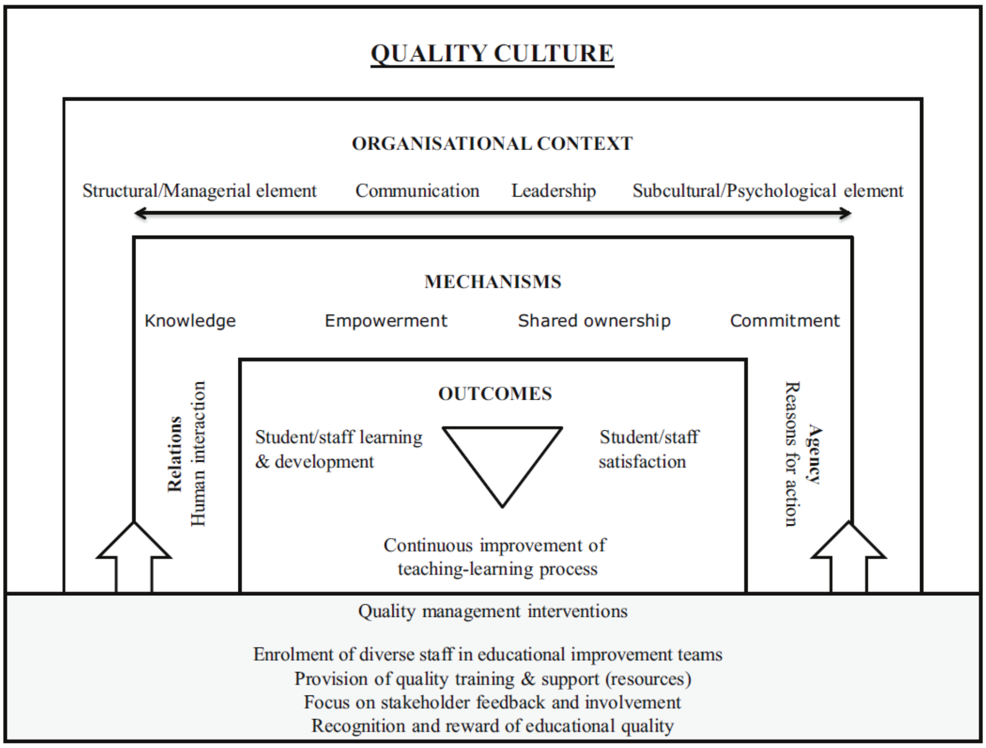

Fig. 2. Context-mechanism-outcome-configuration of quality culture in HEI [5 p. 51].

A third way to look at QC is by means of ideal-types. A framework based on Cultural Theory considers individual behaviour as determined by the degree of group-control and the intensity of external rules [6]. The four ideal-types in *Table 1* are each affiliated with different QA systems and quality cultures. These ideal-types give insight in how tacit ways of dealing with issues should be taken into account when designing and analysing a QA system.

Whereas a responsive culture will proclaim an improvement agenda stressing accountability and compliance, it will be characterised by very low ownership and stakeholder control and be unconnected to everyday experience; yet stakeholders will react to external threats as a group. Reactive quality cultures are equally driven by compliance and accountability, but regard QC as something which is managed or imposed and therefore delegate it to a specific space such as a quality office. Regenerative quality cultures include external opportunities in so far as these are expected to provide learning opportunities or benchmarking possibilities; but will otherwise suppress external QA to the margins or actively subvert it, in a sense equating QC to everyday work practice. Reproductive quality cultures finally minimise the impact of external factors and focus on reproducing the status quo; in these contexts one refrains from open self-reflection and transparent QA practices as these are likely to result in resistance [6].

Table 1. Quality cultures in Cultural Theory framework, inspired on literature by Thompson et al. and Hood [6 p. 436].

Degree of group-control Intensity of external rules	Strong	Weak
Strong	Responsive	Reactive
Weak	Regenerative	Reproductive

A common feature in these frameworks is to emphasize the match between structure and culture, and how managerial and psychological dimensions are inherently connected. A multitude of dimensions interact and influence whether initiatives are successfully implemented. This makes defining and operationalising QC exactly so challenging: strictly isolating the concept is inadvisable. Monitoring QC moreover deals with both the individual and aggregate level. This implies that monitoring QC will necessitate including a variety of QA aspects in a broad sense, with regard to attitudes as well as processes, and to stay responsive to contextual influences all the while. The fact that quality culture is bound to values and expectations, besides, means that social desirability might bias results depending on the methodological approach.

3 MONITORING QUALITY CULTURE

The remainder of this paper will focus on a quality culture monitoring instrument developed in the context of an engineering faculty. The instrument was conceived as an addition to more traditional tools already in use. Its aims were both internal process optimisation and external reporting as is described in the introduction.

3.1 Questionnaire

In the past, external QA in Flanders applied content-related indicators, emphasizing compliance with standards and accountability. Internal QA would likewise focus on similar constructs. Institutional reviews on the other hand now adopt a systemic quality management perspective. The focus has in other words shifted from inputs and outputs to processes [2,9]. The developed tool had to follow suit in the same fashion.

Questionnaire items were chosen to fit with the dual goal of internal optimisation and external reporting, combining structural-managerial elements and organisational-psychological elements as advised by literature [1,3,4,5,6]. These elements were not divided as such though. Clustering questions thematically was more intuitive and reflective of daily practices of the target group, i.e. the faculty's staff involved in education. The survey covered the following sections and corresponding number of questions:

1. Attitudes towards QA in general (5 items)
2. Attitudes towards specific QA tools and practices (12 items)
3. Perceived impact of tools and structures (8 items)
4. Stakeholder needs, perceived priorities and opinions on potential new initiatives (8 items)

The questionnaire was based on scientific literature as well as input by faculty advisory boards. Items were discussed and validated by the faculty's advisory boards of experts on quality assurance, curriculum development and educational policy prior to the administration of the survey.

The questionnaire was concise so as to avoid response dropout. In contrast to literature [3,4], therefore, unique measures were preferred over multi-item scales. Examples of questions and corresponding response scales are included in *Table 2*. Each section included an optional text box where participants could clarify answers or add remarks. As it was the first time the barometer was conducted, this way stakeholders could also signal ambiguities, allowing to improve the questionnaire for future use.

Table 2. Sample items of the quality assurance barometer.

Section	Sample items	Response options or scale
1. Attitudes towards QA in general	I regard quality assurance primarily as the responsibility of…	- Each individual lecturer - The teaching team - The programme coordinator - The programme director - The campus vice chair of education - The campus chair - The vice dean of education - The dean - Other: …
	Which definition of "quality" fits best with your concept thereof?	Definitions obtained from literature [6]. - Quality as exceptional - Quality as perfection or consistency - Quality as fitness for purpose - Quality as value for money - Quality as transformation
2. Attitudes towards specific QA tools and practices	To what extent do you agree with the following statements? - Feedback from students is instructive for me as a lecturer. - Student evaluations of teaching are relevant for HR decisions.	6-point Likert scale ranging from "fully disagree" to "fully agree".
	To what extent do you use the following as a lecturer? - Feedback from the student evaluation of teaching - Peer review by colleagues	5-point scale: never – rarely – sometimes – often – systematically
3. Perceived impact of tools and structures	In your opinion, which of these have the strongest impact on the quality of education in the faculty? (select at most 5 items)	- Programme committee meetings - The student evaluation of teaching - Focus groups - Surveys conducted by the lecturer - Study time measurements - Professional field surveys - Alumni surveys - Personal contacts between lecturers - Personal contacts between lecturers-students - Peer review between lecturers - The faculty's teacher team days - The former self-evaluation reports and programme evaluations - The institutional review - Other: …

4. Stakeholder needs, perceived priorities and opinions on potential new initiatives	According to you, which aspect of quality assurance should get highest priority in the faculty?	Based on the formal protocol for institutional reviews: - Clarify vision and policy - Design processes, structures and instruments - Monitor processes and collect feedback - Encourage reflection on possible improvements
	According to you, which topics regarding quality assurance should the faculty address as a priority?	<Open question.>

Finally, demographic variables (campus, number of years of staff seniority) as well as potentially dependent or moderating variables (types of instructional activities staff engage in) were collected for statistical analysis of results.

3.2 Method

The instrument was approached as an online survey. This allowed for swift feedback by many respondents and conditional survey pathways. Participation was anonymous so as to avoid social desirability bias. As the faculty has an educational offer in Dutch as well as in English, the survey was available in both languages.

All staff members were invited to fill in the survey in May 2018. They were encouraged to do so by means of an announcement during a meeting of the Faculty Council with its 200 members, by email sent by the faculty's vice dean of education to staff email distribution lists, and by one email reminder. Around 400 academic staff members are involved in the educational activities of this faculty; the barometer was filled in by n=167 respondents.

3.3 Lessons learned

As this concept paper deals in specific with the methodological aspect of developing a monitoring tool, the following paragraphs will share lessons learned and reflect on which measures or contrasts proved interesting to include in this type of monitoring survey, in retrospect from the point of view of the faculty's QA team. Readers interested in the empirical report instead are invited to contact the author.

Each section of the questionnaire provided useful insights in its own way.

Attitudes towards QA in general allowed to get an overall idea to what extent staff members recognise responsibilities for QA. Even though healthy QA is a shared responsibility, the sample question in *Table 2* deliberately forced participants to pick one answer so as to be able to contrast the general climate to official policy. Also interestingly, the question measuring which definition best describes respondents' personal vision on quality returned two values as the most popular: on the one hand fitness for purpose, the dominant perspective in the former program evaluations; on the other hand quality as transformation, which has better alignment with the institution's current vision on education and teaching. Similarly, this section included a number of statements on the added value or burden of QA to educational development. Detailed analyses and open comments showed that staff seniority had an impact on responses: colleagues who had been around at the time of the former programme evaluations evaluated QA more frequently as a burden than less experienced colleagues did, giving testimony to the ghosts of the past of former external QA protocols.

Attitudes towards specific QA instruments bear witness to the support for and adoption of different tools and practices by staff members in their everyday activities. Campus and staff seniority were important contrasting variables here as subcultures deal with daily routines in different ways. Some campuses for example had a stronger tradition of informal meetings than others, and moderately experienced colleagues attached higher importance to formal meetings than their juniors and seniors did. Another interesting observation were the consistently positive correlations between several instruments or practices (e.g. surveys, peer review, good practices for curriculum development), giving evidence to the fact that adoption of these tools in daily practice was not a case of either-or but that proponents of one tool were in fact more likely to combine multiple tools. The open text box allowed respondents to share ideas on potential improvements or provided explanations on why certain items were more popular than others.

The perceived impact of tools and structures provides relevant information on which practices might prove crucial to reaching goals, and which might have become obsolete or need reorganisation. Here as well it is advisable to compare answers to formal policy decisions so as to evaluate whether stakeholder perceptions match with management's strategic choices, expectations and future plans.

Stakeholder needs, perceived priorities and opinions on potential new initiatives finally proved useful to confirm support for strategic decisions or to confront policy with blind spots. The recommendations provided through the open question generated useful input for advisory boards and policy actors. In the current context there were no significant differences between answers of subgroups as defined by background variables, allowing to define follow-up without need for differentiation.

4 DISCUSSION

The transition to a new QA context with stronger emphasis on institutional autonomy as well as the emergence of the concept of quality culture call for a different quality monitoring approach. This led to the development of a quality assurance barometer, described in this concept paper.

4.1 Reflection and conclusions

Monitoring whether a healthy quality climate is in place implies identifying and measuring different parameters such as perceptions, practices, attitudes, needs and ideas [3,4,5,6]. This evolution is also reflected in the QA barometer questionnaire described in this paper, as is illustrated by the sample items and lessons learned. The developed instrument indeed combines structural-managerial and organisational-psychological elements from several frameworks. By developing this instrument the faculty highlights quality culture as a relevant monitoring subject.

Follow-up related to the barometer mostly entailed contrasting results to current policy, which provided useful feedback and recommendations to management. Literature indeed suggests grounding the monitoring of quality culture in institutional strategy as the HEI's ambitions and values provide a shared framework for reflection [1]. When and if responses obtained through the barometer deviated from expectations, this was not by default interpreted as a problem to be remedied top-down; it rather provided a bottom-up stimulus for reflection and dialogue, aiding management and staff to stay in touch.

Including demographic, dependent and moderating variables in the questionnaire as well makes sure resulting interventions can be tailored to the expectations and needs of subcultures [5]. Literature also suggests ways of reporting on differences between subcultures, e.g. by visualising them as different profiles [4]. Differences between subcultures were minor in the current case study, yet did help in interpretation of results and gave insight in ghosts of the past.

4.2 Strengths, limitations and directions for future research

Quality culture is gaining relevance in the domain, evidenced by the fact that other entities in the faculty's environment are also becoming more aware of its significance. The university's central services for example are exploring how to translate the quality culture concept into general QA guidelines, and the external QA agency NVAO is paying increasing attention to this in protocols for e.g. initial program accreditation. The type of instrument described in this paper may prove valuable as an innovation and thereby provide inspiration for future developments.

The questionnaire itself may be optimized further. Some dimensions recently identified in literature were not yet included to their full extent, such as leadership and trust. Using unique measures instead of multi-item scales likewise limits the scope and validity of constructs to a certain degree. The instrument and its results were, nevertheless, appreciated by the relevant stakeholders and were able to provide useful insights as well as a baseline for future monitoring. Even if it is only feasible to include a limited array of questions, monitoring remains of added value.

A potential catch is that QA instruments can only succeed as long as the relevant stakeholders are willing to provide fair input and are convinced their answers will be taken seriously [4]. Stakeholder support was achieved by generating awareness about the purpose and process through both oral and written communication, and by keeping the survey anonymous. The fact that the barometer was a faculty initiative instead of being imposed by external drivers also facilitated stakeholder support. The response rate and usability of the answers seem to confirm the reliability and validity of the responses, in any case.

The instrument discussed in this paper will not automatically be transferable to other contexts. Indicators on quality culture do not provide absolute measures; analysis requires contextual interpretation and weighting [1]. Tools and processes should take into account their purpose and available resources, and will therefore differ depending on the context [7]. With regard to the barometer, getting a sound fit was achieved by having relevant stakeholders and experts validate the questionnaire and survey methodology before administration. The sample items and lessons learned may nevertheless provide inspiration to other HEIs as there is still limited literature on the operationalisation of quality culture [3].

Future efforts could relate to translating questionnaire results into follow-up initiatives, and to integrating the quality culture construct further into overall quality assurance systems. Literature provides some hints on when quality culture monitoring may prove useful and on how to report results to stakeholders [4], and stresses that subsequent interventions should be tailored to the context [5,7]. Yet there is still much to learn on how to effectively nurture a quality culture [5].

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E-learning on the lab with lab education software. Deeper learning & more efficiency?

Dr. ir. G.C. Vreman-de Olde, drs. C. Rouwenhorst, dr. J.C. Alers, dr. J.T. van der Veen
University of Twente
Enschede, The Netherlands

Conference Key Areas: Integrated learning environments for the digital native learners. Open and online teaching and learning

Keywords: e-learning, labwork, blended learning

ABSTRACT

In preparing and executing labwork, students experience cognitive overload in understanding their lab work and keeping an overview of the lab experiment. In addition, giving just-in-time feedback to students causes peak loads in working hours for lab-teachers. We investigated the additional value of an inquiry based lab education software tool LabBuddy® on the learning and preparation of students and the peak loads of the lab-teachers.

In LabBuddy®, students co-operated in groups of 4 to prepare a (visual) block diagram representing their protocol and plan of approach for Creating Biological Tissue. Students were in their 2nd yr bachelor within the Biomedical Engineering programme. Students were further prepared by videos and pictures in LabBuddy®. The lab-teacher gave in-line feedback on students' documents. On the lab, tablets and computer screens were available so that students could access their protocol, answer questions and make notes in the digital labjournal.

Data was collected by observations on the lab, focusgroup sessions (with teaching assistants), a questionnaire (41 items) and by comparing students' final test results (70 students). Compared to last year (all preparations and notes on paper), students now feel better prepared for the lab work, have a good overview of the whole experiment while working on the lab and make more notes on their observations. The final reports are improved as students now follow more closely the research cycle. The peak load in working hours for students and labteachers is decreased. Students find LabBuddy® an intuitive system and would like to use the system for other labwork too.

1 INTRODUCTION

The notion of students managing their own learning process is embodied in the concept of Student Driven Learning (SDL) [1]. At our University of Twente, the programmes seek to develop in our students a wide range of skills, and to provide them with the opportunity to create their own development and learning experiences through multiple projects [2]. The SDL projects require students to undergo a mind shift from being a following student to becoming a student who is able to learn entirely in a self-directed manner [3].

Within the programme of Biomedical Engineering, students have quite a lot of practicals. Practicals are used to show students the practical applications of the theory and to learn them the practical skills of performing lab work. One of the practicals is the challenging and complex practical “Creating Biological Tissue” in which students differentiate human stem cells to create fat, bone or chondrocyte cells. The project is not only known for its complexity, but also for its high cognitive load for students and the high work load for teachers. Teachers notice that students ask quite some basic questions on the lab, showing that students have problems in understanding what they have to do (e.g., what is a filtrate? Where can I find the microscope?) and in keeping an overview of the lab work. [cf Johnstone [4]] Therefore, teachers would like to develop ways in which the cognitive load would diminish and students could spend more time on higher order questions.

Abeysekera & Dawson [5] define the flipped classroom as “a set of pedagogical approaches that a) move most information-transmission teaching out of class, b) use class time for learning activities that are active and social and c) require students to complete pre- and/or post-class activities to fully benefit from in-class work”. Chittleborough at al. [6] showed that the flipped classroom setting could be applied to laboratory practicals. In preparation for practicals pre-lab activities can help [7]. Harrison et al. [8] used videos, simulations and quizzes in The Dynamic Laboratory Manual. Rodgers et al. [9] discovered that pre lab videos made students better prepared for lab work. Diederen et al [10] used digital assignments on research experiments. Brame [11] states that in flipping the classroom, students focus on the lower levels of Bloom’s revised taxonomy [12] (gaining knowledge and comprehension) outside of class. During class students focus on the higher forms of cognitive work (application, analysis, synthesis, and/or evaluation) being supported by their peers and instructor.

Van Den Boom & Schlusmans [13] state that giving feedback is one of the learning functions, as it is important to give students insight in their learning process and achievements. Van der Kolk [7] found out that in practicals supervisors often had to spend quite some time on figuring out what students meant, and felt it was difficult to give sufficient adequate feedback on the plans of approach.

Van der Kolk [7] developed LabBuddy®, an e-learning tool that supports learning in laboratory classes. In this e-learning tool students are forced to prepare themselves properly for the lab work: students need to answer questions on the theory of the lab experiment, and need to come up with a plan of approach for their practical. To support students in preparing themselves for the lab environment and lab tasks, photos and videos are available in LabBuddy®. In their preparation, students make a visual overview (block scheme) representing all the steps in the experiment to be executed.

LabBuddy® is an online tool, so that students can collaborate in groups and work on the same plan. The teacher can approach the scheme too, and give feedback (using digital post its). During lab work, students can approach their block scheme, follow the steps and make notes of their observations in a digital labjournal. Using the e-learning tool LabBuddy®, might help students to reach higher levels of knowledge and skills, and might diminish the work load for the teachers.

In this paper we focus on “How can an e-learning tool support the practical at BioMedicalEngineering at the University of Twente”. In the sub questions, we focus on learning, collaboration of students and the workload of the lab teachers:

- How does LabBuddy® contribute to deeper learning (knowledge and skills)?
- What is the effect of LabBuddy® on group collaboration?
- How does the use of LabBuddy® influence the workload from labteachers?

- What are the experiences from students in working with this new tool (functional evaluation)?

In section 2, the relation between the research questions and the methodology will be presented. This is followed by the presentation of the results in section 3, while section 4 closes off with the conclusion and discussion.

2 METHOD / RESEARCH QUESTIONS

2.1 Context

Participants were 70 2nd year Bachelor students from BioMedical Engineering at the University of Twente. Students were divided into 16 projects groups. All groups had to prepare and perform an experiment in which they had to create and analyse biological tissue from stem cells. The e-learning tool LabBuddy® was used to support the learning process, both in the preparation and execution phase of the experiment. In total the project is 4 EC (≈ 110 hrs), of which around 1.5 day lab work.

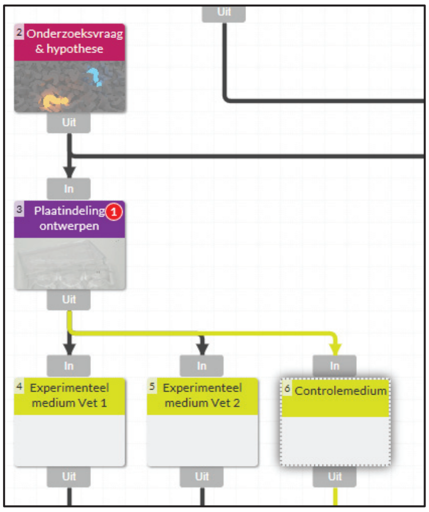

Figure 1: Visual block scheme of the design of an experiment (e.g, a block with the research question (red block), overall experimental design (purple block) and the experimental conditions in the yellow blocks).

2.2 LabBuddy®

LabBuddy® is an e-learning tool that supports students in preparing their labwork and keeps them focused while working on the lab [7,14]. In LabBuddy® it is possible to design and prepare the entire experiment in visual blocks. Figure 1 shows part of an overview of the design of an experiment.

In the implementation of LabBuddy® at the University of Twente, the following elements were added:

- *Questions* on domain knowledge, *videos* showing complex activities and *photos* showing the actual equipment to prepare students for the lab.
- All *protocols* were already available in LabBuddy® in visual blocks, so that students only had to select the appropriate protocols in the right order (see also Figure 2).
- A *digital labjournal* was implemented so that students could make notes on their observations.
- *Digital post its*, so that teachers easily could ‘stick’ their feedback to the visual block scheme and the plan of approach.
- Regarding *hardware*, tablets and computer screens were available so that students could access their protocol, answer questions and make notes in the digital labjournal. Students used large screens to keep an overview of the entire experiment. The tablets were used to read the protocols. For (biological) safety reasons, students were not allowed to use their own equipment on the lab.

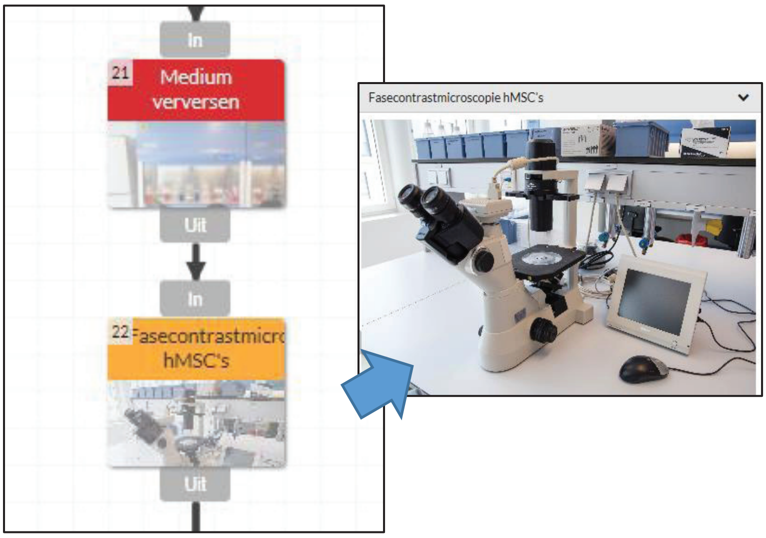

Figure 2. Part of the visual block scheme. After growing the cells, students have to refresh medium (red block contains protocol), and check the condition of the cells. Student use phase contrast microscopy (the orange block contains a picture of the microscope and a video on how to use it) to check the condition of the cells.

2.3 Research questions

Multiple methods and instruments were used to answer the research questions. The first research question was answered by analysing the items in the final exam; the expectation was that students would score higher on these items, as all students had to answer questions in preparing for the lab. In addition, the final report of the research experiment was analysed to see whether the quality of the report would improve. As in LabBuddy® students have to follow the research cycle more closely, we expected an improvement. Finally, student behaviour and their questions posed to the tutors were observed and analysed. It was expected that students would be better prepared and therefore would ask less low level questions. Lab teachers were asked to register their working hours, especially the hours on giving feedback (as that process caused peak loads for teachers). A student questionnaire (41 items) was used to measure student appreciation of LabBuddy®. Table 1 shows an overview of the research questions and methods.

Table 1: Overview of research questions and research methods**.**

Research question	**Comparison** LabBuddy® group to last year's group in which LabBuddy® wasn't used.
1) How does LabBuddy® contribute to deeper learning (knowledge, skills)?	a) Compare grades on written test related to experiment. b)Observation/ focus group: Compare the type of questions asked during labwork. c) Analysis of final report: Description of the research cycle.
2) What is the effect of LabBuddy® on group collaboration?	Student questionnaire: Student evaluation on group work. Observation / focus group: on student collaboration.
3) How does the use of LabBuddy® influence the workload from lecturers?	Registration of working hours.
4) What are the experiences from students in working with this new tool (functional evaluation)?	Student questionnaire on experiences.

3 RESULTS

1.How does LabBuddy® contribute to deeper learning (knowledge and skills)? The research question is answered by comparing scores etc. with performance of previous cohorts of students (no e-learning tool).

a) Comparison of scores on final exam related to the experiment. In comparing the scores on items, related to the experiment, in the final exam (2016-2018) we found no significant difference between the scores on the exam (2016 and 2018; t=1.783, P= 0.07; n=70).

b) Comparison of types of questions posed by students at the lab.

In an observation on the lab and a focus group session with teachers and teaching assistants we found that, compared to last year, students asked less knowledge based questions (e.g. 'What is filtrate?') and less task related questions (e.g. 'How does this device work?'). Based upon the observations and the focus groups session with lecturers we can conclude that students were better prepared for lab work and were more independent than before.

c) Does the use of the research cycle in the final report change?

Based on the experiment, students have to write a final report in which they follow the research cycle (research question, hypothesis, methodology, results, conclusion). In 2017, so before LabBuddy®, lab teachers gave advised to use this cycle and refer back to the research question in writing the conclusions. However, only 27% of the reports contained this connection between conclusions and research question. LabBuddy® helps in following the research cycle and explicitly stimulates students to look back at the research questions when drawing conclusions. Apparently, this helped students to improve their report as now 88% of the reports contained a connection between final conclusion and research question.

2. What is the effect of LabBuddy® on group collaboration?

In lab observations, the authors noticed that students collaborate well within LabBuddy®: Large screens are used to look at the visual block scheme: students stand in front of screen, discuss their experiment, divide tasks and continue working independently. Hand held tablets are used to read the protocol and/or to process notes and questions. All students in the group are active (no freeriding behavior observed) and can explain the experiment. The student evaluation (table 2, item7) showes that 61% of the students thought that their group members equally contributed to the project. Because of some technical issues we realized that large screens and sufficient WIFI capacity is important.

In a focus group session with tutors, we found that one teaching assistant was quite negative about LabBuddy® and its usefulness: he had no interaction with the group as his students followed the instructions more closely. Lecturers, however, were positive about the interaction with the group and found that the block scheme could be used as a starting point for group discussions.

3. How does the use of LabBuddy® influence the workload from lecturers?

Assessing and giving feedback on the student products is time consuming. Last years, that was especially true for the plan of approach. Lecturers and students experienced a peak load in giving and receiving feedback on these plans. This year, all feedback was delivered through LabBuddy®. The block scheme helped to give to the point feedback at an early stage, which reduced moments of stress before the start of the practical.

In comparing the registered worked hours we found that the feedback process took around 40 hrs in recent years. This year, these hours were reduced to 14 hrs.

4. What are the experiences from students in working with this new tool (functional evaluation)?

In a final evaluation questionnaire (41 items, 5 point Likert scale), students were asked for their opinion on several aspects of working with LabBuddy® (preparation, background information in LabBuddy®, cooperation, overview of the project, feedback, time investment, labjournal and manual). The main results can be found in Table 2 (41 students completed the questionnaire).

Table *2:* Results student questionnaire (question, mean score on 5 point Likert scale, standard deviation and percentage of students that answered 4 or 5 on that item).

Preparation	**Mean**	**SD**	**≥4 (%)**
1. The preparatory questions from LabBuddy® made me feel well prepared for the project.	3.8	0.8	71
2. The background information that was available through LabBuddy® fitted in well with my prior knowledge.	3.5	0.8	54
3. The videos helped me to better understand the methods and techniques used.	3.5	1	56
4. The use of Prepare mode in LabBuddy® ensured that I had (more) confidence in the correct execution of my experiment.	3.6	0.9	63
Collaboration			
5. LabBuddy® makes the exchange of information between group members easy during preparation.	3	1.2	42
6. In communication with the tutor, LabBuddy® made it easier to exchange information.	3.2	1	48
7. Everyone in our group contributed more or less equally to the project.	3.5	1.1	61
Working on the lab			
8. Because of the visual block diagram I always knew what I was doing in the project.	4	1	81
9. The questions in Work Mode provided more insight into the project.	3.8	0.7	78
10. The photos of techniques and equipment made sure that I could work more independently.	3.3	1	54
11. By using LabBuddy® I had the feeling that I could work (better) independently.	3.7	0.8	71
Feedback			
12. The feedback on the open questions helped me to better understand the project.	3.3	1.1	51
13. The feedback from LabBuddy® on our Schedule helped our group to come up with a good schedule independently.	3.5	1.1	68
14. It was handy that the teacher could add the feedback to our schedule in LabBuddy®.	4.3	0.7	93

15. In the preparation I found it useful to get automatic feedback from LabBuddy®.	4	1.1	80
16. The automatic feedback helped me to better understand the project.	3.4	1.2	61
17. During the project, automatic feedback on, for example, the calculations of dilutions was useful.	2.8	1.2	29
Labjournal			
18. In general, I like being able to make digital notes at a practical.	3.5	1.1	61
19. In LabBuddy® I was able to write down my observations.	3.6	1	63
20. In LabBuddy® I was able to write down my calculations.	2.6	1.1	24
Practical manual and future			
21. LabBuddy® is a good alternative to a paper practical manual.	4.1	0.6	73
22. In other modules (eg M11) I would like to use a digital learning environment, such as LabBuddy®	4.1	0.6	88

The results of the questionnaire show the following:

- *Preparation:* In general, a majority of students felt better prepared because of the LabBuddy® activities (table 2, item 1 to 4). For example, 71% of the students felt that the questions prepared them for the project.
- *Feedback / workload*: The survey showed that feedback through LabBuddy® worked out well. 93% of the students found it handy that the teacher could add feedback to their visual block scheme in LabBuddy® (table 2, item 14) and 80% found it useful to get automatic feedback (on MC-questions) (table 2, item 15), The automatic feedback on calculations (e.g., calculations on cell density) scored really low on usefulness (29%, table 2, item 17). Most likely this was due to too small error margins on calculated answers. For subsequent practicals this can easily be adjusted.
- *Labjournal:* The new digital labjournal function worked out well for making digital notes (61%, table 2, item 18) and observations (63%, table 2, item 19) at the practical. Students preferred to make the calculation on paper (24%, table 2, item 20).

4 CONCLUSION AND DISCUSSION

In this paper, we investigated “How can e-learning tool support the practical at BioMedicalEngineering” at our University of Twente. We focussed on student learning and collaboration. As giving feedback caused peak loads for teachers, we investigated the feedback process and working hours for teachers. Finally, we asked students for their opinion on the e-learning tool. In this section, we will look back at the research question, discuss the main results and give suggestions for further research.

How does LabBuddy® contribute to deeper learning (knowledge and skills)?

In the preparation for their lab work in LabBuddy®, students had to answer questions in the lower levels of Bloom’s revised taxonomy [12] and watch videos on basic lab skills. This resulted in autonomous behaviour on the lab, as students knew what they had to do [cf 11]. Neumann and Welzel [15] conclude that ‘a systematic and strategic support seems necessary to allow for an acquisition of metacognitive and content specific knowledge in open learning environments’. In LabBuddy®, our students were supported in this process by several questions and prompts for taking notes and reflection. This support helped our students to follow the research cycle more closely: in the final report, students referred to their research question while drawing conclusions on the experiments. Our functional evaluation, the questionnaire, of LabBuddy showed that students find LabBuddy® an intuitive system and would like to use it for other labwork too. This attitude towards the e-learning tool on the lab, opens opportunities for scaffolding the learning process at the lab. Within LabBuddy®, the information needed for the experiment is chunked into little blocks (see Figure 1). Within our SDL projects (1), students take responsibility for their own learning. For learning on the lab, this process could be supported by increasing the complexity of the lab work and decreasing the amount of scaffolding: e.g., in the first year, the visual scheme and blocks are pre-defined, whereas in later years, students have to select the right blocks and structure (e.g., the experiment as described in this paper). For their final bachelor project, students could be asked to come up with their own building blocks and plan of approach. In this way, students are challenged to take responsibility for improving their research skills.

Quite some digital videos and photos from equipment on our lab, were added to LabBuddy® to support students in learning the complex lab skills. Those videos were created using the multimedia principles from Mayer [17]. Just recently, a study by Rodgers et al. [9] revealed ideas to even improve our videos.

The effect of LabBuddy® on group collaboration.

In previous years, students sometimes complained that not everyone contributed equally to the project, mostly because of the fact that those free riders did not understand the complex experiment. This year within LabBuddy®, cooperation in the preparation and during the practical phase went smoothly: students sat together, divided tasks and could continue working independently. Tutors checked whether all group members could explain the whole experiment and found no freeriding behaviour. The interaction between the project group and the teaching assistants at the lab changed. One teaching assistant thought that his interaction with project groups had diminished compared to last year and he noticed that his groups followed the instructions on their tablets more closely. Therefore, he was quite negative about LabBuddy® and its usefulness. This observation might be an interesting element for further research in the lab environment since the role of the teaching assistant might change from an expert role to a more cognitive coach as described by Wallace and Walker [16]. In a follow up our study, it might be good to have a look at the new role of the teaching assistants and how to prepare them for that role.

How does the use of LabBuddy® influence the workload from lecturers?

In our study, teachers used ‘digital post its’ to give feedback on the plans of approach (check correctness of approach, feasibility regarding labwork), on open questions and on calculations. All feedback was given within the e-learning tool LabBuddy®. Feedback could be very specific (e.g, check dilution of cells in your experimental condition) and just-in-time (as students were still working on their plan). Students easily adapted their plans based on the feedback (which makes the whole process efficient and effective). Hours spent on giving feedback were reduced with 65%, while students were still very satisfied with the feedback. Most probably, this reduction was caused by the fact that all plans of approach were easily available (via the visual block scheme), had a similar structure and all feedback could be given within the system (so no separate e-mails). All in all, this shows that the e-learning tool simplified the process of feedback, while keeping the quality high.

Functional evaluation of the e-learning tool

As was mentioned before, students found the e-learning tool an intuitive system and would like to use it for other projects as well. The third author asked for an improvement of the labjournal function in LabBuddy®, so that students could make notes digitally on all their observations. Although this new labjournal function was still a ‘pilot’, around 60% of the students were already happy with this opportunity. Most students prefer to write their calculations on paper. We did not experience any influence of this pilot on the outcomes of our study.

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Set Sail from the Old Sea?

Naval Architecture Education in the Wave of New Generation of Learning

J.-P. Wang
National Kaohsiung University of Science and Technology
Kaohsiung, Taiwan

W.-L. Hong[1]
National Kaohsiung University of Science and Technology
Kaohsiung, Taiwan

Conference Key Areas: Integrated learning environments for the digital native learners, New notions of interdisciplinary in engineering education

Keywords: Naval Architecture, Cyber Technology, 4th Industrial Revolution

ABSTRACT

Naval Architecture, better understood as shipbuilding engineering, is a form of technology since the ancient time. The science of shipbuilding mainly involves with ship hull shape and structural design until the 19th century when machines begin to power ships. Today, the curriculum in authors' department still focuses largely on mathematics and mechanics. Students' motivation to learn is low and the discipline seems to be trailing behind the new wave of cyber-centred technology. To encourage naval architecture students to think creatively and act innovatively is very challenging because shipbuilding looks like a traditional heavy industry. To help the students to establish a good foundation for future development in the new digital oriented technology and to utilize them in shipbuilding industry, authors introduced new teaching approaches in courses of '*Engineering Software*', '*Data Acquisition and Analysis'* and '*Fundamental Maritime Engineering*'. Students were introduced to software similar to the commercial software used in the trade. They gained hands-on experience and continue to build the capacity with the software. The tasks in the classes were intentionally designed to be a combination of achievable simple ones and real-world complex problems. Students were guided to learn and use digital tools in conjunction with fundamental science, they showed confidence in acquiring a more holistic understanding which combines large complicated physical objects (like ships) and cyber possibilities. For the shipbuilding industry to evolve with the 4th industrial revolution, engineers who can use new digital technology on cumbersome objects are needed. A task-based learning with carefully chosen software in universities can be helpful.

[1] Corresponding Author
W.-L. Hong
wlhong@nkust.edu.tw

1 INTRODUCTION

Building boats and ships is a very old skill if we look back into human history. However, according to what Ferreiro and Hocker discussed in [1], French astronomer Pierre Boubuer was the one invented the field of Naval Architecture scientific knowledge in the 18th century in the mountain of Peru. Pierre Boubuer provided a complete set of principles governing naval architecture scientifically, or can also be understood as a combination of hydrostatics, hydrodynamics. He also defined stability by inventing the metacentre, which pave the ground for future study on characteristics and behaviours of ships. In the old time, master shipwrights who were capable of designing and managing the entire process of shipbuilding (usually the wooden ones), ran the secretive trade. Today, naval architecture programs around the world teach engineering and science of ships, the knowledge and skills for the design, construction, production and operation of marine vessels and systems. However, as ships become bigger and the scientific knowledge becomes more and more complex, it is really difficult for undergraduate and master students to develop intuition and overall understanding of ships.

1.1 Typical naval architecture curricula

In Taiwan, the modern version of shipyard first appeared in 1918 when Japanese mining entrepreneur Kimura Kyutaro started ship repairing business in Keelung. The first naval architecture program (a 5-year program for middle school graduates) was established in 1959, first master programme was established in 1973. *Table 1* shows the naval architecture curriculum in author's department today, which is not very different from how it was 30 years ago.

Table 1. Sample Naval Architecture curriculum

Year	Math. & Mechanics	Engineering & Ships
1st	Calculus, Physics, Statics	Introduction to Naval Architecture, Computer Application, Drawing, Engineering Shop
2nd	Engineering Math., Material Mechanics, Dynamics	Lines & Calculation, Stability
3rd	Fluid Mechanics, Mechanics Experiments, Structures, Thermodynamics	System Dynamics, Resistance & Propulsion, Model Making
4th		Ship Design, Ship Structure Design

This curriculum focuses on building theoretical competency through teaching mechanics and mathematics in the first 2 years. There are basic shop courses and model making in the first year and third year. But design courses are reserved until later because the underlying belief is that, to design a complex system one should acquire theoretical capacity first. However, students have continued to reflect their frustration and anxiety about learning theorems and lack of “feeling” towards shipbuilding in and off class. Many have complained about the absence of hands-on experience and not being able to advance their shop skills.

1.2 Connecting with the cyber technology

A contracting example comes from design school. A design educator from Copenhagen Design School has commented in authors’ previous work of designing a Science, Technology and Society (STS) program for engineering education to enhance inclusiveness and diversity, as in [2]. He provided the example which design school students have to engage in design and model making since the beginning of their study. Therefore, the practical skills were exercised every semester, enabling them to integrate what they have learned into the design as they go along the curriculum. Similarly, architecture education also requires students to make models to showcase their design of community and buildings, similar to design students.

Naval Architecture curriculum arrange design courses at the last year and most students would not be able to experience the completion of a ship design process. Also there is no requirements on making a model to realize the ship design. As a result, naval architecture students do not have the luxury of time to establish their intuition and many critical concepts about ships from diverse means of learning.

Kyu-Yeul Lee and colleagues had witnessed similar problems in Korea and they applied project-based and collaborative learning on 2 courses, “Planning Procedure of Naval Architecture & Ocean Engineering” and “Innovative Ship Design” as discussed in [3]. The students were encouraged to enter ship design contests and the results was positive in enhancing students’ design ability. They also stressed on the continue update of the subject to reflect latest issues in shipbuilding industry.

In author’s department, even though students’ frustration is obvious and their lack of incentive to learn is troublesome, little has been done to improve the situation. Therefore, without causing too much disturbances to the program curriculum, we want to provide students with opportunities to build conceptual understanding and practical skills at the same time in selected courses. This paper discussed our efforts to utilize the new tools of software, introduce key concepts of cyber technology and build students’ intuition about complex engineering systems.

2 MATH TOOLS FOR ENGINEERS

2.1 Cracking the math demon

For junior students, author offered this course “*Application of Engineering Software*” to bring them software-using experience without burdening them with programming or code writing. Several open source software packages were introduced to solve common engineering task.

2.2 "*Application of Engineering Software*"

Freemat and GNU Octave (the open source counterpart of Matlab) was introduced to solve simultaneous equations, inverse matrix, etc. Solvers like Fast Fourier Transform help students to see the relationship between time domain and frequency domain more easily. They also tried to solve ordinary deferential equations without writing complicated codes and debugging. Students also learned how useful these software packages are in plotting equations for a quick understanding of the forms of the equations. It's like a revisit to Engineering Mathematics without hand calculation. Students were surprised to learn that computer can help to solve equations and it's more reliable than their hand calculation. After the course, they also expressed less anxiety towards using software because these software packages are more intuitive and responsive than programming languages.

3 CONNECTING WITH SONSORS AND DATA

3.1 Building the sensor system

Shipbuilding is a heavy industry concerning manufacturing large and complex objects. Measuring have long been a part of the shipbuilding industry, for example, measuring vibration caused by the main engines, temperature variations in the engine room, etc. Naval Architecture students are often foreign to the idea of acquiring information with digital data and analysing them for specific purposes. Thus, they are not connecting the 4th industrial revolution or the concept of the Internet of Things when they learn about shipbuilding. However, both shipbuilding and shipping industry are fast in integrating the cyber technology into autonomous ships and better efficiency and security of seafaring.

3.2 "*Data Acquisition and Processing*"

To establish a foundation for students to bridge into the cyber technology for future shipbuilding, tactic experience with data acquisition and processing are really beneficial. [4] discusses how they uses digital tools of video, web TV, blog to promote learning and recording of the tactic knowledge. Similar effects can be achieved by even just having a little experience in seeing how data can be collected and analysed.

In the course "*Data Acquisition and Processing*" for senior students, we introduced automatic measuring using affordable Arduino sensors. Students tested infrared sensors, accelerometer and thermometer, etc. Some simple control loops were also applied in the tasks in the class. Students were amazed with how much micro sensors and controllers can do, and this fuelled their innovative thinking about ships and vessels at sea. Many of them went on to build autonomous vehicles to compete in handmade ship model contests.

4 REAL WORLD APPROACH

4.1 Tackle the big problem

In the course of "*Fundamental Maritime Engineering"* for master students, we focused on all the fundamental knowledge and aspects needed for developing an offshore wind farm, including oceanography, wave mechanics, geotechnical engineering and survey engineering. This is a fast-growing industry in the region and it involves very complex knowledge and engineering practices. We intended to provide students with a holistic overview from the very beginning when they started to learn about offshore wind farming. Therefore, we decided to introduce basic concept of various fields together. We also pointed out key issues which involves 2 or more given disciplines and asked them to work out how to communicate and collaborate with peers from different background.

4.2 Real world design tool

We introduced students to Q-Blade, from the very beginning[2]. Q-Blade is an open source wind turbine software which allows users to design blades rapidly for a wind turbine and simulate its performance right away. It's used for hands-on design and simulation. Students can produce the results of different design choices and turbine performance very easily. There are also online tutorials from which students can learn by themselves. They also reported feeling to be part of a bigger engineering community when they learned from the tutorials.

4.3 Thinking of the real situation

The term project was to design a 1MW wind turbine. Students researched the local wind farm locations, wind profiles and other parameters to decide on the best design criteria. Fig *1*. shows the example of one student's simulation of her wind turbine design.

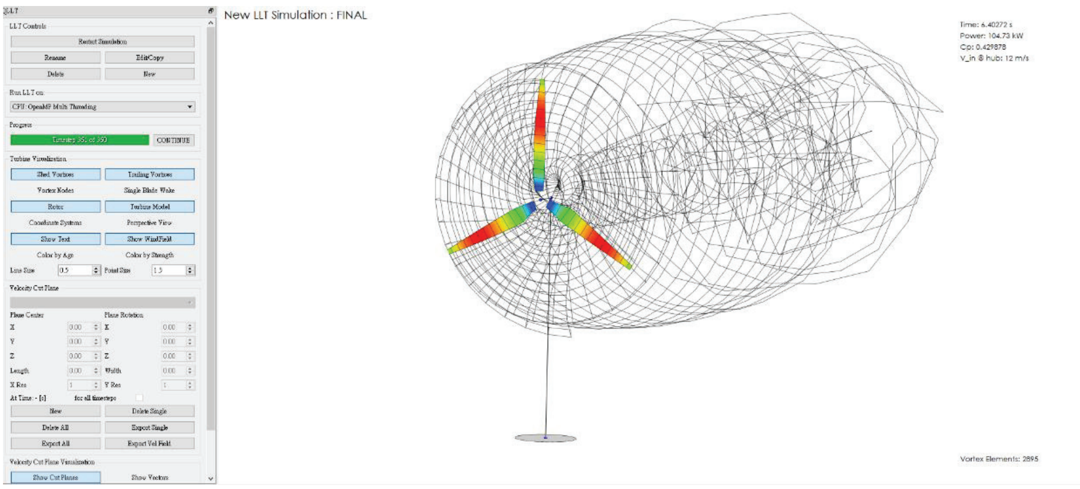

Fig *1.* Student's term project of designing a 1 MW wind turbine

Many students expressed how good they felt after completing the design project. One of them wrote:

> *The final project is very challenging. I started with some basic review and a lot of trial and error approach, and I failed many times.*

[2] http://www.q-blade.org/

> *Therefore, I felt especially accomplished at the end. I took this course because I was curious about wind turbine. But I started to build up my interests about the wind power industry and I want to develop a career in it. I am very optimistic about it and I hope I can get certified and contribute to the growing industry.*

This was very encouraging as we have seen students developing interests and self-learning capacity. Of course, further design details should be examined carefully when students were engaged in real situation.

5 SUMMARY AND ACKNOWLEDGMENTS

We intentionally incorporated many software packages on the shelves into our teaching contents. With the help of computer software packages, students obtained better understanding of theoretical and technologies learnt from textbooks and lectures. The use of open source software eliminates the difficulties of establishing conventional computer-aided teaching environment constructed by commercial software packages. We are excited to see the “dated and traditional” Naval Architecture curriculum in our department can come closer to the 4th industrial revolution. The real-world tasks and projects in the class facilitated active discussion between students and instructors. It also generated many new ideas about using cyber technology as an agent for building capacity in practical engineering. We hope to rejuvenate shipbuilding learning for contemporary higher education. It is certain more work is needed for further investigation on course design and outcomes. However, this effort serves as an exciting and encouraging start.

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Global Competence of Chinese Engineers for the Belt and Road Initiative
--An Exploratory Study based on Grounded Theory

Chu Zhaowei[1]
Zhejiang University
Hangzhou City, China

Yao Wei
Zhejiang University
Hangzhou City, China

Hu Shunshun
Zhejiang University
Hangzhou City, China

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ABSTRACT

Numbers of qualified Engineers are important guarantee for the successful implementation of BRI (Short for Belt and Road Initiative), and there is still insufficient research on the global competence of Chinese engineers. Several human resources managers from 12 state-owned enterprises were interviewed. These enterprises were developing main businesses along Belt & Road countries. Conversation records（16 hours）were analysed based on grounded theory After a series of abstracted process, these data are organized into three main categories related to global competence with its elements, consequences of lack of that and how to improve it. The study found that the cultural competence, global mindset, adaptability, communication and lifelong learning are the main elements of global competence of engineers. Some implications are proposed, such as universities and colleges in China need to have a global perspective and change their educational concepts. Enterprises should also actively participate in students training, and boldly carry out institutional exploration. Engineers themselves should take the initiative to learn international knowledge, improving their learning ability, and establish the concept of lifelong learning.

[1] Corresponding Author
Chu Zhaowei
chu312@zju.edu.cn

1 INTRODUCTION

The paramount leader of the People's Republic of China, Xi Jinping, originally announced BRI (Short for Belt and Road Initiative) during official visits to Indonesia and Kazakhstan in 2013. The initiative is an effort to improve cooperation and connectivity, to strengthen infrastructure, trade, and investment links between China and other countries [1]. Countries in B&R (short for Belt and Road) area are mainly developing countries (89.06%), most of which are in early stage industrialization and have a huge and urgent need on infrastructure construction. Labor in these countries are featured by unqualified and junior engineers [2]. According to the statistics of Chinese Ministry of Commerce, investment in the B&R region is mainly engineering aspects. In 2017, the turnover of engineering activities of Chinese enterprises in B&R region was US$168.59 billion, up 5.8% than that in 2016, and the value of newly signed contracts was US$265.28 billion, increased8.7% [3]. It is foreseeable that the commercial activities of Chinese enterprises in the B&R countries will further increase the demand for engineers.

In more complicated and unfamiliar investment environment, the investment business in B&R region has brought up new challenges on the global competence of Chinese enterprises and engineers. At present, the research on the global competence of Chinese engineers is still quite scarce. It is necessary to research and help them to improve global competence. Therefore, the research focused on two questions: (1) What are the global competency elements of Chinese engineers? (2) What are the consequences of a lack of global competence for engineers? (3) How to improve the global competence of engineers?

2 REVIEW OF THE GLOBAL COMPETENCE

After McClelland proposed to replace intelligence with competence in test, the word “competence” has been widely used. “Competence” usually referred to “the knowledge, skills, abilities, and traits necessary to enable someone to achieve performance” [4]. The editorial of EJEE (European Journal of Engineering Education) once made a semantic analysis of the word “competence” in engineering education and found that the meaning can be given as knowledge, competence/competencies, ability/abilities, skills, etc., but they believe that the conceptual connotations of these terms are basically consistent [5].

The requirement for global competence of engineers is the result of the globalization of engineering activities. It is obviously significant to clear up the meaning of global competence, as Magleby said: “If this ability is to be taught, developed and assessed, it must first be clearly defined” [6].

At present, researchers have different interpretations of global competence of engineers. Magleby defined 13 dimensions and attributes of global competence. Based on the research of literatures and official documents of several countries, May identified four central global competence related to engineers:

(International)communication, understanding of the engineering profession in a global context, (international) teamwork and ethical reasoning [7]. Patil made a finding to show the significant gap between the expectation of industry to what graduates bring to the work force in global environment [8]. Downey set up a criterion for global competence based on learning outcomes [9]. Most scholars have established their own global competence model for engineering students based on their cultural features and studying environment. Although their interpretations to global competence are so distinct, generally, most of them contain several basic elements such as global awareness, shared values, professionalism, communication.

As for developing global competence, Lohmann summarize several approaches to instil global competence for engineering students such as dual majors, minors and certificates, international experience [10]. Downey classified methods for achieving global competence as five: international enrolment, international project, international work placement, international field trip, integrated class experience [9]. Jesiek introduced a China Research Abroad Program to improve American students' global competence [11].

Compared with the amount of practices and researches on global competence worldwide, there are very few studies on global competency in China [12], due to the current educational system in China is more focused on serving domestic talents needs. At present, there is a general lack of basic theoretical exploration and individual level training practice research, not to mention the special needs for talents in the B&R region. This paper attempts to construct theories for developing Chinese engineering students through grounded theory.

3 .DATA COLLECTION AND ANALYSIS

3.1 Samples and Data

This research is an exploratory study with the aim of theoretical construction, and thus adopts grounded theory. The whole research process includes interview and data collection, coding and theoretical construction. The coding process is divided into initial coding, focused coding and axial coding.

This study fully considered the needs of representativeness and theoretical construction, Interviewees are directors of overseas HR department, overseas business managers or engineers who involved in overseas businesses who are from 12 Chinese state-owned enterprises. Those enterprises have a large volume of business (over 10 billion RMB in turnover), extensive engineering coverage (transportation, construction, energy, communications, etc.) and rich experience in engineering talents management (employees exceeding 1,000) in B&R region.

There are two main ways to collect data: first, interviews, including group interviews, personal interviews, and telephone interviews. Second, examine disclosed information and visit companies and collecting public information. Until it is difficult to generate new theoretical insights after fresh data collected, it reaches a saturated state and the information collecting will be stopped [13]. In the process of information collecting, this study adopts rolling research, designing open interview outline, and constantly searches for new materials and codes them. When the new coding no longer appears, the data collection process will be stopped and the existing data will be used as a source of data for grounded theoretical research.

Triangular validation method is used to ensure the reliability of data. During the interview process, more than 100,000 (Chinese)words of interview materials were collected and the content was adequate. The coding process was completed by two coders, and the reliability of the encoding is high after calculation. Limited to length, the paper could not offer more details.

3.2 Initial coding

In the Initial coding stage, the interview data was analyzed word by word, and the observed phenomena were “labeled” and the “native code” was retained as much as possible. Finally, 392 initial concepts were formed. Due to space limitations, this article chose a partial encoding as shown in Table 1.

Table 1 Examples of Initial coding

typical reference	Initial coding
“... Later, some engineers with good English skills were given priority in promoting, to ensure all of our project managers can communicate without (English) translator.”	Promoting priority
The company's business is mainly based on engineering projects, actively participating in some operations, trade, industrial parks and free trade zone investment and estate development, to help the local economic developing fully. At the same time, we are trying to achieve business transformation and diversification."	Business Diversification
"Some engineering students can come to a country as a director (project management) in two or three years. Students, who ranked top in grades but lack comprehensive abilities, are often eliminated. Some time ago, we just eliminated a undergraduate form Tsinghua University.	Requirements for comprehensive abilities
...	

Source: According to the interview data.

3.3 Focused coding

In the focused coding, the initial concepts are continued to be summarized and refined, and the same initial concepts are integrated to 60 initial categories. Based on the initial categories that have been extracted, this paper attempts to use the classical paradigm "Casual Condition-Phenomenon-Context-Intervening Condition-Action/Interaction-Consequence" proposed by Glaser to link these concepts [14]. Table 2 takes the two paradigms of causal conditions and intervening condition as examples, and illustrates the all the initial categories.

Table 2 Initial categories using typical paradigm combinations

Paradigm	Amount	Concrete Initial Categories
Causal Condition	8	lack of engineering practice in school; evaluation system based on grades; rigid choice system; company's business shifts from home to abroad; company's business diversification; company's business upgrading; high cost of employment; hiring local worker;
Intervening condition	12	engineering leadership; teamwork ability; English communication skills; non-universal language learning and application; engineering investment management; operational management; risk management; cross-cultural leadership; communication with local community; limited promoting ways; rigid incentive system;

3.4 Axial coding

In the axial coding phase, it is mainly to combine similar initial categories. As shown in Table 3, in the analysis of "causal conditions", it is easy to find that three initial categories: insufficient engineering practice training in university; Score-oriented evaluation system; rigid talents selection system, have similar meaning and can be reduced to the main category "defect of talents training". Some initial categories are related to the company's strategic options. such as: business shifts from home to abroad; business diversification; business upgrading, which can be reduced to main category "Company business transformation". Other initial categories can be reduced in the same way.

after the collections of initial categories are gradually abstracted one by one, all the concept categories are organized into three main categories finally. These main categories are shown in Table 3.

Table 3 Main categories using typical categories

Paradigm	Insufficient global	Talents structure	Engineering human

	competence	contradiction	resources improvement
Causal conditions	Deficient talents training	Company business transformation	High cost for company
Phenomenon	Narrow skill for engineers	Talents structural mismatch	Weak capability of work adaptability and job rotation
Context	Cross-cultural engineering environment	Cross-cultural business environment	Fierce business competition
Intervening condition	Frequent communication and collaboration in engineering field	Comprehensive business capabilities	Insufficient incentives mechanism
Action/ Interaction	Enhance employees' global competence	human resources structure Improvement	Training and incentives Improvement
consequence	Restricted business operation	Multiple Restrict on development	Exploration on human resources management

4 DISCUSSION

4.1 The lack of global competence and its impact

According to the above three core categories in Table 3, we can sort out related issues from three aspects and understand the global competence of engineers.

First of all, the talents selection for international business, Chinese companies find that engineers are obviously lacking of comprehensive quality and global competence. These weaknesses are further magnified in frequent communication and collaboration with foreign officials, engineers, and communities when they were undertaking engineering project in transnational and cross-cultural environment. As a result, companies have to spend a lot of time and money, starting from talents selection and internal training to improve that. The lack of global competence has led directly to constraints the business development of the company.

Secondly, in developing overseas business, Chinese engineering companies generally develop core international business first, and then gradually diversify according to the core business, then transform and upgrade it. When human resources mismatched with company's requirements, the phenomenon of talents structural imbalance will appear. This phenomenon could be mainly manifested in "two contradictions": abundant engineers who are capable of profession but scarce engineers who are capable of management and international business activities; sufficient basic engineer but deficient top talents. In the transnational and cross-cultural business environment, the development of business activities focusing on engineering construction poses a comprehensive challenge to the business ability (or non-technology ability) of engineering talents. Enterprises try to improve the talent structure through process optimization on personnel recruitment, internal selection and targeted training etc. A series of problems caused by the structural contradiction of talents make the development of enterprises face many constraints, such as capital shortage, risk increasing and business upgrading hindering.

Finally, when undertaking international business, local employment will bring challenges to the risk of cost and management. However, Off-site work strategy also has some defects, such as poor rotation ability, inadaptable work and insufficient skills of domestic employees, so enterprises are in a dilemma of "talents shortage". Furthermore, under the constraints of the incentive system, employees lack the motivation to self-improvement. In response to this situation, one thing the company only can do is to actively improve the training and incentives for employees, and to some extent, to achieve a “breakthrough” of the inherent system.

4.2 Global competency and its elements

Through the above analysis, a global competence model has been built in Fig. 1. It can be found that in this model the global competency of the B&R engineers generally has the following five capabilities. Firstly, cultural competence. It is the ability to understand and respect local culture and values. Actively understanding the religious beliefs, customs, cultural traditions and values of the territories is significant.

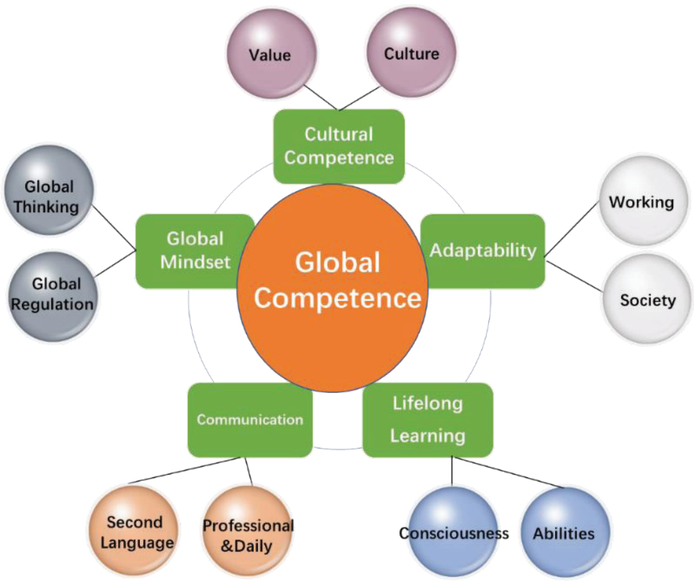

Fig. 1. Global competence model

Secondly, Global mindset. It means global vision, global knowledge and global thinking. In the B&R project, we need to consider and organize engineering activities from the perspective of globalization, and maintaining a good cooperation relationship. Thirdly, Adaptability. It is the ability to actively integrate into local culture and society. Engineers are not only "builders", but also "national cards" and "cultural messengers". They must be able to maintain relationships, shape a good national and organizational image and create a well investment environment. Fourthly, Communication. It is the ability to compete daily and professional communication. Finally, Lifelong learning. It means strong learning motivation and ability. Engineers must have self-improved learning awareness and learning ability as a guarantee to continuously improve their abilities.

5 IMPLICATIONS FOR PRACTICE

Considering a lot of defects mentioned above in talents training, we proposed some suggestions to improve this. First and foremost, it is urgent to change the educational goal. At present, the goal of Chinese education system is only focus on fulfilling the needs of domestic industry development and overlooks consideration of international demand, thus led to inadequate global competence. As Teng said, what Chinese students need most now is systematic global competency education rather than a kind of knowledge or ability. Propelling the school-enterprise cooperation in students training will be a considerable way, by forming a whole training-chain of “school training, internship program in school, and internship in enterprises”. It worth noting that Chinese universities should strengthen cooperation between them and multinational companies, and encourage or help their engineering students to practice or work in a real international background.

For companies, they should try to hire more local employees. Whether it is economic or legal, that will be beneficial for company's long-term development. However, they should actively promote the two-way flow of engineers in the company, to improve engineers’ global competence, and enable engineers to be qualified for international background in language, values and emotions. In addition, the company should provide more exchanges, cooperation and even mobility opportunities for employees in different jobs to enhance their cooperation. Also, while they are expanding their engineering experience, it is time to help them to be a project manager gradually.

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ANALYSIS OF SERVICES FOR THE PROJECT ACTIVITY UNDER THE BLENDED LEARNING SETTING

I. Yustyk
Junior researcher
The Bohdan Khmelnytsky National University of Cherkasy
18030 Cherkasy, Ukraine
E-Mail: irynayustyk@gmail.com

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Keywords: project-based learning, blended learning setting, information technology, web design

ABSTRACT

During the course of computer graphics and web design at the Bohdan Khmelnytsky National University of Cherkasy for first-grade students, we performed the selection and analysis of services for the project activity organisation. The research was carried out for students of engineering specialities in the blended learning setting. The purpose of the research was to solve the problem of increasing project work organisation effectiveness.

Students got a collection of services (cloud, online and offline) for each stage of the project. The respondents analysed these services advantages and disadvantages, performed a research on additional resources for work on the tasks. Besides, we analysed the services for the project management that fit for creating a website layout.

Students can easily use the current criteria to selecting services for their education and professional tasks solution. These tools provide the possibility of group interaction. The accessibility of software (free distribution), the flexibility of interface, cross-platform, multilingualism and integration with other services for most of the proposed tools are key advantages.

During the study, students used a collection of services and tools to work at different project stages. Each student, respectively, tested the services and provided a review of their usage. After that, we made a comparative analysis of the student and expert reviews for the appropriate services.

Students can use the created list of tools while working on real projects and during the learning experiment. It is also important that these services are well adapted for blended learning setting.

INTRODUCTION

Recent data from several studies and surveys prove that the implementation of project-based learning in the educational process is a socially logical step. The approach provides opportunities for increasing information technology and education interaction [1, p. 6].

The main goal of using project-based learning in the area of higher education is to form fundamental soft and professional skills and students' project thinking to use these methods in future professional activities. It is especially important during the initial phase of the project method studies for effective group learning environment organisation. That is why participants in the educational process need to create a database of tools for every stage of the project.

During working on the problem of creating a list of the best services for group work and work on the project, students can choose their own base of tools for organisation of educational, scientifically and workspace. The list of services they are going to use in future courses and during the working at individual tasks from the companies in the educational university hub. The list of best practises almost repeated the list of services, which presented by specialists the field of Automation and Computer-Integrated Technologies who use it for the educational process at their course and during organisation work ecosystem at the university.

As a part of the course "Computer Graphics and Web Design", the teacher offered a list of services for work on different project stages. Students chose services, whom they used during educational semester at different stages of the work. They analysed the advantages and disadvantages of these services. They also made their own list of tools for project activity. Through group discussion, we carried out the choice of the most useful service.

Students' project activities should promote the forming of creative skills and ability to ask questions, development of independence, activation of brain activity and teamwork skills, necessary for the future professional activity. The work on the problem is effectively solved by methods of brainstorming. The project-based learning encourages students to a constructive investigation.

Without information and communication technologies (ICT), we can use the project method, but it provides great advantages since it allows realising the opportunities for cooperation between teachers and students.

The organisation of project activities for the information and educational ecosystem of higher education provides opportunities for enhancing students' motivation, developing teaching possibilities and necessary competencies of students [2, p. 4].

The project-based technology follows the concepts of research-related articles on "project-based learning", "problem-based learning", "active learning", "design conception", "collaborative learning, "information technology education", and "design experiments", that conform to the criteria above [3]. The analysis of literary sources reported that professional problem-solving skills in information technology (IT) require an ability to reach a solution using data, whilst attempting to satisfy the clients' demands.

The growing pool of online materials represents another aspect of sustainability, as the experimental results are more persistently visible in comparison to the usually written paper protocols that vanish after correction by the supervisors. Online services for project management turn out to be suitable tools presenting the results of project activity and performing a human self-reflection. Students use these tools for working in groups, performing research, preparing and conducting an experiment, working on the interface of a new product or service.

The project and problem-solving methods contribute to students’ independence in all spheres of life, provide for student’s individualisation in the educational process and develop communication skills.

1. CONCEPT OF PROJECT-BASED LEARNING IN ENGINEERING

Project and problem tasks are closer to professional activities and therefore, take a longer period than other learning tools (they may extend over a semester, a week or a few weeks) [2, p. 11].

At the research stage, project participants (4 groups of students) discuss the tasks and begin to understand what they should get as a result. From this moment, it is important to realise all project stages, how much time it takes to implement, what are the target audience and the stakeholders [4].

At the planning and training stage, it is necessary to coordinate different task parts between the team participants, to agree on the best way to solve these tasks, to divide the responsibility areas between the participants. It is also necessary to draw up an action plan in accordance with the time management principles [5].

Communication is important at the project implementation stages. That is why the student projects' organisation is effective with the use of blended learning. This method involves continuous inclusion in work (using social networks or specialised services for online or offline exchange of ideas) [6].

During the project work, students can make the application of their knowledge, while during problem-based learning, they need to focus on the knowledge improvement. Time and resource management, as well as task and role differentiation, are extremely important in the education process. Self-education is stronger in project work, which is especially useful for engineer courses [7]. The projects are usually combined with traditional education methods within the same course. One person or small groups can carry out them [8]. The teachers in project-based learning are facilitators and advisers.

2. PROJECT METHOD TOOLS FOR WEB-DESIGN COURSE

Services are an important component of the project work, as they accompany all activities of the team members. That is why the proposed project "The Creating a Services List for the Project Activity" in the field of web design has provided a practical aspect for problem-solving.

The research objective is to analyse the designing stages and tools for creating the site's layout during the group work.

Methodological background of the research:

- conceptual analysis of available specialised scientific and technical literature;
- study and generalisation of tools, solutions and services for project implementation;
- using the methods of generalisation, comparison, selection.

During the work on the course materials, including practical tasks, the author of the course made a software list for using at every stage of the project realisation (see Fig. 1).

Tools for the Project Work:

1. Communication (Voice, Text).

2. Task Management (Team, Individual).

3. Requirements Management.

4. Storage of Project Artefacts (Documents, Tables, 3D Models, Wiki).

5. Drawing and Mind Mapping.

6. Designing Interfaces.

Students need to analyse services that provide project activity, solve project tasks and develop product outcomes. The experiment is implemented for a group of students from information technology speciality within the course "Computer Graphics and Web Design". Students can enhance the tools list with the services they use in their activities.

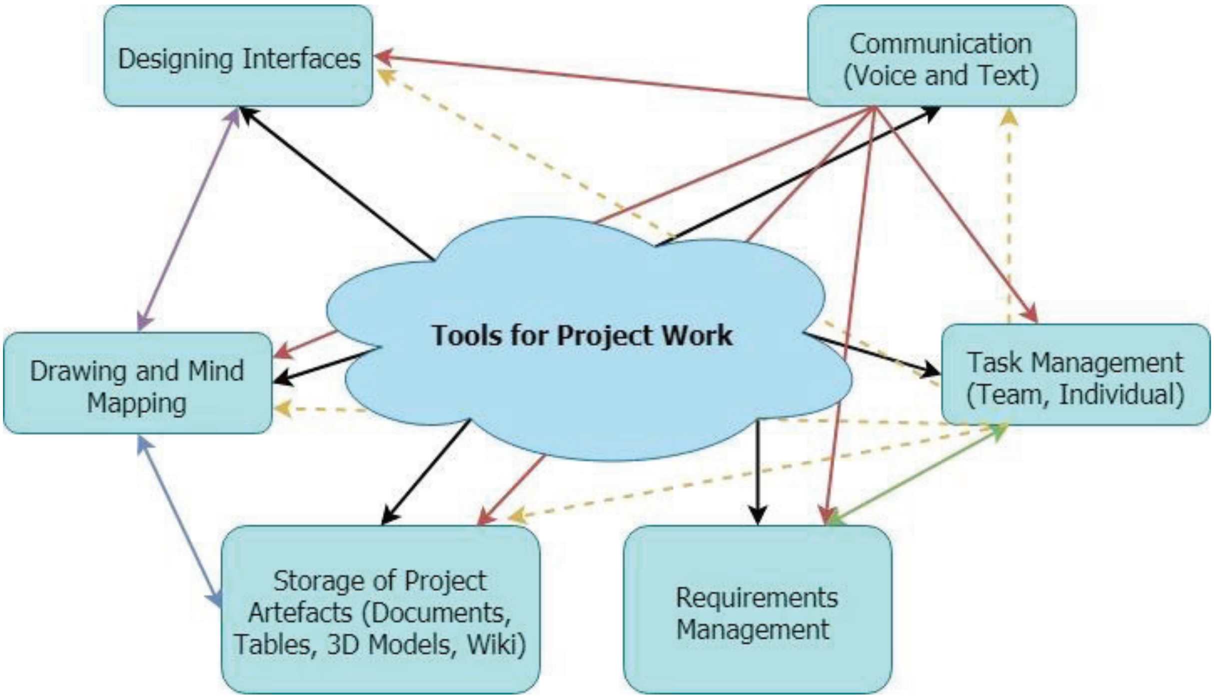

Fig. 1 Tools for Project Work

At the end of the project, students have to present a protocol at an online platform: make a presentation, video or infographics with describing the conducted experiment and the results.

Fig. 1 presents tools for project work. These tools have different connections. The black arrows indicate the number of instruments. The red arrows indicate on communications that provide the relationship. The yellow dashed arrows show the communication between management and other tools. Double arrows point to an inverse relationship between tools.

3. RESULTS

During February and March of the educational year 2018/19, students participated in the Command Project for the blended course "Computer Graphics and Web Design". We have posted the course activities on the Google Classroom platform. The service provides support for blended learning. On the platform, students performed group assignments, worked on the project, exchanged experiences and presented reports. The course is accessible via the URL: https://classroom.google.com/c/Mjg3Njg4Mjg2NDJa. Class code: 27m520.

During the work at the project, each team developed a peer-reviewed report of the best services for communication between project participants, created a new list of the most suitable tools (see Table 1), and tested all services during the educational semester. They also made a survey of stakeholders from IT sphere, which helped in realising all stages of work on the project.

The real-time sessions in this course were designed with flexible structures to help the students to better engage in it. For instance, practice sessions, ground rules, and guidelines were presented prior to the meeting while scaffoldings and technical aids supported the students' discussion activity during the project. In addition, after each meeting, the students were required to write reports and a reflection paper that aimed to help the students' reflection on their performance.

Table 1. Comparative Analysis of Services for Communication

Services for Communication	Chat	Voice Messages	Computer and Mobile Version	Web-version	Possibility of Attaching Documents	Video and Photo Messages	Group Chat	Online Conference
Telegram	✓	✓	✓	✓	✓	✓	✓	X
Viber	✓	✓	✓	X	✓	✓	✓	✓
Messenger	✓	✓	✓	✓	✓	✓	X	X
WhatsApp	✓	✓	✓	✓	✓	✓	✓	X
Instagram	✓	✓	Just mobile	✓	X	✓	✓	✓
Slack	✓	✓	✓	✓	✓	X	✓	X

Analysis of services was rated the following criteria: free workspace for using, flexible interface, the possibility of group work, AGILE, the possibility of integration with other services, explicit instruction of using. The model ADDIE [9] was used for the analyses of each service and building an effective system for teamwork.

It has shown that it is best to use the *Trello* service to organise workspace (https://trello.com/). The students immediately organised the activities with the tool: they created a joint room for the team, distributed the task and monitored the progress.

They also noticed the *Basecamp* tool (https://basecamp.com/), project management service and team communication software. The tool provides the ability to communicate with the team, share documents, create to-do lists, assign tasks responsible for assignments, add comments etc. *Jira* (https://en.atlassian.com/software/jira) is a complex and versatile system that allows bug tracking and agile project management.

For storage of artefacts *Google Drive* (https://drive.google.com) is the most suitable and flexible service. *Draw.io* (https://www.draw.io/) is a great service for drawing, building diagrams and models. The benefits of the service include integrating with Google Drive.

Most web designers use wireframing design techniques to create layouts. It is necessary to understand the structure of the site, its components and their placement. *NinjaMock* (https://ninjamock.com/) is the best tool for creating a layout. The process of creating a project framework for this service is fast enough. Users can easily share results with the client or with someone from the team.

The practice of group activities forms self-determination and responsibility for one's work and work of the team as a whole. Work on the project showed that teachers could use the following techniques for managing the project team:

1. Painting at the stage of project preparation to highlight the main criteria of service work.

2. Design thinking (empathy and definition) to show that it is necessary for the user of services: "Are there analogues of the proposed services?", "How to improve the existing list?".

3. Principle CDIO (Conceive Design Implement Operate) at the stage of goal setting. The system and project approach application to analyse the services technical component.

4. TRIZ for the project implementation. At this stage, students need to formulate the problem: Why do not the relevant services dispose of users to solve specific problems? Describe what resources we need to use the most effective services.

5. The human self-reflection. Its goal is to summarise results, main conclusions and suggest new problems, self-reflect (on the part of students and teacher). We can implement the human self-reflection with using conceptual tables, infographics or diagrams for representing the students' understanding of the functional features of the services to project work. The students expressed an impression of the work that they would like to change or do next time.

6. When students are working on a web page layout, it is important to do prototyping (creating a site prototype). In fact, this is a visual diagram of a page or its skeleton, which shows the logic between the functional blocks of the site and the script.

4. DISCUSSION

Introducing the project method for part of tasks during the course is a very successful way of organising educational activities. The method provides the teacher with the opportunity to use group tasks, create problem cases with the next effective solution by students [10]. These approaches ensure the development of creativity and critical thinking.

The work uses blended learning technology, which provides more opportunities for effective interaction between group members and tutors.

Blended learning model in Google Classroom helps students valued time flexibility; give more opportunities for the development of virtual teaming skills. The course organisation with the flipped-classroom model [11] for collaborative work in groups is helpful. Possibility of preparing to work in class before the lesson with online services show that teamwork is more important than independent work for their online learning. Students can choose the place where they can receive content online and control the study pace. In this case, they review professional and technical skills. The complementarity of everyone's skills is maximised in the collaboration.

Unlike traditional learning, with project learning, students can effectively design the project, managing its activities, making reports, and reflection. In this case, students have possibilities to develop research skills, can learn collaboration with stakeholders and team members. Project-based learning is focused on the students' knowledge and their experience, while classical education has based on the theoretical approach.

Within a variety of learning forms, a mix is made of online and offline, individual and group, synchronous and asynchronous activities. The range of types is provided to facilitate the learning process. Students perceive well clear course timelines, course notes, and easy to understand course descriptions were found to be helpful. According to the participants, the relatively tight deadlines and regular supervision under the guidance of competent tutor are determining factors for successful completion of the process.

However, the provided method has some disadvantages. Some students do not perceive the classroom climate as motivating or supportive. For example, computers and smartphones have diminished the students’ attention span and distracted them from developing the project. Some of them could not learn in their own way, because they have a low level of self-motivation.

Hence, we need to restructure the learning process and adjust their classroom material to accommodate such change, or else some parts of the tasks will appear tedious to students. The students also say that online communication is less personal. These results emphasise the importance of virtual individual and collaboration skills for the online learning effectiveness of students.

Proposed services for the organisation of project-based learning are effective in planning and providing group and individual activities, and presentation of product results.

We can analyse the problems for the project-based learning, the setting of the research objectives with using online services by collaborative working at the platform for online learning Google Classroom, through brainstorming, by using tools for graphical interpretation of information. Besides, to analyse the target audience of the project and to solve problems, students can create mindmaps or infographics, based on the results of the collection and structuring the information [2, p.8].

We can solve problems by using interactions in Slack, with Google Services. Teamwork, research planning can be organised using a variety of tools (such as Trello or Jira).

We assume that for most of the students, especially in the early stage of their studies, they may not have the skills of group and project work. That is why it is important to introduce the technology of blended learning in the educational process. Such an approach will help to human self-reflection on face-to-face meetings and train methods for solving problems, developing critical thinking, group activities.

We can evaluate students at the course "Computer Graphics and Web Design" based on executed projects, presentation of the result of the project and human self-reflection. That is why the estimation of the project work is often more important to them. They can see how academic work can quickly connect to real issues and understand the benefits of flexibility the project-based learning.

Interviews with the students showed that especially the groups who had experience with tools for working on projects during their school time were quick in finding project ideas or even wanted to proceed with their former school projects.

We assume the key components needed to succeed in the project are:

1. Facilitator presence.

2. High level of IT tools knowledge.

3. Ability to ask questions.

4. Communicativeness.

5. Ability to independently choose a leader and follow his instructions.

5. CONCLUSION

The main aim of the research services for project-based learning is to introduce students to situations of real project research and they should be motivated for hard group working and engaged in solving difficult issues in Engineering field or IT.

Students can easily use the current criteria for selecting services to their education and for solving professional tasks. These tools provide the possibility of group interaction. The accessibility of software (free distribution), the flexibility of interface, cross-platform, multilingualism and integration with other services for most of the proposed tools are key advantages.

Students confirm the appropriateness of choosing the best services using the "Why?" Method [12, 13]. According to the method, the member of the project team needs to ask a colleague about the service and its features, starting with the question "Why?". In answer to the question, the respondent needs to justify why he chose the appropriate service for work.

The created list of services students can use during working on real projects and during a learning experiment. In completing their projects, students also refine their organisational and research skills, develop better communication with their peers and adults, and often work in their community, watching the positive impact of their work [14].

It turned out that this concept of organisation educational process is highly appreciated by the students. Especially students positively judge the flexibility in scheduling the time for the project work.

We believe that the concept of project-based learning in engineering studies together with transdisciplinary tools, for example, by blended learning elements such as online content or tools for brainstorming, is highly attractive and improve problem-solving research projects. Nevertheless, the project method should also allow the freedom of a researcher to choose his questions, to design experiments and to schedule his time on his own.

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Systemic approach to address complexity in the training of engineers in innovation and creativity: Modelling process of implementing innovative projects

I. ZERGOUT[1]
ENSEM- University of Hassan II
CASABLANCA, MOROCCO

S. AJANA
ENSEM- University of Hassan II
CASABLANCA, MOROCCO

S. BAKKALI
ENSEM- University of Hassan II
CASABLANCA, MOROCCO

C. ADAM
ENSTA Bretagne,
BREST, FRANCE

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ABSTRACT

Innovation has always been considered as a complex and multidisciplinary phenomenon. The understanding and representation of this complexity has been addressed in several works in the field of management sciences from a systemic approach that clarifies the different components of innovation and defines their interrelationships. In this work, the systemic approach to innovation has been addressed in a different complex context, which is the training of mechanical engineers in innovation and creativity. This concept can be regarded as a process involving the interaction of a set of human and material resources managed in order to develop the skills necessary for innovative projects. The main objective of this work is to test the validity of a systemic modelling of the innovation training process for engineers. To this end, the action-research methodology made it possible to experiment with the model proposed during Project-Based Learning (PBL) activities within an engineering school. The analysis of the results confirmed the hypotheses of the effectiveness of the approach adopted in stimulating innovation among engineering students. This approach divides the main process into sub-processes (the implementation process, the support process, and the management process). The contribution of this study lies in the design of a new method that could be applied by professors and students, and which could improve engineering students'

[1] Corresponding author: zergout.imane@gmail.com, ID: 1682

ability to innovate while ensuring the professionalization and management of innovative projects.

INTRODUCTION

The stimulation of innovation among engineers go hand in hand with the socio-economic development of countries that have oriented their concerns towards together knowledge and innovation based economy, namely Morocco [1]. Indeed, the development and production of major innovative projects in the various socio-economic fields are largely based on the skills of engineers and their capacity to innovate [2].

The ability to innovate is based on a set of skills and knowledge that generate innovative thinking among engineers and future engineers and motivate them to produce something new in the field of their expertise. These skills are not limited to technical ones, but soft skills are also crucial in boosting innovation, in particular; autonomy, proactivity, empowerment, communication, problem solving...etc.[3] These skills are encouraged through active teaching methods such as digital integration, international opening, learning through individual and collective projects, interdisciplinary projects, etc. [4]. Several authors have shown the vital role played by students' projects realised in their schools or during internships in the development of innovation and creativity in students [5] [6] [7]. Project based learning (PBL) involves a set of actors in real situations, including future engineers, which allows them to follow the different technical and analytical steps (understanding, analysis, solution proposal, evaluation...etc.) to solve complex problems located in socio-technical contexts. This type of learning leads students to reflect deeply while taking into account all the characteristics and issues of the project's scope (social, cultural, economic, political, technological...) [8]. Nevertheless, the solutions proposed by future engineers to solve problems related to their fields are still standard solutions and do not demonstrate a big deal of creativity and innovation [9]. This is mainly the result of a lack of precise models of the organization of the means, resources and methods deployed to boost students' ability to innovate within engineering training institutions [4]. In an attempt to address these problems, we have conducted researches aiming at understanding and improving the process of training engineers in innovation through PBL. This issue deals with a subject considered complex since it aims to design a systemic model that represents the complexity of the innovation training process and integrates a set of material and human resources. A complex system consists of a set of varied elements characterized by autonomy, freedom and interaction with its environment [10] [11]. In this work, complexity is perceptible through different aspects: the complexity of engineering training, which is in dynamic interaction with its environment (industry, research centres, etc.), the complexity of the innovation phenomenon, and the complexity of adopting a modelling approach for a set of human practices and behaviours in the form of processes. In an initiative to understand the complexity of the system under study, we have proceeded through a systemic approach based on models, methods, and technical tools.

The objective of this article is to test the validity of a proposed innovation process model that could be implemented in projects realized by mechanical engineering students in an engineering school in Morocco. This model has already been designed in previous work based on theoretical data and an empirical study. Our systemic modelling of innovation process aims to represent and organise skills, knowledge and resources in innovation projects in a logical and interactive way. We begin by presenting the methodology, the proposed model and the working hypotheses. Then we describe the details of the different experiments of the model such as the context, objectives and results obtained for each case studied. We conclude with the contribution and perspectives of the study.

1 METHODOLOGY OF THE STUDY

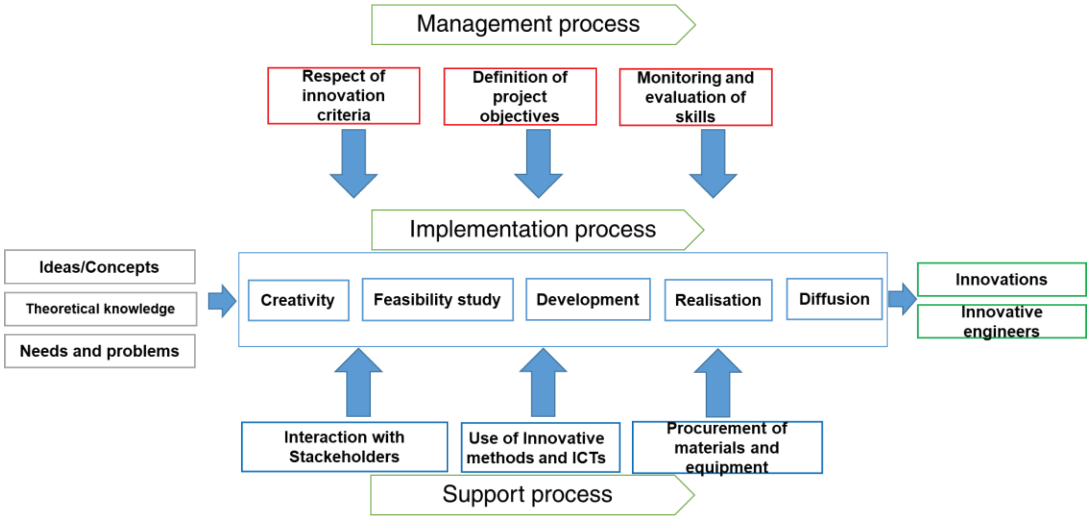
This work is carried out according to a qualitative approach based on the action research method that we have conducted within the Mechanical Engineering Department at the High National School of Electricity and Mechanics (ENSEM) in Casablanca, as a researcher and teacher. This approach allows a return between practice and theory, and highlights the direct involvement of the researcher in the action. The tools used in our method are active and participatory observation, which results from the researcher's integration into the study, as well as actual intervention and evaluation of results [12]. This method allowed a cycle of experiments to be carried out to put into practice and test the validity of our proposed model on the one hand, and to demonstrate the relevance of the systemic approach to understand a complex system, on the other.

2 SYSTEMIC MODELLING OF THE INNOVATION PROCESS IN ENGINEERING EDUCATION

Systemic modelling consists in understanding a complex phenomenon through the development of a graphical and intelligible representation that makes it possible to represent it and to predict the results of possible interactions between this phenomenon and the components of its environment [11]. There are various methods and tools available to develop a systemic model. In our case, we have adopted the process approach which is considered as a systemic approach characterized by the study of several levels of analysis [13]. It consists of a methodical and detailed description of an organisation or activity generating added value in order to control and continuously improve it by acting on the interactions between the process and its environment[2]. Innovation training can be considered as a process because it consists of a set of sequentially linked steps aimed at transforming engineering students into innovative engineers in order to meet the needs and requirements expressed by different organisations in the socio-economic

[2] https://www.iso.org/obp/ui/fr/

world. The process approach divides the system studied into three main sub-processes interacting and exchanging a flow of information and resources: the implementation process, the support process, and the management process [13]. It's important to mention that this model represents a nonlinear process, because there are interactions among the different components of the process, and the different phases of the process could not respect the order proposed in this model. That



means that we can start a new phase without completing the last one, or we can return to change some details in another past phase.

Fig. 1. The proposed systemic model of the innovation process in students projects

The proposed model in figure 1 and detailed in table 1 allowed us to identify steps and guidelines to be implemented when supervising projects carried out by engineering students so that they are innovative and creative.

Table 1: the components of the process for the implementation and support of innovative mechanical engineering projects

Stages of the implementation process		Elements of the support process		
		Means	Methods	Actors
Creativity	Define and analyse a problem	Control charts, metrology tools, questionnaires, calculation and statistics software,...etc.	Active observation, experimental design, statistical control of processes,...etc.	Any person concerned by the problem, supervisors
	Generate creative ideas	Internet, scientific databases, sites concerned by technology,...etc.	Technology watch, brainstorming,...etc.	Supervisors, PhD students
	Evaluate and choose a solution	Calculation software,...etc.	Decision-making methods, benchmarking,...etc.	Supervisors, PhD students
Feasibility study	Listening to the needs of different stakeholder s	Questionnaire, social networks, applications for studying audiences and market news,...etc.	Market research, customer orientation, design thinking,...etc.	Project clients, supervisors, engineers
	Study of the	Project management software (MSProject),	Project management, finance, risk	Engineers, supervisors,

	technical and financial feasibility	calculation software (Excel),...etc.	management	accountants
	Define the business plan	Project portfolio	Innovation management tools	Engineers (project managers or contractors)
Development	Define the functional specifications	Standard NF X 50-100	Functional analysis, Value analysis...etc.	Supervisors, engineers, doctoral students
	Design and dimension	Computer-aided design and drawing and mechanical calculation software (Catia, Abaqus, Autocad...etc.)	Calculation of structures	PhD students, R&D engineers, supervisors
	Test and validate (make a prototype)	Manufacturing machines, 3D printer, Metrology tools, three-dimensional metrology machine, computer-aided design and manufacturing software, mechanical testing and non-destructive testing machines, raw material, miscellaneous equipment	sizing, design and technical drawing, eco-design	Technicians, supervisors, mechanical production engineers, ...etc.
Realize	Search for ways and means	Quotation, sponsorship file, contact database	Mechanical engineering techniques, manufacturing process of materials...etc.	Customers, sponsors
	Realize and implement	Manufacturing machines, 3D printer, Metrology tools, three-dimensional metrology machine, computer-aided design and manufacturing software, mechanical testing and non-destructive testing machines, raw material, miscellaneous equipment	Negotiation and communication skills, marketing	Technicians, supervisors, mechanical production engineers, ...etc.
Diffuse	Evaluate	PPT, prototype, implementation results....	Mechanical engineering techniques, manufacturing process of materials...etc.	Professors and industrialists
	Diffuser	Poster, Packaging, Social Networks	Evaluation criteria	Customers

This model was built on the basis of data from the literature review on the one hand, and a set of empirical studies on the other. In our work, we focused only on progressive innovation, because it was difficult to achieve radical innovations requiring more advanced resources and considerable time [14]. In order to prove the validity of our proposal, we formulated hypotheses based of the model, which we verified through experiments. The hypotheses of our study are as follows:

H1: The respect of the steps of the proposed implementation process improves the ability of engineering students to produce innovative solutions.

H2: A support process involving the interaction of different means, methods and actors in connection with each step of the implementation process improves the ability of engineering students to produce innovative solutions.

H3: A management process controlling the level of skill acquisition at each step of the process improves the ability of engineering students to innovate.

3 IMPLEMENTATION OF THE MODEL

3.1 Pedagogical experimentation 1: Case of graduation projects

3.1.1 Context and objectives of the study

The objective of this experimentation is to produce innovative solutions for graduation projects dealing with complex industrial issues by following the stages of the proposed innovation process and the elements that characterize it. This experiment made it possible to test the effect of the respect of the implementation process, as well as the use of technical and material methods and means on the ability of engineering students to innovate.

3.1.2 Procedure of the experiment

The sample consists of ten graduation projects carried out by students from the last year of mechanical engineering at ENSEM in different industrial companies acting in the following fields (Energy production, food-processing industry, automotive industry, Aeronautic industry, and Phosphate industry). These projects belong to different domains of mechanical engineering such as: mechanical system design, quality management, and mechanical maintenance.

We participated in the supervision of five of these projects with the academic and industrial supervisors. During this experiment, we ensured that the steps of the proposed process were applied and that its components were respected. The remaining five projects are considered as demonstration projects, which were carried out under equivalent conditions in order to compare results. It is important to note that the demonstration projects and the projects concerned by the study took place in similar conditions (study programme, company where the internship takes place, students' courses, supervising professors belonging to the same mechanical engineering department), the only different element is the approach to supervision and implementation of the project.

These graduation projects last 4 months. Weekly meetings are held between academic supervisors (our team) and engineering students. On the other side, students meet approximately every day with their industrial supervisor in the company hosting the project.

In the first phase of the project, we focused on the creativity and the generation of innovative ideas. After having carried out an inventory and an analytical study of the various problems in the field, the engineering students are led to use tools from the creative problem-solving process to generate innovative ideas. Then decision-making methods are used to choose the most appropriate solution. Then, we have carried out a preliminary study of the technical and financial feasibility of this solution in order to define the business plan and verify the applicability of the project. The next phase consists of the technical study of the project, where the engineering students applied the various technical knowledge they acquired during the training years, including design, dimensioning, technical drawing and calculation methods. In the last phase, students were required to seek funding and equipment to implement their solutions. Finally, the diffusion of project results can take different forms: first, the presentation of the project report to the managers of the company where the internship took place. Secondly a presentation of the project in the school to a jury composed of professors and industrial actors who will assess the results. If the result of the innovation process is a new product, the latter could be marketed by the company itself or by another means. During the whole project, engineering students are invited to interact with different actors within the company (technicians, administrators, engineers...), and within their school (doctoral students, professors...) by asking for their advice and contribution to make their projects a success.

3.1.3 Project assessment and analysis

A jury composed of professors and industrial actors first assessed the innovative aspect of the various solutions proposed through every project on the basis of the innovation criteria of the OMPIC (Moroccan Office of Industrial and Commercial Property), which is the Moroccan organisation responsible for granting the following patents[3] : novelty and creativity, added value, industrial applicability. Then, the jury noted the level of respect of each project of the different components of the innovation process presented in Table 1. This rating is based on the following Likert scale (1: not respected; 2: poorly respected; 3: respected; 4: much respected. Then we calculated the average respect obtained by all the supervised and the demonstration project for the different components and stages of the innovation process. The table below summarizes the results obtained.

Table 2. Analysis of the impact of the support process on projects

Phases	Creativity			Feasibility study			Development			Realization			Diffusion			N
Support elements	Methods	Means	Stages	Methods	Means	Stages	Methods	Means	Stages	Methods	Means	Stages	Methods	Means	Stages	
Supervised projects	3,33	2,67	3,33	3,00	2,67	3,00	3,33	2,67	3,67	2,67	2,33	2,33	2,00	1,67	2,00	5
Demonstration project	1,67	1,33	2,00	2,33	1,00	1,33	3,00	1,33	3,67	1,67	1,00	1,00	1,00	1,00	1,33	1

[3] http://www.ompic.org.ma/fr/content/propos-du-brevet-dinvention

N: number of innovative solutions proposed

We clearly observe that the five projects that we have supervised based on the proposed approach have a more innovative aspect compared to the five pilot projects that followed a traditional supervision following a technical approach. According to the averages obtained, 60% of the supervised projects respected the stages of the innovation process. These projects respected 60% of the means proposed by the process and 80% of the methods proposed. This allows us to confirm hypothesis H1 and H2.

3.2 Pedagogical experiment 2: case of projects carried out during a course

3.2.1 Context and objectives of the study

The objective of this experiment is to work on innovation projects in parallel with a course on environmental and sustainable development management. We focused in this experiment mainly on the level of skills' acquisition needed to innovate and their impact on the production of creative and innovative solutions by students. These last include technical and soft skills detailed in the table 3. Technical skills are derived from the syllabus and objectives of this course as well as other courses that assist in the realization of projects (product design, problem solving, technical drawing...), obtained from internal accreditation documents. As for transversal skills, we have identified the common ones among skill models necessary for innovation developed by some authors [2] [4] [8].

3.2.2 Procedure of the experiment

Our sample consists of a class of 24 mechanical engineering students. This course lasts 1 month and consists of 6 sessions. The first two sessions were devoted to the theoretical concepts of the course. Then, we devoted two sessions to the first three steps of the process: creativity, idea generation and development. Unfortunately, we were unable to continue the rest of the process due to lack of time and financial resources. A final session was dedicated to the evaluation and presentation of project results. These sessions were in the form of workshops in which we participated in supervision alongside the course's teacher. During these workshops, students formed teams of 4 people, and worked on solving technical problems related to the respect of environmental standards in different areas of their school (dormitories, spaces for mechanical workshops and practical work, classrooms...) by proposing innovative solutions. The conduct and supervision of the workshops were similar to Experiment 1, and we ensured the implementation of active teaching methods and the integration of digital technology to help students acquire the skills necessary for innovation.

3.2.3 Projects assessment and analysis

The results of projects are evaluated by a jury composed of the professor and doctoral engineering students based on the innovation criteria of Experiment 1: novelty, added value and industrial applicability. We invited the jury to analyse the reports and the presentation of the studied projects, and to note the response of these deliverables to certain criteria related to some aptitudes that could contribute to the acquisition of the skills needed to boost innovation. The rating is based on the following Likert scale (1: no Satisfactory, 2: poorly satisfactory, 3: satisfactory, 4: very satisfactory). The results of the evaluation are presented in the table 3. Then we calculated the average of satisfaction to all the required skills and we studied the correlation with the innovativeness of the project.

Table 3. Analysis of the relationship between innovation skills and innovative projects.

Projects	NOTES													Average	Innovativeness of the project
	Soft skills						Technical skills								
	Analytical thinking	Risk taking	Interprofessional communication	Creative problem solving.	Systematic analysis	Ability to adapt	Define and analyse a problem	Use ICTs	Define a business plan	Define a functional specification	Map a process	Design and dimension	Use of specific tools for innovative problem		
Intelligent water recovery system	4	2	4	4	4	4	4	4	3	2	4	3	4	3.53	Positive
Sorting of waste using a "Smart Bin"	4	2	3	4	4	4	4	4	2	2	4	4	4	3.46	Positive
Recycling of mechanical parts	3	2	4	3	2	4	4	1	2	2	4	3	4	3	Positive
Design of an intelligent dust misting system	4	2	4	4	3	4	4	1	2	2	4	3	4	3	Positive
Change management using ICT	3	2	4	2	1	2	4	1	2	1	4	2	4	2.46	Negative
Intelligent green space watering system	1	2	3	1	1	2	3	1	2	1	4	2	4	2	Negative

The results show that the ability to produce innovative solutions increases with the rise of the acquisition level of the various skills required for innovation by students. This leads us to the confirmation of the hypothesis H3 of the study.

4 CONCLUSION

This article aims at validating an educational system proposed through our research study in order to understand and represent the complexity of engineering innovation training. We tested the validity of a systemic modelling likely to boost innovation in future engineers. We have carried out two experiments to show the positive impact of the interaction between diversified resources (resources, methods, actors) and the management of the skills needed for innovation, in strengthening the capacity to produce innovative and creative solutions in complex industrial and academic contexts.

The contribution of this work is to shed light on the importance of developing an interdisciplinary approach in which the theoretical notions call for complementary scientific disciplines (engineering, management and educational sciences) to understand what's at the core of innovation in engineering education. As perspective, we aim to extend our experiments through the application of the proposed model to a set of projects carried out within the other departments of the ENSEM (electrical, industrial and computer engineering) in order to ensure continuous improvement of our process.

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Application of Continuing Engineering Education Talent Training Model and Mixed Learning Model Based on the Construction of "Intelligent Chinese Academy of Sciences" in Lifelong Education

Sisi Zhang
Yixia Zhao
Runqiang Wang
Yiyuan Tao
Qi Zhang
Computer Network Information Center, Chinese Academy of Sciences
Beijing, China

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Keywords: Lifelong Learning, Continuing Education, Project-based Teaching, Talent Training

ABSTRACT

The training of talents in continuing engineering education should be closely related to the reality of science and technology development, pay attention to the updating of frontier knowledge, strengthen the cultivation of multi-disciplinary integration and innovation ability, and integrate into project-based teaching, so as to construct a new model of engineering education which aims at practicality and effectiveness. Based on the informatization project of Chinese Academy of Sciences (CAS for short), "Intelligent CAS ", we explore a new model of continuing engineering education personnel training with cutting-edge features, and it is guided by the frontier scientific research and technology projects, and supported by the "8+2" fields of the CAS (frontier crossing, advanced materials, energy, life and health, ocean, resources, ecological environment, information, and photovoltaic space, as well as two public support platforms) and based on the multi-terminal lifelong learning environment integrating open education resources. What's more, we study the mixed learning mode which is based on point, line and surface for scientific and technical engineers and integrate online and offline deeply. We design and practice it from teaching objectives, educational models, the three-level knowledge system, and thematic training, so that we can build a long-term, systematic and practical lifelong education mode, which is centered on learners. So far, the CAS has carried out four years of practice to serve nearly 70,000 scientists. The rapid growth of the learning data shows the effective and practical of this model, which conforms to the law of the development of continuing engineering education itself.

1 INTRODUCTION

With the rapid development of economy and science and technology, the skills required by the labor force in today's world have been constantly redefined. Continuing engineering education urgently needs to deepen the reform of personnel training mode aiming at practicality and effectiveness. Interdisciplinary education is particularly necessary today as future careers are likely to lead graduates from all over the world to work in industries that are currently undefined and undeveloped.

In the field of Higher Engineering Education in the world, the Massachusetts Institute of Technology (MIT) of the United States has been acting as the pioneer in the reform. After the new century, it has launched three major engineering education reforms: one is to develop CDIO curriculum syllabus with three Swedish universities in 2001, to emphasize the return of engineering education to engineering practice; The other is to release the survey report of MIT education task force for the future in 2014, [1] to advocate to the "project-based"; The third is to launch and implement the "new engineering education transformation" (NEET) plan in 2017, to comprehensively construct the new engineering education talent cultivation mode of "project-centered curriculum", which promoted the transformation of talent cultivation from discipline center to project center, that is, students aimed at completing the project under the support of related courses. [2] This is an important revelation for the reform of engineering education, especially for the mode of "project-centered curriculum" based on multi-disciplinary integration, which can be used for reference in the exploration of new engineering talent training in China.

The sustainability of the development of Open Education Resources (OER) is a global problem. Since UNESCO proposed OER in 2002, governments have attached great importance to the construction of OER projects. The European Commission launched the Open Education Action Plan; [3] The U.S. Department of Education has established a grant scheme to guarantee the construction, diffusion and evaluation of OER and redesign degree courses based on the OER Degree Program; [4] The Ministry of Education of China has set up a National High-quality Curriculum Project to provide financial guarantee for its development and maintenance, and also set up a teaching excellence award. [5] The CARE model proposed by the National Research Council of Canada and the OECD center for innovation in education research in 2018, which aimed to help individuals, institutions or organizations become excellent managers by developing and creating OER, reasonably classifying ORE attributes or labels, sharing, publishing and spreading, and encouraging others to participate. [6] All of these help us deeply understand the importance of the construction of OER for continuing engineering education, and provide more new ideas for the implementation of long-term, systematic and practical lifelong education mode in the learner-centered learning society.

2 CONSTRUCTION OF NEW FRONTIER INTERDISCIPLINARY CONTINUING ENGINEERING EDUCATION AND TRAINING MODEL

With the rapid development of global economy and society, the formation and consolidation of core competitive advantages among countries, especially the competition for leading and dominant position in the development of global economy, science and technology and industry, all countries have cultivated outstanding engineering talents as their national strategy in the future.

In terms of training engineering science and technology talents for the future, the Chinese Academy of Sciences has done four main tasks in continuing engineering education:

1) Design project-oriented engineering education system on frontier cross field;

2) Establish a multi-terminal online and offline environment integrating OER for lifelong learning;

3) Research on point, line and surface-based mixed teaching model for engineering science and technology personnel;

4) Cooperate with other institutions to actively participate in the implementation process of the training program.

2.1 Project-led education training in cutting-edge cross

As the largest scientific research institution in China, the Chinese Academy of Sciences (hereinafter referred to as the CAS) aims to build an international first-class scientific research institution with important influence, attraction and competitiveness by 2020. The CAS will build a number of scientific research centres and innovation plateaus with distinctive academic characteristics and world influence in some areas of dominant disciplines, and actively participate in global innovation governance. This will play a positive role in promoting the training of high-level engineering talents in China.

In March 2017, the CAS officially issued the Outline of the 13th Five-Year Development Plan of the CAS (hereinafter referred to as the Outline of the Plan). In the Outline of Planning, it is pointed out that in the next five years, the CAS will put forward 60 breakthroughs and 80 key cultivation directions (excluding national defense scientific and technological innovation) which are expected to achieve leapfrogging development, involving organ repair and reconstruction, and tracing the causes of atmospheric haze, focusing on eight areas: Based on Cutting-edge Cross, Advanced Materials, Energy, Life and Health, Sea, Resources and Ecological Environment, Information Technology, Photoelectric Technology and the Space. The CAS, relying on its unique advantages, undertakes major scientific and technological projects oriented to economic and social factors, sustainable development and national security. Based on these cutting-edge projects, this paper constructs a project-guided mixed teaching (see Figure 1) to help engineering talents improve the integration ability of multi-disciplinary knowledge and enable them to understand the scientific correlation and solve engineering problems in the face of complex engineering projects.

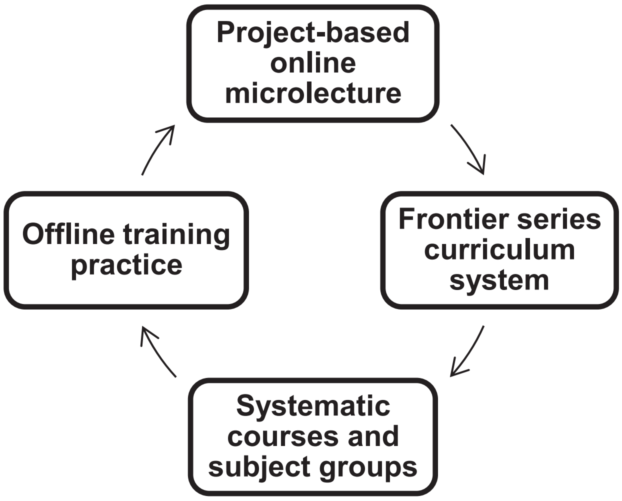

Fig. 1 Project-led mixed education training process in cutting-edge cross

The Project-based instructional design emphasizes that clear learning objectives should be taken as the start teaching, and instructional guidance plans should be formulated according to the learning evidence required by the standards and teaching activities to assist learners in learning. In order to enable learners accustomed to a complete way of solving problems, the "project" set up includes knowledge of many courses, and ultimately implements a complete "project" teaching activities.

In the online classroom environment, the knowledge unit of "micro-learning" guided by projects (microlecture on line) is designed, and then on the basis of these micro-knowledge units, a scientific chapter structure is combined to form a series of curriculum knowledge system. Finally, these systematic curriculum linkages are integrated into a logical relationship between professional frontier knowledge and ability training system courses and subject groups to help engineering science and technology talents to study in depth, expand and extend their thinking. In the offline classroom environment, it pay more attention to the interaction between lecturers and students, discuss and practice as the main means to explore the problems and solutions in actual projects and practical work.

2.2 Frontier Interdisciplinary syllabus design based on talent type

According to the differences of training objectives, the training of new engineering talents should be guided by the development path of talents in accordance with their aptitude, so as to achieve the ultimate goal of effectively training talents in the future. We design different teaching for two different talents by taking "Brain Science and Brain-like Intelligent computing" as an example (see Table 1).

Table 1.Frontier Interdisciplinary syllabus design based on talent type

Talent type	**Project objectives**	**Frontier project guide**	**Frontier series of brain science courses**	**Frontier series of artificial intelligence courses**	**Course project**
Academic type	Put forward innovative research ideas, verify them through experiments and data, and put them into practice to achieve the level of writing academic papers and participating in academic research	Academician frontier project microlecture	● **Human brainnetome atlas series** 1.The winner-take-all choices 2.Brief introduction of neuroanatomy 3.The development of human brainnetome atlas 4.Cross - scale brainnetome atlas technique 5. Cross - scale brainnetome atlas: from rodents to primates 6.Human brainnetome atlas and its application 7.Application and case study of brain network atlas software	● **Data intelligence and deep learning series** 1.The development and opportunity of big data management system 2.Scientific big data analysis 3.Scientific big data processing technology 4.Visualization and analysis of spatiotemporal data in scientific computing 5.Research progress and status of deep learning 6.Machine learning 7.Pattern recognition research 8.Case analysis of scientific research informatization	1.Write a research paper 2.Complete a practical project of deep learning algorithms by integrating brain cognitive concepts
Professional type	Be able to combine theory with practice in discipline, technology and application, and be skilled in using tools and software to complete practical tasks	Associate researcher and above level key topic microlecture	● **Human brainnetome atlas series** 1.Human brainnetome atlas and its application 2.Brief introduction of neuroanatomy 3.The development of human brainnetome atlas 4.Cross - scale brainnetome atlas technique 5.Introduction of brain network atlas and its drawing related technologies and methods 6.Multimodal brain imaging data processing software platform	● **Data intelligence and deep learning series** 1.Development trend of information technology 2.Big data management technology and system 3.Big data and data intelligence 4.Data analysis techniques and visualization 5.General computing development status 6.Machine learning 7.Tensorflow foundation 8.Tensorflow platform framework and application practice	1. Use software to draw zonal brain atlas 2.Building the prototype of the latest generation of AI computing and data platform

3 INTEGRATING ORE ONLINE AND OFFLINE IN LIFELONG LEARNING

3.1 WEB, APP multi-terminal intelligent environment construction

Continuing engineering education bears the heavy responsibility of updating the knowledge and improving the ability of new engineering and technical talents. Based on the "Intelligent Lifelong Learning Platform for Serving Talents Highland Construction", the CAS constructed the education and training system in frontier cross-field, and provided the online and offline integrated lifelong learning service for engineering talents. We actively cooperate with the Chinese Association of Science and Technology, colleges and universities to provide the high-quality resources to serve the lifelong education environment and the construction of continuing engineering talents (see Figure 2).

Fig. 2 WEB and APP multi-terminal intelligent environment support

3.2 Accumulation of a large number of OER

Based on the "Eight Areas" of the CAS, we have produced thousands of open education resources, and teased out conforms to continuing engineering education professional development and lifelong learning of 12 major series, including "The latest information technology and mathematics science", "Space exploration and manned space", "New energy and renewable energy use", "Health and health management", "The mysteries of life", "Environmental ecology and sustainable development", "Materials and engineering", "Ocean exploration and technology development", "Scientific literacy and scientific research ability", "Transformation of scientific and technological achievements and innovative entrepreneurship", "Cultural heritage and history of science", "Popular science", etc. The following pictures courses sample (see Figure 3).

Fig. 3 Courses sample

4 DESIGN A THREE-LEVEL CURRICULUM SYSTEM OF POINT-LINE-PLANE

4.1 Knowledge cycle system

Usually, new theories induce innovative methods and tools, that is, to transform theories into practical experience that knows how to implement them, and then to pursue new goals and experiences. This is the general law of human knowledge growth. Peter Senge and Daniel h. KIM figuratively compare it to a tree. The root is the theoretical support, the trunk is the method and tool support, and the final leaves and fruits are the practical knowledge nurtured. This system design will be based on the knowledge cycle construction, but the traditional teaching process lacks such a cycle process.

4.2 Point-line-surface design of knowledge structure

The system design is guided by knowledge points, micro-problems, micro-points and micro-lecture from the point of "fragmentation". Then it gives professional theoretical guidance and practical learning. It helps students to self-exercise and expand learning resources, to master learning methods and output learning results from three aspects of theory, method and practice, and finally form a knowledge tree in a certain field. And even the personal knowledge forest system. Micro learning is claimed to have positive effects on mastery learning and be an important part of blended learning. [7] In the construction of deep learning knowledge system, all knowledge information will be divided into small learning units, and then organized integration. Learning in small steps is made possible with the aid of small and well planned chunks of units or activities. [8] What we need to achieve is point-based micro-teaching design, line-based knowledge chapters design and face-based curriculum design and discipline groups (see Figure 4).

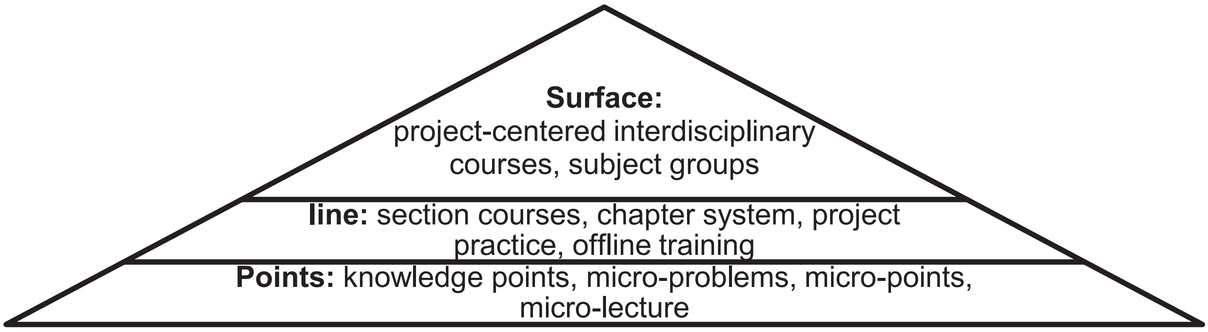

Fig. 4 Knowledge structure of point, line and surface

In the course of "Brain Science and Brain-like Intelligent computing", we have compiled a curriculum outline integrating "fragmentation" and "systematization" (see Table 2) to help students pay attention to the core knowledge points of each microlecture. At the same time, using multimedia technology, micro-lectures are divided into as small as possible knowledge fragments, which is convenient for mobile learning.

Table 2 Syllabus of human brainnetome atlas series (chapter 5 example)

Chapter	Section	Knowledge points	Topic & Question
The fifth chapter **Human brainnetome atlas and its application**	**5.1What makes a brain area distinct**	Input-output connections, Connectional fingerprint, Patterns of gene expression, Criteria for human brain parcellation	What is the neocortex?
	5.2Connectivity-based parcellation towards human brainnetome atlas	Brain atlases: in vitro & in vivo, A framework for multimodal information integration, Connectivity-based parcellation(CBP), etc.	Why do we map the human brain network based on connection patterns?
	5.3Applications of human brainnetome atlas in cognitive science	Anatomy and functions of PHR, Connectivity-based parcellation of PHR, etc.	What evidence can brain atlas provide for the memory system?
	5.4 Applications of human brainnetome atlas in clinical medicine	Precision therapy of brain diseases, Clinical applications in schizophrenia	Why is the brain atlas important in treating brain injury or mental illness?
	5.5 Applications of human brainnetome atlas in biological evolution	The nucleus accumbens, Parcellation results of the macaque Acb, rsFC profiles, Accumbens Shell and Core	According to brain atlas analysis, what is the biggest difference between the evolution of monkey brain and human brain?
	5.6 Applications of human brainnetome atlas in brain-like intelligence	From circuits to behavior, Brain-Inspired Computing, Brain connection pattern projection and mathematical algorithms	Does the drosophila olfactory system recognize odors through hash functions?
	5.7Summary and prospect	Fine-grained anatomical parcels, Detailed anatomical and functional connections, etc.	What more valuable research can we do next?

4.3 Distribution of discipline groups oriented to frontier cross-cutting fields

In the aspect design of the above knowledge structure, a multi-disciplinary interdisciplinary subject group system had established. On the one hand, cutting-edge knowledge should be integrated to transfer closely related professional foundation and core courses. On the other hand, characteristic research and practice courses should be established to realize deep learning from cutting-edge cognition to basic consolidation and then to practical innovation, aiming to promote cross-field, cross-institution and cross-disciplinary engineering innovation personnel training (see Table 3).

Table 3 Distribution of frontier interdisciplinary groups (Listing some practices)

Frontier interdisciplinary direction	Direction of talents training	Frontier discipline system courses
Brain science and brain-like intelligent computing	Research and application of related personnel engaged in brain science, brain diseases and brain-like intelligence technology in cognitive neuroscience, neural network analysis, computational simulation of cognitive mechanism, brain heuristic computation, brain-computer interaction, etc.	1.Brain sciences 2.Cognitive analysis of brainnetome atlas 3.Cognitive mechanism calculation 4.Artificial intelligence integration
Precision medicine and health	Research and practical application of relevant personnel engaged in life science, clinical medicine, medicine and psychology in human genome, 4P medicine, precision medicine, precision drug therapy, precision health management, instrument use and other aspects	1.The human genome 2.Precision medicine 3.Cancer screening and prevention 4.Drug research 5.Health management 6.Use of life science instruments

5 BREAKTHROUGH OF MULTIMEDIA TECHNOLOGY IN COURSES

The microlecture teaching platform represented by Khan Academy and MOOCs rises in foreign countries, but at the same time it also develops rapidly in China. The continuing engineering education of CAS created live broadcasting, three-point screen courses, green/blue virtual scene courses, electronic documents and other multimedia courseware by using advanced multimedia technology, so as to better integrate multimedia with education and achieve a breakthrough in educational informationization. The goal is to develop all kinds of teaching and aesthetic characteristics courses, help students understand the complex scientific content.

The virtual and real scenes are combined to enhance the immersive experience (see Figure 5). In the course of animation production, the two-dimensional animation element production is mainly completed by drawing, and the three-dimensional animation elements is mainly embodied in the modeling, mainly used in the cosmos, computational science, life science. We strive to keep pace with the international level by learning from TED-Ed. At the same time, in order to enhance the effect of online and offline learning, we use multimedia technology to build a live learning platform to facilitate the large-scale coverage and dissemination of offline activities in continuing education (see Figure 6).

Fig. 5 Virtual scene synthesis

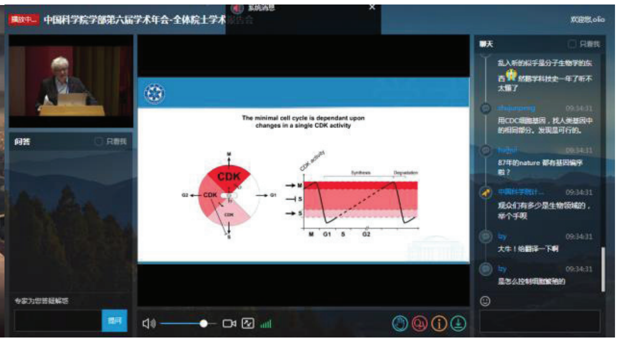

Fig. 6 Live of the congress of CAS

6 STRENGTHENING RESOURCES SHARING AND ACADEMIC EXCHANGE IN CONTINUING ENGINEERING EDUCATION

6.1 Collaborative education between universities and research institutes

Continuing engineering education undertakes the important task of renewing knowledge and improving ability of new engineering technical talents. The CAS has actively cooperated with the colleges and universities to provide the high-quality education services to more institutes in order to serve the lifelong education environment based on the learning society. For example, in cooperation with Beijing Open University, we had undertaken Beijing citizens' Lifelong Learning Curriculum Construction Projects in 2016 and 2017, and implemented the themes of "humanities and science", "career development", "improvement of teachers' scientific research ability", etc. It promoted the sharing of continuing engineering education resources. For example, in the humanities and sciences, integrating cutting-edge scientific and technological knowledge groups, such as information revolution, space journey, precision medicine in the digital age, environmental hot spots and sustainable development, we provide free lifelong education services for more than 20 million people in Beijing.

6.2 Actively participate world conference on continuing engineering education

The 16th International Association for Continuing Engineering Education (IACEE) has held at the University of Science and Technology Monterrey, Mexico, from May 22 to 25, 2018. The theme of the conference is "Shaping the Future of Continuing Education". More than 100 experts from various regions participated in the meeting to exchange research and future development trends of continuing engineering education. Yixia Zhao, the senior engineer in charge of the Continuing Education Network of the CAS, led the team members to participate in the meeting for international exchanges, and shared with Professor Patricio Montesinos of UPV University in Spain and Professor Clara Pioto of MIT the training experience of scientific research personnel management ability and e-Learning.

7 SUMMARY AND ACKNOWLEDGMENTS

In order to support the informatization of the continuing education and training system, the CAS launched its Continuing Education Network in April 2016, providing lifelong learning services to nearly 70,000 employees. In 2018, 11588 researchers participated in 62359 training records. These training records come from 2137 training projects, including management skills training, on-the-job training, series of lectures, academic and thematic lectures, academic conferences, short-term special technology training, advanced professional and technical seminars and other training. Based on these research experts and special trainings, the CAS Continuing Education Network invites scientists to develop the large number of resources of Continuing Engineering Education, and to lay out the subject groups in cutting-edge. At present, it has accumulated thousands of courses. The CAS will effectively play the role of academicians, researchers and other scientists and engineers, to form a new mode of innovative talent training and contribute to the sustainable development of continuing engineering education.

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Practical Research on the Lifelong Learning Model of the Largest Scientific Research Institution in China

Yixia Zhao[1]
National Science Library，Chinese Academy of Sciences, Beijing, China;
University of Chinese Academy of Sciences, Beijing, China;
Computer Network Information Center, Chinese Academy of Sciences, Beijing, China

Yiyuan Tao
Computer Network Information Center, Chinese Academy of Sciences, Beijing, China

Kun Jin
Chinese Academy of Sciences, Beijing，China

Runqqiang Wang
Computer Network Information Center, Chinese Academy of Sciences, Beijing, China

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Keywords: CAS; lifelong learning; MOOC; continuing education

ABSTRACT

In the era of knowledge economy, the time cycle of knowledge updating is shortened to 2~3 years. The development of the fourth research paradigm puts forward new requirements for big data and computing ability of researchers. As the highest academic institution of Natural Science in China, the Chinese Academy of Sciences (CAS) has more than 70,000 scientists who distributed in 23 provinces and cities. How to meet the lifelong learning needs of the distributed researchers has become the focus in recent years. CAS has practiced for 5years in keeping up with the needs of scientists since 2014. Finally CAS proposed a lifelong learning model and built lifelong learning environment. All kinds of learning data indicate that this learning model is effective and sustainable.

1 INTRODUCTION

CAS was established on November 1, 1949, in Beijing, where it is headquartered. CAS is China's largest comprehensive R&D organization in the natural sciences and high technology. CAS is the linchpin of China’s drive to explore and harness high technology and the natural sciences for the benefit of China and the world. CAS brings together scientists and engineers from China and around the world to address both theoretical and applied problems using world-class scientific and management approaches. CAS comprises more than 100 research institutes which are located in

[1] Yixia Zhao
zyx@cnic.cn

23 provinces and autonomous regions across China. These institutions are home to more than 100 national key labs and engineering centres as well as nearly 200 CAS key labs and engineering centers. Altogether, CAS comprises 1,000 sites and stations across the country. CAS Headquarters in Beijing manages the entire organization under the leadership of the CAS president. CAS has a staff of 70,023, including about 58,697 professional researchers. With the rapid development of information technology CAS is facing the challenge about how to satisfy the lifelong learning needs of 70,000 researchers who are distributed across China.[1]

The main objective of this proposal is to explore effective lifelong learning models and to create a special learning environment that is in line with the lifelong learning needs of researchers using advanced technologies. The main work includes the following 3 aspects: 1) study of various effective Lifelong learning model such as MOOC etc. 2) through online survey, analysis of CAS scientists' lifelong learning needs;3) Practices on the lifelong learning model of scientists including study all kinds of learning resources that CAS scientists need and formulate effective assessment methods and assessment mechanisms and construct a continuing education environment that is in line with the lifelong learning of CAS scientists.

1.1 The development of knowledge updating

According to the study launched by the United Nations Educational, Scientific and Cultural Organization (UNESCO), information technology has brought the high speed development to human knowledge. In 18th Century, the time cycle of knowledge updating is about 80 to 90 years, from nineteenth Century to early 20th Century, it’s been reduced to 30 years, the last century 60~70's, the general time cycle of knowledge updating is about 5 to 10 years, and in the 80~90's of last century, the time has been shortened to 5 years, entered the new century, the time cycle of most disciplines has been shortened to 2~3 years.[2]With the development of Internet, 90% of the data of human beings are generated in the first two years. The IDC report shows that by 2020, the total number of global data will exceed 40ZB (equivalent to 4 trillion GB).[3]

1.2 The learning needs the fourth scientific paradigm proposes [4]

Jim Gray who received the ACM A.M. Turing Award in 1998 put forward that scientific paradigms could be categorized in four models. Thousand years ago science was empirical. Last few hundred years theoretical branch occurred that scientists did their work through using models and generalizations. When it came to last few decades scientists carried research by simulating complex phenomena that was called a computational branch. Today we meet the fourth science paradigm that was named data-intensive scientific discovery. It was developed in the big data era. New scientific paradigm poses challenges on today's scientists. Today’s scientists must catch up with the development of new technology and grasp a few kinds of skills such as the ability of analysis of big data and cloud computing. Most scientists should know how to integrate heterogeneous data and how to deal with mass data and many kinds of domain algorithm and how to visualize the research conclusion. At the same time big data improve the development of interdisciplinary. It means that scientists should know more subjects beyond their only major. Only by doing so can scientists discovery new knowledge.

1.3 The rapid development of information technology changes learning model

With the development of information technology and multimedia technology our learning model changes accordingly. In 1989 University of Phoenix launched its online program [5]. The term of open educational resources (OER) was firstly coined at UNESCO's 2002Forum [6]. The organization for Economic Co-operation and Development (OECD) defines OER as “digitized materials offered freely and openly for educators, students, and self-learners to use and reuse for teaching, learning and research”. There is no universal usage of open file formats in OER. The term OER describes publicly accessible materials and resources for any user to use, re-mix, improve and redistribute under some licenses. Massachusetts Institute of technology (MIT) announced OpenCourseWare on April 4, 2001[7]. Under this project MIT put all of the educational materials from its undergraduate- and graduate-level courses online, freely and openly available to anyone, anywhere. MIT OpenCourseWare is a large-scale, web-based publication of MIT course materials. Khan Academy is non-profit educational organization created in 2006 by educator Salman Khan with a goal of creating a set of online tools that help educate students [8]. The organization produces short lectures in the form of YouTube videos. The videos show a recording of drawings on an electronic blackboard, which are similar to the style of a teacher giving a lecture. Its website also includes supplementary practice exercises and materials for educators. David M. Penrose (aka the One Minute Professor), an independent instructional designer and eLearning consultant, has articulated the process for creating microlectures[9]. Microlecture is used to refer to actual instructional content that is formatted for online and mobile learning content using a constructivist approach.

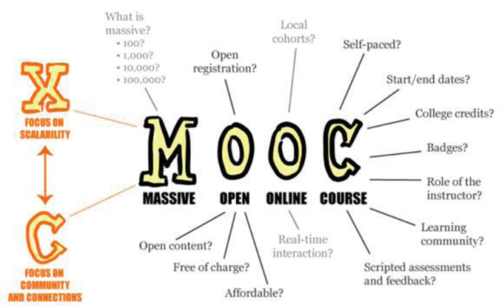

Fig.1. MOOCs

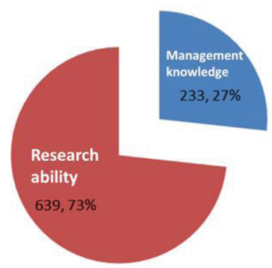

Fig. 2. Researchers and managers

According to The New York Times, 2012 became “the year of the MOOC” as several well-financed providers, associated with top universities, emerged, including Coursera, Udacity, and edX. A massive open online course (MOOC) is an online course aimed at unlimited participation and open access via the web. In addition to traditional materials such as lectures, readings, and problem sets, many MOOCs provide interactive user forums to support community interactions among students, professors, and teaching assistants [10]. Moocs as shown in *Fig. 1.*

2 THE SCIENTISTS' LIFELONG LEARNING NEEDS

The fourth scientific paradigm proposes new challenges on the researchers. In consideration of the training needs of CAS we also must understand the researchers' personal lifelong learning needs. We gathered the researchers' learning needs mainly through questionnaire and interview. We mainly do two kinds of questionnaire. Firstly CAS launches a training need survey every 5 years. This kind of survey covers all the workers of CAS. The investigation issues focus on content needs and learning methods. Secondly every research institute carries out investigation among its own staff every year. The second type of survey focuses on subject learning needs and expected teacher. The results of the two types of survey could give us enough data to analyze the researchers' needs thoroughly. In this research we mainly analyze the data form the survey that carried out among all the researchers in 2014. This survey was named "A questionnaire on the needs of continuing education and training in CAS". A sampling survey among 872 researchers was carried out. According to the proportion of different title levels the training superintendent of HR Department decided the list who took part in the survey. The survey was executed from March to June in 2014.

2.1 More working time less learning time

The 872 researchers that took part in this survey are from 117 scientific institutes. Among them, there are 233 science and technology managers and 639 scientific researchers. As shown in *Fig. 2.* For the purpose of understanding the learning needs of various post we sampled 255 junior researchers and 338 middle level researchers and 279 senior researchers. As shown in *Fig. 3.*

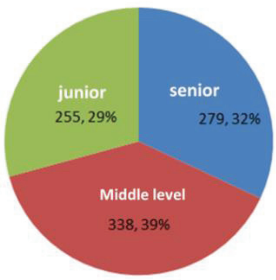

Fig. 3. Levels of researchers

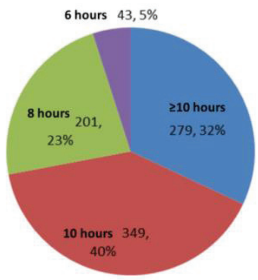

Fig. 4. Working time statistics

We try to know the researchers' learning time by the question "how long time do you engage in researching work every day". 72% of the Interviewee work more than 9 hours a day. 95% of the Interviewee work more than 8 hours a day. Even 32% of the Interviewee work more than 10 hours a day. These results show that work takes the researchers much time every day that they could not have enough time to learn. We need to think about how to balance work and study time. As shown in *Fig. 4.*

2.2 The effective training way

As the learning time was so limited we want to know the most effective way of training. 324 researchers thought it is more effective to study while working. 190 interviewees believed that the best way is to get away from the job and concentrate on learning for a while. 358 researchers regarded all kinds of lectures, visits and exchanges as the best way to meet their learning needs. It means that 41% of the interviewees prefer to visit and interact with each other. As shown in *Fig. 5.*

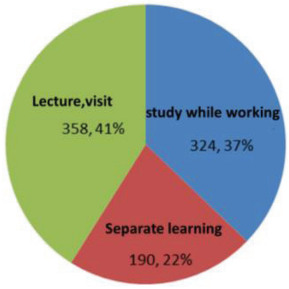

Fig. 5. Effective training way

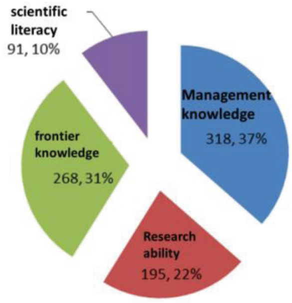

Fig. 6. Learning content needs

2.3 The learning content needs

Furthermore we want to know what kinds of learning content the scientists needed to improve their work. The options for this problem included management ability, frontier knowledge, interdisciplinary knowledge, scientific research ability, and scientific literacy. While CAS is engaged in almost fields in natural science the researchers' needs were distributed in many fields. 37% of the researchers wanted to learn more knowledge about scientific management. 31% of the interviewees needed to know more about frontier knowledge and interdisciplinary content. We can infer that these researchers were interested in cross field. 22% researchers thought they need to improve their research ability. Finally there were 91 researchers want to improve their scientific literacy. This means that 10% of the interviewees wanted to understand general knowledge beyond their own research fields. As shown in *Fig. 6.*

2.4 Other personal learning needs

For getting more details of personal learning needs we design some subjective questions. One question is "what service do you want the institute to provide you according to your career planning and development." Mostly every researcher wrote down their own needs. We sorted these answers into three major aspects.

(1) Strengthening continuing education support through policy

Many researchers advised CAS put forward independent policy about continuing education. There are four points in details. Firstly CAS should design all the continuing education work from Top-level to improve training work Standardized and systematized. Secondly CAS was supposed to ensure learning time for every researcher to resolve the conflict between learning time and work time. Thirdly CAS should provide more continuing education opportunity such as studying abroad or exchanging abroad. Finally CAS was supposed to ask every institute to set up funds to support continuing education and encourage every researcher to learn.

(2)Building learning platform to promote the sharing of resources

Some researchers suggested building learning platform to promote the sharing of resources. This can solve many problems by a learning platform. First of all every researcher can learn any time anywhere by learning the resources online. Many scientists who major in the same field often are distributed across China. How could they exchange each other's ideas effectively and share knowledge quickly? Through a learning platform many researchers can interactive effectively and even develop deep cooperation.

(3)Individualized and problem-based learning

As mentioned above, the interviewees wanted six kinds of learning content. It included research ability, interdisciplinary, information literacy, scientific literacy, management ability and industrialization. Which way do the researchers prefer to get these knowledge and ability? Scientists put forward three learning modes. The first was to provide training service for various kinds of post, and provide corresponding training content according to the levels of posts. Second was to provide individual learning service. The third was to concentrate on the research focus to improve the occurrence of effective learning through the problem oriented learning model.

3 PRACTICAL RESEARCHES ON THE LIFELONG LEARNING MODE

The continuing educational resources CAS provided before 2014 were consisted of training classes. This kind of training mode can fix the learning needs about frontier knowledge and management ability effectively. In a training class the participants can exchange face to face. It was proved that training class is an effective way.

Under the fourth scientific paradigm scientists should update their knowledge especially the knowledge about big data and cloud computing. And scientists may develop more and more cooperation between similar or different subject. How to update scientists' knowledge effectively? Training class is an expensive model. The learning materials cannot be stored and shared widely while a training class can only accept no more than one hundred participants one time. And we cannot gather all the learning data. While the period training class ends the learning ends.

3.1 Drafting policy to ensure the learning time for every scientist

In order to guarantee the time for every researcher to study, CAS drafts a policy named "Measures for the registration and management of continuing education and training time". It claims that the scientists have the right and obligation to receive continuing education and training, and the institutes have the duty to carry out continuing education and training. In this policy a scientist's learning time should be up to 100 hours, and the leaders' learning time should not be less than 110 hours every year. Scientist's study time is related to job promotion and annual assessment. This regulation is made to protect scientist's learning rights.

3.2 Establishing training implementation system

CAS has established a training implementation system for every kind of post. CAS is responsible for the training of the strategic management. Various bureaus are responsible for various special management training. The Institute is mainly responsible for scientific and technical professional training for researchers. The Continuing education bases under CAS are responsible for the integration of training in the field of discipline. The Continuing education bases under the Ministry of Human Resources and Social Security of China are responsible for professional and technical training for all of the scientists. Based on our practices we carried out theoretical research to standardize the training process for all the institutes mentioned above. The standardized training process includes six phases including survey, plan, implement, resource, assessment and statistical analysis.

3.3 Developing many kinds of training resources to meet individualized needs

The training implementation system has clearly defined the training responsibilities of all institutes. Under this training implementation frame we have carried out further work to specialize training content and methods.

(1) Building competitive training classes

The training class is implemented offline. It focuses on the frontier knowledge and management ability. We further subdivide training classes into short term special technical classes, professional technical high research classes, post training, academic conferences and academic lectures to meet every post's learning needs. CAS has implemented more than 5000 classes every year. In addition we have increased support for studying abroad, and supported researchers to carry out short-term academic exchanges abroad.

(2) Online courseware

Fig. 7. Science micro course

Fig. 8. Three-part- Screen Course

CAS builds science microcourses and three-part-separated Screen Web Course to update scientists' knowledge. The length of each science micro course is less than 20 minutes, which is taught by CAS's researcher. A science micro course can be a series of short videos or only one short video. We divide the series into two category, scientific professional research micro courses and science popularization micro courses. The scientific professional micro courses are produced for scientist to improve major research ability while the science popularization micro courses are produced to promote interdisciplinary. In addition, we have invited the academicians to tell the scientific story to develop micro course to meet the needs of the scientific spirit. Based on the excellent training classes offline we build three-part-separated Screen Web Course. This kind of web course lasts for 1 to 3 hours and it can explain professional knowledge systematically. Science micro courses as shown in *Fig. 7.* Three-part-separated Screen Web Course as shown in *Fig. 8.*

(3) Teacher database

Through building teacher database we guarantee the quality of courseware. We set up a variety of evaluation indicators to select better teachers and provide learning opportunity to improve teacher's teaching skills. As shown in *Fig. 9.*

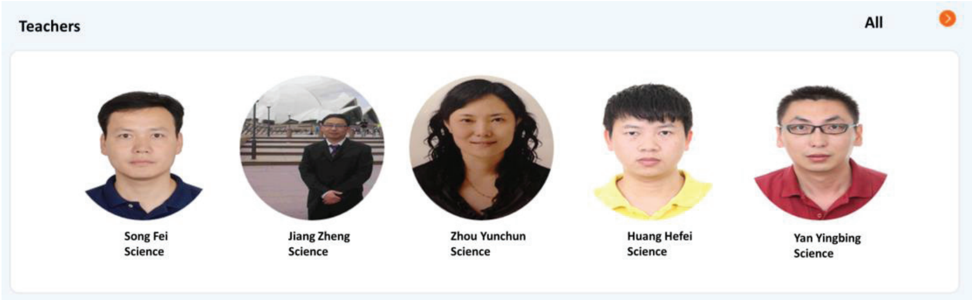

Fig. 9. Teacher Database

3.4 Organizing training assessment to improve the training work

In order to ensure the effect of the continuing education, CAS has developed a series of assessment indicators. This assessment indicator system mainly includes organization guarantee, policy, curriculum system, training need analysis, plan making, training implementation, and project evaluation, training funds, training materials, training teachers and resources sharing. CAS evaluates every institution's outputs of training work each year through data extraction and Interview.

3.5 Building CASmooc eLearning system and recording big learning data

Now we have many kinds of continuing education resources such as training classes and online courseware and teacher information distributed in every research institute of CAS. And we have set up a standard training process. Based on all the work mentioned above we build CASmooc. In 2016, CASmooc was officially launched online to provide learning service for every scientist anytime anywhere and record every researcher's learning data. The CASmooc platform's function mainly consists of three parts including management, learning and resource sharing. Its management function means it can support every institute implement the total continuing education. Its learning function means it serves every scientist in online learning and registering training class and taking part in surveys. Every learner can interact with others while learning the same courseware and participating in the same class. In order to ensure the authenticity of the learning data, every scientist must use his real name on CASmooc. It supports every institute determine whether open their resources or not autonomously. We developed CASmooc applications on android and IOS which supports offline learning. While scientist takes part in a training class he can record his learning data by scanning QR code. Scientist also can record learning data anytime anywhere by using mobile terminal. CASmooc supports live course and it reduces the cost of participating in a training class.

4 RESULTS

4.1 The Lifelong Learning Model of CAS

Since 2014, CAS has been initially drafted "Measures for the registration and management of continuing education and training time", established the continuing education implemented system, developed a variety of training resources, and organized training assessment work several times. CAS has formed its effective life-long learning mode for researchers. As shown in *Fig. 10.*

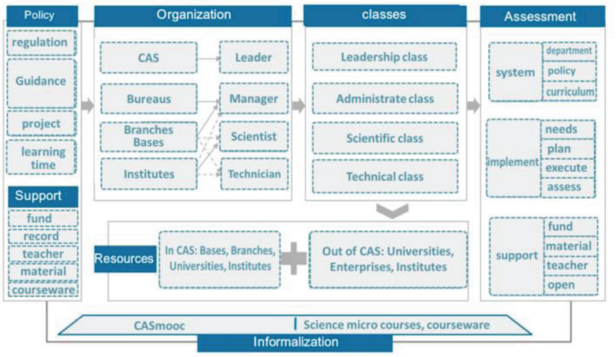

Fig. 10. Lifelong learning model

Through the comparison of the learning data in 2014 and 2017, we can see that our lifelong learning model is effective and has gained some achievements.

4.2 The learning data comparison

Through analysing the learning data in 2014 and 2017 we can see there are three changes. Firstly there has been a big increase in the learning data and the learning data is more detailed. Secondly the scope of learning data statistics becomes larger. The third is to set up a study file for each scientist. In 2014, CAS held 2224 training classes and there are 146 thousand trainees involved. In 2017, CAS held 5765 training classes and there are 321 thousand trainees attended. 250 thousand scientists are trained outside CAS in 2017 while there is no record about this data in 2014. The learning data mainly included the training classes held in CAS in 2014. The learning data included both in CAS and out of CAS, and these data was identified as offline learning data or online learning data in 2017. In 2017 the learning data was 5415868.9 hours, of which the online learning data was 621966.2 hours and the offline learning data was 4793902.7 hours. The internal learning data was 2387246.1 hours, and the external learning data was 3028622.8 hours.

4.3 Feedback

A questionnaire survey was carried out in 2016 while CASmooc has been running for half a year. More than 100 researchers participated. 95% of the users thought that CASmooc is beautiful and easily used. And later we have an interview with 20 researchers from 8 research institutes in Wuhan branch to get user’s suggestions. They suggested making more science micro - courseware to meet fragmented learning needs. They suggested that sum up all kinds of success experience in using CASmooc and carry out various exchanges to share experiences to improve the use of CASmooc. They suggested that policy incentives combine with the construction of high quality resources and change passive learning into active learning.

5 CONCLUSIONS & RECOMMENDATIONS

After more than 5 years of exploration, CAS has initially established a life-long learning model for researchers. All kinds of feedback data indicate that CAS has achieved some achievements. But with the development of information technology, especially the development of big data technology and the scale of open resources, CAS in the future will still take efforts to promote deep learning and build sharable learning environment. We plan to further describe the resources, and use knowledge map and ontology to integrate resources at the semantic level so as to better meet the individualized learning needs of scientists [11]. We will deepen the level of service, from the Institute to the laboratory, eventually to person. By analysing the big learning data, we have a plan to build model for every scientist. Using a variety of algorithms to realize the personalized recommendation of learning resources and improve the learning experience of users. On the basis of the continuing education network of CAS, we will share our resources with various scientific research institutions all over the world to promote the exchange of disciplines and cooperation.

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Innovative methods of teaching Sustainable Development

Gyula Zilahy[1]

Budapest University of Technology and Economics
3 Műegyetem rakpart, Budapest, 1111 Hungary

Ágnes Zsóka

Corvinus University of Budapest
8 Fővám tér, Budapest, 1093 Hungary

Conference Key Areas: Sustainability reflecting the complexity of modern society; New notions of interdisciplinarity in engineering education

Keywords: Sustainable development, innovative teaching methods, complexity, collaboration, involvement

ABSTRACT

Solutions to problems related to Sustainable Development require a complex, multidisciplinary approach. Experts representing the fields of engineering and natural sciences, as well as social sciences should collaborate in order to achieve meaningful, long term results in the environmental, social and economic domains of sustainability. This requires a shift in how we understand problems and how we develop solutions to them.

However, current teaching practices are not able to develop the knowledge and skills required for the solution of our contemporary problems. For this reason, new, innovative methods of teaching are required, especially in higher education.

In this article we identify the most important limitations of traditional teaching methods and will also make an effort to provide an overview of available innovative methods currently used around the world. We will share our experiences with three specific innovative teaching methods we used over the last ten years: 1) role plays, which simulate negotiation processes dealing with global environmental and social problems; 2) teaching through consultation projects with the participation of civil sector organisations (NGOs) and 3) social innovation labs, which have been growing all around the world and which promote a better understanding of the environmental and social implications of new technological solutions.

Our experiences show that these methods do not only teach invaluable knowledge and skills (e.g. creativity, team decision making, negotiation skills, etc.) to the participating students, but also provide them with a once in a lifetime experience of facing real world problems and inventing solutions to them.

[1] Corresponding author. E-mail: zilahy@eik.bme.hu

1. INTRODUCTION

Transforming our society to a more sustainable one requires decision makers who have a deeper understanding of our current challenges, can take a holistic view while working out solutions to them and possess a set of hard and soft skills to evoke real change. Educating students to become such decision makers – so that they can elaborate innovative, appropriate and widely acceptable solutions to the complex and highly intertwined problems of our world – requires innovative, new methods of teaching in institutions of higher education.

This paper provides an overview of the nature of sustainability challenges and how this should be reflected in higher education. Based on the literature and our practical experiences, we provide evidence why traditional teaching methods cannot be successful to adequately address the complexity of sustainability issues. Then we introduce three innovative teaching methods, namely, role plays, Pro Bono consultancy projects and social innovation labs, which were designed to equip students with knowledge and skills crucial to create truly sustainable solutions.

We argue that there is an urgent need to integrate new, innovative methods in the education of all disciplines, not only those focusing on sustainable development. Our experiences show that using such innovative methods of teaching do not only make studying more engaging and enjoyable to students, but also significantly contribute to a lasting learning experience.

2. REVIEW OF THE LITERATURE

2.1 The nature of sustainability challenges

Sustainable development is often defined in relation to human welfare, which in turn is dependent on our natural and social environment (see e.g. [1]). Major crisis situations relating to these brought about an explosion of discourse about the meaning and nature of sustainable development, as well as potential ways of achieving it.

While we still lack consensus regarding many facets of sustainability, most experts agree that sustainable development should integrate at least three broad areas: the natural, social and economic domains related to human existence.

Most challenges to implement sustainable development can be considered as wicked problems. Originally using the term in social policy planning, Rittel and Webber defined wicked problems using the following criteria [2]:

1. There is no definitive formulation of a wicked problem
2. Wicked problems have no stopping rule
3. Solutions to wicked problems are not true-or-false, but good-or-bad
4. There is no immediate and no ultimate test of a solution to a wicked problem
5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and error, every attempt counts significantly
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan
7. Every wicked problem is essentially unique
8. Every wicked problem can be considered to be a symptom of another problem

9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution
10. The planner has no right to be wrong.

Taking human induced climate change as an example, one can easily see its 'wicked' nature. Debate about its existence, extent, nature and urgency is still on the agenda in spite of considerable research effort on behalf of various scientific disciplines. It is even challenging to define what the desired state of global climate should be, let alone how and with what tools to achieve it. The solution to the climate issue cannot utilize (or only to a very limited extent) our previous experiences with other wicked problems. For example, lessons learnt and solutions developed to solve the depletion of the ozone layer cannot be transferred directly – if at all – to climate change efforts. Climate change, being a threat to human welfare itself, has implications for many other sustainability issues including eco-system health, the provision of drinking water and food, as well as various related social issues.
Similar to climate change, many other sustainability challenges can be identified as wicked problems: environmental issues such as species extinction, the degradation of the soil, the pollution of the oceans and social issues such as access to basic amenities, education and the job market, violation of human rights and conflicts over natural resources are only a few of the many examples. In fact, the 17 priority topics identified by the United Nations Sustainable Development Goals cover issues that can be understood as wicked problems.

Taking an engineering methodology point of view, Yearworth identifies sustainability as a 'super-wicked' problem using the additional concerns of Bernstein et al.: „(i) time is running out, (ii) no one authority is in control, (iii) we are the cause of the problem anyway, and (iv) we inherently discount the future in our everyday decision-making" ([3] in: [4]). Taking our previous example further, it is easy to see how problems related to climate change can be considered 'super-wicked'.

While identifying sustainability challenges as wicked problems does not make them any easier to solve, this approach can provide us with some insight regarding how to prepare the future generations so that they can elaborate appropriate solutions to them.

2.2 Implications for higher education

According to Svanström et al. [5] the integration of different perspectives and the concept of sustainability is challenging because it makes systemic and holistic thinking and radically innovative ways of education necessary.

With the deepening of our understanding in every discipline, the scientific method of working in silos is more justified than ever, since it is needed to promote excellence and even newer results. However, the tackling of wicked problems, such as many sustainability challenges, also requires that we build bridges between these silos. The need for such an interdisciplinary approach is widely accepted in both science and education.

To some extent, engineering education has already opened up to the ideas deriving from other disciplines (e.g. some aspects of social sciences). However, efforts to integrate various scientific domains in higher education often do not reach their objectives. Students and professors are preoccupied with their home territories and either do not understand the necessity of the interdisciplinary approach or are too busy pursuing their own research agendas.

Management education also suffers from taking a narrow perspective: how businesses should react to changing stakeholder demands and how the sustainability challenge will influence their bottom lines. On the contrary, ethical issues, complex problems and social responsibility are softer areas, which would require careful consideration, emotional intelligence and – as a result – different teaching approaches [6].

Innovative methods of teaching sustainability are also necessary, because the intensity of student involvement is a significant factor in the shaping of their opinions and behaviour regarding environmental and social issues (see e.g. [5], [7], [8] and [9]).

Traditional teaching methods often focus purely on the transfer of factual knowledge, which may raise concern and awareness, but has clear limitations regarding achieving behavioural change ([10] and [11]). While being necessary drivers for action, even changes in attitudes and values have been found insufficient to alter behaviour in a predictable way ([12] and [13]). Shaping the school as a social setting, raising interest in sustainability topics and commitment to them is crucial in determining the relationship between sustainability education and sustainable behaviour [9].

According to Kerekes and Wetzker over the coming years more effort should be put into developing teaching methods than into developing content in management education [6]. There are three well-known arguments which support this proposition. First, the e-society requires to rethink the ways of teaching because it creates a new kind of student and permanently changes the quality of information they have access to. Second, the expectations and demands of well-educated students are also changing. The value of soft skills is increasing, while the value of factual knowledge is decreasing. Creativity, convincing communication, collaboration skills, empathy and other forms of social behaviour are attributes that employers are looking for. Third, “Planet Earth has become a global village. Everything is interconnected. Complexity and uncertainty dictate business. These things cannot be described accurately with simple, deterministic tools” (ibid. p.18).

Several papers are emphasizing the role of higher education institutions in representing and supporting the values, knowledge and actions in order to prepare students to be change agents and transform society from unsustainable, irresponsible to more sustainable and responsible patterns ([9], [14] and [15]). The integration of sustainability issues into university curricula and the teaching methods are discussed among others by O’Brien and Sarkis [16], Steiner and Posch [17], as well as Du et al. [18]. An ultimate message from those papers is that motivation and perceived effectiveness are key factors of behavioural change (see also [26]).

3. METHODOLOGICAL APPROACH AND LESSONS LEARNT

The authors of this paper have been actively involved in teaching various topics related to sustainable development over the last 25 years both to engineering and business students. Our experiences cover traditional teaching methods, as well as innovative solutions to engage students in the form of curricular or extra-curricular activities.

In the following sections we introduce three innovative teaching methods, which have gained popularity in recent years in the education of sustainable development: role plays, Pro Bono projects and social/sustainability innovation labs.

We will concentrate on the potential benefits, the requirements and limitations of each of these innovative solutions as we experienced them at the Budapest University of Technology and Economics and the Corvinus University of Budapest during the past years and will make suggestions for their use in university education.

3.1. Role plays and simulation games

The exposition of the complexity of sustainability related problems is one area, where traditional classroom based teaching methods often fail. While students learn about the different domains of sustainable development, namely the economic, social and environmental aspects of development, the interrelatedness of these domains and the need for integrated solutions is hard to comprehend.

Additionally, students of engineering and business programs master their specific disciplines during their studies, but learn little about the political context, which has a major impact on how innovative solutions can gain a foothold and generate change towards a more sustainable society.

One way of familiarizing young people with real life problems and their solutions is teaching through simulations/role plays where the complexity of contemporary economic, social and environmental issues and the need for interdisciplinary solutions can be exposed.

Role plays may serve several objectives and may focus on a wide variety of issues, local, regional or global in nature, but apart from providing a bigger picture than usual classroom activities, they can also improve a number of useful skills, such as negotiation, communication and speaking in public, problem solution, team work and facilitation skills, etc.

One such initiative is the worldwide series of Model UN conferences organised since the late 1940’s, but dating back even earlier to the Model League of Nations simulations. A Model UN Conference is an extra-curricular activity for students who play the role of delegates to the United Nations and simulate the negotiation processes within UN committees. Model UN conferences are often initiated by high schools and universities with the active participation of students in the organisation of the event. Students take on the roles of UN representatives, members of other international bodies and national cabinets and learn about the workings of international politics and problem-solving (mun.bme.hu).

In Spring, 2019 a Model UN Conference, namely the BME Model UN Conference was held at BME for the second time with about 100 participating students. While this is a small number compared to other Model UN events, the professional quality of the Conference was high and attracted students from 35 countries.

The main objectives of the Model UN Conference at BME are:

- “to build relationships beyond classrooms, facilitate learning and to develop intercultural dialogue
- to make students understand the world around them, that their contribution as a global citizen is a must for a greater tomorrow

- to provide an interactive educational experience that teaches in an interesting and enjoyable way about the United Nations and
- to make students realize the power of dialogue in solving global issues" (mun.bme.hu)

Experiences of two Model UN conferences at BME show that students are eager to engage in such events, which help them gain a deeper and at the same time more holistic understanding of contemporary social problems. Participants at the BME Model UN Conferences have diverse backgrounds, many representing various engineering disciplines, but students studying business and natural sciences also joined the Conference. The emphasis of this type of diversity has major implications for finding and implementing solutions in real world scenarios later during the participants' career.

Another innovative teaching tool developed by Paschall and Wüstenhagen addresses the complexities of the international negotiation process relating to human induced climate change [19]. Combating climate change became one of the biggest challenges of this century and the ability of our societies to solve this challenge significantly depends on the complex understanding and appropriate mindset of current and future decision makers. Paschall and Wüstenhagen developed a "multischool negotiation simulation that is unique in its intensiveness, cross-sector design, and transdisciplinary nature" [21]. The course called "Model UNFCCC – Climate Strategy Role Play" has been offered to students jointly for 11 years by the most renowned universities of the CEMS network across Europe ending in a two-day long simulation of a climate summit, with the participation of 100-150 students.

The authors of this paper have themselves been teaching this very special and innovative course for several years. According to the experience of the teaching staff in the participating countries, the level of enthusiasm and the impact of the course on expected learning outcomes, awareness and commitment of students towards finding viable solutions to the climate challenge and sustainability problems in general, are exceptionally high, compared to traditional courses.

The main objectives of the course are:

- To provide students a deeper understanding of the negotiation process under the United Nations Framework Convention on Climate Change (UNFCCC), the difficulties of how to reconcile the often opposing interests of negotiating parties, including governments, sector-specific industry associations, global companies and environmental & humanitarian non-governmental organizations (NGOs);
- To highlight the interconnections between corporate strategies and public policies.
- To provide students a highly interactive and fully international simulation situation, where they need to be able to effectively negotiate, according to the mutual gains approach of negotiation, in order to develop consensus solutions, while gaining a better understanding of bilateral and multilateral negotiation dynamics, related to climate change.

The course consists of four modules, covering an extensive introduction to the topic of climate change and climate policy, discussing the role of business in climate change, providing a profound theoretical background and a skills training to negotiations, as well as the two-day role play itself. This mixed teaching model results in deeper knowledge and understanding of climate related issues but also in getting a more holistic overview of the complexity and interconnectedness of sustainability problems.

Beyond theoretical knowledge, students learn several skills, relating to multilateral negotiations, cooperating in smaller and bigger teams, elaborating common solutions and managing conflict situations. At the end of the course, students have to reflect on the whole experience, focusing on their own contribution, lessons learnt, skills which need further improvement and individual takeaways. This self-reflection is the final, but one of the most important step of creating long-lasting learning outcomes.

3.2 Teaching through consultation projects with the participation of civil sector organisations (NGOs)

In recent years, the practical aspects of higher education have increased in importance and both students and employers demand knowledge, which can be utilised directly and immediately in real life situations. The tackling of sustainability related problems also requires practical solutions rather than the continuous re-iteration of theoretical considerations.

One way of bringing real world problems into the classroom is cooperating with different types of organisations and working with them to solve their problems with the participation of students.

Such an approach has been used in the education of management students at the Corvinus University of Budapest within the framework of the master course titled „Corporate Sustainability and CSR". The Pro Bono project, integrated into the course, can be best described as a one semester long journey through which participating students carry out a project, together with a consultancy company, targeted at a civil organisation, with the academic support of the instructor of the course. Based on the experiences of running the Pro Bono projects for three years, the innovative approach taken by the course can help students gain a deeper understanding of the meaning of sustainability and the solutions available to society.

The task of the students during the course is twofold. Based on the project scope defined together with the civil organisation, student groups have to deliver solutions to the problems of the organisation using the mentorship of the consultancy business. At the end of the project, students present their results in front of the entire project team.

Meanwhile, students receive useful insights during the classes and elaborate a related assignment, based on predefined criteria of sustainability performance evaluation. The assignment consists of a team presentation and a reflection paper.

Team presentations include the following aspects:

- The analysis, carried out during the project, based on the problem statement and targets set by the student group, the civil organisation and the consultancy company.
- Evaluation of results by providing a SWOT analysis regarding the implementation of the suggested solutions to the problem statement.
- Setting up KPIs for performance evaluation of the activities of the NGO, including KPIs, which are related to responsibility and sustainability.
- Exploring the perception of the society regarding the "business model" and "value creation" of the civil organisation. Suggestions to increase visibility and acceptance.

- Discussing the expected impacts of the successful implementation of the project, from business and social points of view. Considering possible trade-offs between economic and social goals as well as outcomes, related to the project.
- Formulating suggestions for the civil organisation to demolish possible barriers to long-term success and proposing ways of future collaboration between such organisations and the society.

Reflection papers should provide a 5 to 6 page long reflection of the team, on the problem statement, the target setting, the process itself, communication with the civil organisation and the consultancy company, the different roles (with the students' role in focus) and features of the workflow (how the team approached the issue and the whole project). Furthermore, main lessons learnt, identified success factors, suggestions for future Pro Bono Projects, and any other takeaways are formulated.

The expected impact of integrating the Pro Bono project into the CSR course is to ensure long-lasting learning outcomes using a real project as an example and to make students better understand the difficulties and challenges of an intensive collaboration with civil organisations and other types of organisations.

There are some clear lessons learnt from Pro Bono projects. The scope of the project has to be clearly specified. To identify the problem and understand the main scope of the project are often challenging in Pro Bono projects. Project planning and time management are important to achieve results on time and in high quality. Visiting the NGO and getting involved in its everyday operation proved to be very useful, not only for better understanding of the scope of the project and mutual acceptance, but also to become more sensitive to social issues and the main mission of the civil organisation.

During the project, it is necessary to gather first-hand information and start asking for data as early as possible. Pro Bono project teams should be prepared that the NGO does not collect and track all its data in a consistent way, as compared to a company.

To have more contact persons at the NGO side seems necessary, for the sake of facing different opinions and ensuring a higher probability of implementing the resulting ideas of the project. Adaptation of the student team to the contact persons and the organization is crucial. Students often realise the hardship of working with several stakeholders and it is a very important learning outcome how to manage this effectively.

Continuous communication and validation of the ideas and solutions with the NGO is vital. Students have to learn how to ask the right questions to understand the underlying issues as the terminology, the language, the way of thinking and decision making at an NGO may be completely different from what students usually learn about organisations during their studies.

The consultancy company (mentor) is necessary and should be supportive during the whole project in order to facilitate a fruitful and effective cooperation between the student team and the NGO. In a Pro Bono project, students have the chance to learn how to approach a consulting project, narrow it down to a reasonable scope that would be attainable within the given period, and identify solutions for existing problems of an NGO.

Main benefits of embedding Pro Bono projects into a course with strong focus on sustainability and responsibility stem from the synergic effects of acquiring knowledge about sustainability while, at the same time, making use of the theories in real situations, at real problems, with the aim of providing creative and feasible solutions.

3.3. Social innovation labs

Innovation is at the forefront of the activities of many institutions of higher education. This is especially true in STEM universities, where both students and staff actively participate in technological innovation projects in order to accumulate knowledge as well as to seek funding.

Innovation processes and their results, however, can only be interpreted in their economic, social and natural surroundings.

First, technological innovations should be examined from the various aspects of sustainability. What are the environmental and social implications of a new process innovation? Are new products and services developed less harmful to the eco-systems during their full life-cycles? How do they influence consumer behaviour? How do they effect different social groups?

Second, technological innovations directly aiming at the solution sustainability issues should be developed with the participation of relevant stakeholders. Businesses and the civil sector should collaborate to work out viable solutions to environmental and social problems. Governments should facilitate change and make required resources available.

Third, social innovation should be fostered in order to facilitate change towards a more sustainable society.

Social innovation includes ‘new social practices created from collective, intentional, and goal-oriented actions aimed at prompting social change through the reconfiguration of how social goals are accomplished’ [20].

Social innovation is an outcome-oriented, collaborative process which is able to deliver effective and relevant solutions by responding to pressing challenges and being a mechanism for achieving systemic change [21].

Murray et al. summarise ways to design, develop and grow social innovation, which is an inspirational open book for initiating social innovation labs, which have sprung up in recent years at many institutions of higher education [22].

Social innovation labs generate solutions to societal challenges including many sustainability issues. These solutions can be new products; new ways of doing things (e.g. processes, regulations, strategies); new structures of resource allocation; and new organizational models [23].

Social innovation labs generate new networks (developing initiatives for long-lasting problem-solving and building high-trust relationships between members of a peer-group for a specific problem); capacity-building (advancing the lab-participant’s capacities to enable problem-solving) and knowledge provision (knowledge and perspective exchange between different stakeholders) ([23]).

According to Tiesinga et al., social innovation labs (SI-Labs) have four levels of impact:

- “Impact at the level of the lab itself as a manifestation of a new social practice which changes and enables new ways how problems are solved in contrast to the “state of the art without a lab”.

- Existing SI-Labs often inspire the creation of other SI-Labs or are directly involved in the generation of spin-off labs.
- Impact on the level of new social innovation initiatives and the "innovators and change-makers" who have been empowered through the SI-Lab process.
- SI-Labs tell their stories about the ways in which they have solved challenging problems. These emerging narratives help to understand the complexity of societal problems and the work of SI-Labs and, finally, allow to see the necessity of the existence of SI-Labs." ([24] in: [25] Wascher et al, 2018)

STEM universities, such as the Budapest University of Technology and Economics, are ideal scenes for setting up and operating social innovation labs. The co-existence of different disciplines can give rise to new ideas and can help their implementation to tackle real world problems. Social innovation labs can facilitate collaboration between faculties, between students and professors, as well between academia and other sectors, such as civil society and businesses. As such, social innovation labs can bring together the best of both worlds: facilitate effective learning and foster societal change at a larger scale.

4. FINDINGS AND CONCLUSIONS

The main objective of this paper was to highlight the necessity of shifting the education of Sustainable Development from traditional teaching methods to innovative ones, which are able to provide profound, long-lasting and exceptional learning outcomes for students – for the sake of evoking real change.

The analysis of the literature shows that sustainability issues are typical 'wicked problems', which are difficult to solve and need a specific mind-set to manage the complexity, the uncertainty and the strong interconnectedness of those issues. Implications for higher education suggest the requirement of integrating systemic and holistic thinking and radically innovative ways of teaching into study programs and courses. Traditional teaching methods have clear limitations in evoking behavioural change, while an intensive engagement of students is a significant factor in both constructive thinking and behavioural change.

Based on a 25 years of experience in teaching Sustainable Development, the authors described three innovative teaching methods – focusing on their objectives, requirements, learning outcomes and lessons learnt.

Role plays and simulation games prove to be very effective in deepening the knowledge in specific fields, while developing and practicing negotiation skills, multilateral decision making and elaborating consensus solutions to difficult real life problems. To meet the requirements of such role plays is demanding, but the enthusiasm and the reflections of students prove the high impact of this innovative method.

The experience of Pro Bono projects shows how important and mutually beneficial it is when different stakeholders – student teams, a consultancy company and an NGO – are working together in a project, the aim of which is to improve the quality and the operation of NGO-related programs which provide high social value and are crucial for a better and more sustainable society. Successful cooperation with NGOs enhances a better social and economic performance of the related projects, while on parallel, it contributes to the development of important soft skills – like sensibility, ethical considerations and responsibility – as well as hard, analytical skills of the participating students. The course functions as a facilitative surrounding through transferring well-structured knowledge and approaches, as well as providing continuous academic support during the whole project.

Social innovation labs also facilitate cooperation with stakeholders, but are not limited to NGOs: businesses, policymakers and any other interested parties can participate in lab induced projects. Moreover, in a university setting, social innovation labs can also contribute to the sharing of knowledge between the representatives of different disciplines (i.e. engineering, natural sciences and social sciences) within the institutions.

Based on our positive experiences with innovative teaching methods we believe that they should be used in more institutions of higher education all around the world to address sustainability related problems and to be able to implement viable solutions for a better future.

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RESEARCH

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BY LEADING AUTHOR

An exploration of second-year students' engineering ways of thinking

A Agrawal[1]
University of Cape Town
Cape Town, South Africa

M Blackie
Stellenbosch University
Stellenbosch, South Africa

R Smit
Centre for Research in Engineering Education, University of Cape Town
Cape Town, South Africa

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ABSTRACT

This research paper explores the role of chemical engineering curricula in engineering identity development among second-year chemical engineering students. We use Gee's notion of affinity identity as the theoretical framework, which is defined as the identity derived from engaging in the shared practices of a group. One way these shared practices manifest in engineering students is the development of engineering ways of thinking. We posit that as students participate in the shared practices of the discipline through engagement with their chemical engineering curricula, they start developing distinct ways of thinking guided by their disciplinary practices.

Semi-structured interview data were collected from twenty second-year chemical engineering students at two different South African universities. The interview questions asked students what they considered to be a typical way in which engineers think and how engaging with the curricular experiences was helping them develop this thinking. Preliminary analysis of data suggests that students described engineering ways of thinking as an enhanced awareness of real-world problems and an increased capacity to solve these problems. Additionally, students noted that engagement with the curricula makes them more curious about how real-world tools and systems work. Some students also described learning the language and problem solving techniques unique to engineering as an engineering way of thinking. Our data also suggest that not all students were aware of the development of an engineering way of thinking in them.

[1] Corresponding Author
A Agrawal
ashish.agrawal@uct.ac.za

1 INTRODUCTION

There has been growing interest in research on engineering identity formation with the understanding that development of a professional identity could be strongly linked with a student's retention and persistence in the discipline [1]. Research in STEM has shown that disciplinary culture has strong implications on students' identity formation. This paper brings together the two concepts of disciplinary culture and disciplinary identity by exploring how engaging with the engineering culture shapes the formation of students' engineering identity. In this paper, we particularly focus on how second-year chemical engineering students develop engineering ways of thinking through engagement with the course curricula.

We use Gee's [2] notion of affinity identity as the theoretical framework, which is defined as the identity derived from engaging in the shared practices of a group. We posit that as students start participating in the norms and practices of engineering, they start forming a disciplinary identity, which can be described as affinity identity. This affinity identity manifests in students as engineering ways of thinking.

2 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Engineering way of thinking

The idea of engineering way of thinking stems from the work on disciplinary cultures that treats each academic discipline as a culture with its unique set of assumptions, values, and practices. Several scholars have argued that academic disciplines differ from one another in the nature and structure of the knowledge that forms the core of a discipline [3], [4]. The differences in the knowledge structures then manifest in the teaching and learning practices adopted by students and lecturers. Additionally, these differences also shape the values and beliefs of individuals and how they interact with others in the discipline, thus giving each academic discipline a unique disciplinary culture. Referring to academic disciplines as cultures, Becher [4] noted "[d]isciplines are also cultural phenomena: they are embodied in collections of like-minded people, each with their own codes of conduct, sets of values and distinctive intellectual tasks" (p. 109). Hence, engineering can be thought of as a cultural phenomenon with its own set of beliefs and practices.

To better understand the cultural landscape of engineering, Godfrey and Parker [5] identified six different dimensions of the engineering culture: an engineering way of thinking, an engineering way of doing, being an engineer, acceptance of difference, interpersonal relationships, and relationships to the environment. In their study, they found that some of the most deeply ingrained assumptions with respect to the engineering way of thinking was that engineering dealt with a tangible and quantifiable quantity, and valued knowledge was knowledge that could be used for solving real-life problems.

2.2 Affinity identity

As students enter the discipline of engineering as first year undergraduates, they start learning the engineering culture by participating in the teaching and learning processes, and interacting with lecturers, researchers, and their peers within the discipline. Participating in the various norms and practices of engineering develops an engineering identity among students.

To understand the development of this engineering identity, we use the notion of affinity identity as proposed by Gee [2]. Affinity identity is derived from a distinct set of shared practices of an "affinity group." Gee further defines an affinity group as a group of people dispersed across geographical locations who share "*allegiance to, access to, and participation in specific practices*" (italics in original, p. 105). Hence, by participating in the practices of engineering, students start developing an engineering identity that can be characterised as affinity identity.

Affinity identity can serve as a crucial starting point to develop professional identity in engineering students. As students enter engineering, their affinity identity toward the discipline of engineering gets reinforced through their educational experiences, leading to the formation of an engineering identity. Therefore, Stevens and colleagues [6] recommend providing students with experiences of "real" engineering work early in their careers so that they can identify with the profession of engineering. Similarly, to increase the persistence of students in engineering, Pierrakos et al. [7] recommend creating educational experiences for first-year students in engineering related activities so that they can understand the engineering community of practice and start developing an engineering identity.

2.3 Engineering ways of thinking as affinity identity

Recognizing the importance of developing a sense of identification with the engineering discipline early on in students' careers, this paper explores the development of engineering identity in second-year chemical engineering students. For this paper, we focus one aspect of engineering culture: engineering ways of thinking.

Besides focusing on students' engineering identity development early on in their careers, this paper also reduces another significant gap in the scholarship on identity development in engineering. The existing research on engineering identity formation has generally focussed on the influence of campus culture and interaction of students' social identities with the engineering culture [1]. Thus far, there has been little work done on the role of the engineering curricula on engineering identity formation. This paper reduces this gap by focusing on the role of the chemical engineering curricula on students' engineering identity formation. As students engage with the chemical engineering curricula, they start learning the shared practices of the discipline through courses and related assignments, resulting in the development of engineering ways of thinking. The following question is addressed: **How do second-year students describe their engineering ways of thinking developed through engaging with their chemical engineering curricula?**

The focus of this paper specifically on chemical engineering students' identity formation is guided by findings from the studies (e.g., [8], [9]) that suggest that different engineering disciplines differ from one another in pedagogical methods and learning environments. As these aspects form an integral part of the course curricula, it is important to study students' identity formation in different engineering disciplines separately.

3 METHODS

3.1 Participants for the study

Participants for this study included twenty second-year chemical engineering students from two research-focused South African universities (U1 and U2) – one historically Afrikaans and other historically English – both offering four year undergraduate engineering degrees. A total of 10 students were interviewed at each university.

Participants were sampled through purposive sampling from the participant pool of a larger longitudinal study [10] to ensure variations in gender, race, and nationality. To ensure anonymity of participants, each participant is referred to by a unique identifier in the later sections. For example, U1CHE15 refers to a unique participant (numbered 15) enrolled in chemical engineering at U1.

3.2 Data collection and analysis

Data for this paper were collected as part of an international longitudinal study aimed at understanding the development of student agency through students' engagement with their undergraduate curricula in two different STEM disciplines [10]. For the larger study, data are still being collected in the form of class recordings and semi-structured interviews done with students and lecturers. The student interviews focus on eliciting details about curricula, assessment of learning, disciplinary knowledge, students' future plans, and their overall university experiences.

This paper focuses on the segment of data collected at two South African universities that explores how second-year chemical engineering students describe the engineering ways of thinking and reflect on the manner in which their engagement with the chemical engineering curricula shapes their thinking. Probes were added to get clarification on how their thinking differed from that of their peers who were not studying chemical engineering. It should be noted that the interviews were conducted in the second half of the year and students had been exposed to a significant portion of their second-year chemical engineering curricula by then.

Interviews were conducted either in English (19 interviews) or Afrikaans (1 interview) to allow students reflect on their experiences in the language of their preference. The interview carried out in Afrikaans was translated into English after transcription for analysis purposes.

Data were analysed by Author 1 using inductive coding to identify emergent themes around engineering ways of thinking. To enhance the reliability of the emergent themes, intercoder reliability checks were conducted with Authors 2 and 3 in that they read the coded data and a consensus was reached on the coding decisions. The following section discusses these themes in detail.

4 RESULTS

Based on our data analysis, we identified five major themes emerging from the data. These themes represent the various ways in which students described engineering ways of thinking. The themes include: understanding of how things work, enhanced awareness of problems, enhanced capacity to solve problems, knowledge of engineering language, and no discernible curricular influence. Table 1 presents these themes along with their operational definitions. The table also presents how many students noted each theme to give its frequency estimate. The themes are discussed below in detail along with representative quotes.

Table 1. Emergent themes representing students' engineering ways of thinking

Theme	Frequency	Definition
Understanding of how things work	12	Student talks about having a better understanding of and more interest in understanding the industrial processes including how things are manufactured and how different tools around them operate
Enhanced awareness of problems	3	Student notes having an enhanced awareness of the problems that need to be addressed
Enhanced capacity to solve problems	12	Student talks about learning real-life problem solving including improving the existing systems and optimizing the use of available resources
Knowledge of engineering language and/or problem solving techniques	5	Student notes learning about engineering-specific language along with the distinct techniques that engineers use or the assumptions they make to solve engineering problems
No discernible curricular influence	2	Student notes that they cannot identify any change in their thinking due to their engagement with the chemical engineering curricula

4.1 Understanding of how things work

Developing an understanding how things work was one of the major themes in the data. Several participants noted that engaging with their chemical engineering curricula increased their curiosity about and helped them better understand how industrial processes work and how different things are manufactured. As one student reflected:

> *Looking at your water bottle over there some would think, oh, cool water bottle. And you're like, "yes, I know it is like this thing you can pull out this top." But an engineer will be like, "oh, well, do you know that material was manufactured like this and this is how the bottle works and like the air pressure, oh, but that keeps the water cold and fresh and stuff?" So, over analysing [to figure out the details] is quite an engineering thing. [U2CE1]*

In this quote, the student described how engaging with the chemical engineering curricula makes an engineer more aware of the manufacturing details of objects around them as opposed to a regular user who would be more interested in the operational details of the water bottle. Similarly, another participant noted:

> *I can look at air conditioning, for example, and I understand the basics and the principles behind it. And I can look at sewerage works, for example, and I've got a greater appreciation for that, and the clever processes that go behind that. You open the tap and water hammering takes place and you know exactly, "okay, we can describe that, we understand that phenomenon." [U2CE11]*

In this example, the student described how studying chemical engineering for a year and a half influenced their way of looking at the various tools and systems they encounter in everyday life. They now have a greater appreciation and understanding of how the different things around them operate.

4.2 Enhanced awareness of problems

While engaging with the chemical engineering curricula helped many students better understand how systems around them work, this engagement also increased some students' awareness of the problems around them. Three students reflected on how either engaging with their curricula or interacting with their peers helped them gain a better understanding of the problems to be solved around them. For example, a student described how interacting with their peers on a field trip made them more aware of the negative impact of seemingly insignificant human activities, such as using plastic straws, on the environment:

> *I remember we went on a field trip, this June/July vac, and we were put into teams and we were sent to various plants and stuff. And while we were spending time together in our team, some of my team members were really passionate about this whole recycling thing, and you find out more about how what you do every day affects it. Like these plastic straws, they're a really small amount of plastic, but since they're used in bulk and transported and just manufactured in bulk all the time, they actually significantly affect pollution. [U1CE15]*

The student further added that this experience helped them become more cognizant of the presence of recycle bins on university campus.

4.3 Enhanced capacity to solve problems

Besides an increased awareness of problems, participants also noted an enhanced ability to solve problems they encounter in everyday life. More than half of the participants described how engaging with their curricula has developed a capacity to solve problems through optimisation, efficient use of resources, or simplifying a complex problem by breaking it into smaller pieces. For example, a student reflected:

> *As an engineer, when you look at some things you're not going to think of it the same way a person's going to think of it. So as an engineer, when you think someone [without an engineering background] is thinking maybe of dirty water, they might be thinking of throwing it away, and you [an engineer] might think "oh, I can filter it and then maybe use it to water something." Or when they see maybe scrap chairs and stuff, you [an engineer] think "oh, maybe this can be used to make something else." So, with an engineer you're always trying to optimise what you have. [U1CE5]*

In this example, a student compared the problem solving abilities of an engineer with someone without an engineering background. The student noted that someone with an engineering background would be keener to make an optimal use of items which others would simply throw away.

It should be noted that students' problem solving capacity extended to their personal problems as well. For example, one student reflected on how engaging with their engineering curricula helped them learn the skills to solve a complex problem by breaking it into smaller parts and solving each part separately. In the quote below, the student described using this approach to plan the logistics of their birthday party:

My birthday party was six months ago, and my dad actually pointed this out, he said to me, "you're becoming such an engineer." We had to estimate, there were about 30-40 people that were going to come to my party, and we were going to hike the mountain, and sleep on the mountain so it was quite a logistical issue. And we had to go and buy groceries for everyone for the evening up on the mountain. And I remember us going to the milk aisle and saying, "okay, we need to buy milk for tea the next morning," and I said, "okay, so we're going to have 30 people, each person's probably going to drink two or three cups of coffee, maybe three cups let's be on the safe side, and on average people drink maybe 30 ml in their [cup], okay so 30 times this, times, okay, we need maybe five litres of milk. Maybe, I think it was ten litres of milk. And ten litres of milk, will people be able to carry ten litres? Yes, two kilograms for five packs, okay five people." So I think that's a good example of breaking down a pretty abstract problem to little things, little pieces and putting them together. [U2CE3]

4.4 Knowledge of engineering language and/or problem solving techniques

Closely aligned with an enhanced capacity to solve problems in general, developing a knowledge of language and/or problem solving techniques typical of engineering was also noted by a few students. While students referred to the technical language and jargon used in engineering in general, and chemical engineering in particular, multiple times during the interview, two students explicitly noted learning about these terms through their studies. Additionally, some students noted how engineers use a distinct set of assumptions to solve engineering problems. For example, a student reflected:

I don't want to diss accountants, but accountants might have this certain way of thinking with regards to solving a problem. They'll have a reference book and then they'll look at that and be like, "okay, so, there's this problem, I apply this method," whereas engineers have to know all those methods at once and then be very specific about identifying a problem. Be like, "okay, it's this type of problem, I can make these assumptions." Engineering is very assumption based. They have to be clever assumptions because, obviously, if you make a ludicrous assumption, you blow stuff up and you don't want that. So, I think it's very much assumption based and being very clever and sly almost. [Engineers make assumptions about] things that are negligible with regards to the greater picture. For example, if you're doing an energy balance and there's some change in position in the gravitational field, then you can disregard that because that changed energy that comes from that change is so small, relative to everything else, then you can disregard it. [U2CE11]

In this example, the student pointed to the importance of knowing how to decide which method is appropriate for solving the problem. The student further added that engineering problem solving requires a lot of "clever" assumptions. Describing these assumptions, the student gave the example of neglecting a small change in the gravitational field leading to a small change in energy during computing energy balances as one such assumption. The student noted that this assumption simplifies engineering problem solving without significantly affecting the final results because they are of higher order of magnitude than the quantity neglected. In this example, the student also uses technical language – gravitational field – to make the illustration.

4.5 No discernible curricular influence

While a majority of students described developing engineering ways of thinking in some form, two students noted that they had not started developing this way of thinking. However, both noted that they were aware of this concept. For example, a student recounted:

> *Interviewer: Now that you are studying chemical engineering, do you see things in your everyday life differently?*
>
> *Student: No, I don't.*
>
> *Interviewer: Do you think there is an engineering way of thinking?*
>
> *Student: Yes, in fact I heard about that, but I'm not sure if I'm at that level yet. [U1CE10]*

In this example, the student noted that while they have heard of "engineering way of thinking," they are not yet aware of this cognitive development. Due to this lack of awareness, there is no significant difference in the way the student looks at everyday objects.

5 CONCLUSION

5.1 Situating the findings in literature

Our initial analysis of data suggests that students have varied level of affinity for the discipline. Most students discussed engaging in the practices of the discipline by through engaging in understanding how things work and developing problem solving capacity, evidenced through the application of these skills in everyday life. Through engagement with the disciplinary curricula, some students could also identify the nuances in problem solving that is typical of engineering. However, a few students noted that they were still not at the level where they could identify any changes in their thinking due to studying chemical engineering.

Our results also support the findings by Godfrey and Parker [5] who found an engineering way of thinking to be closely linked with solving real-life problems while working with tangible and quantifiable quantities. Several students in our study noted developing an interest in understanding the engineering principles behind different things around them and solving problems related to their everyday lives.

The findings also reflect the changes in the nature of problems solved by engineers in current times. Engineering problem solving now has expanded beyond catering to the industry's needs to include problems like sustainable energy and climate change [11]. Our data suggest that through their course activities students were aware of environmental problems such as pollution caused due to plastic and were developing an inclination to devise sustainable solutions such as recycling of dirty water and scrap.

5.2 Implications for practitioners

The results discussed above point to two major implications for curricula development. First, curricula designed to help students connect engineering knowledge to their lives can not only help them learn the course material better but also develop a stronger identification with engineering, leading to higher chances of retention and persistence in the discipline [1]. While several students in the study were able to transfer their curricular learning to applications in their everyday lives, a few still struggled to do so. The fact that a few students who are nearly half way through their degree were still not able to make connections between their daily lives and their engineering expertise is worrisome. This suggests that more emphasis on the connection to daily life within the engineering curricula could serve the students better in terms of the development of engineering thinking and engineering identity.

Second, curricula should also emphasise the importance of developing professional skills such as ability to communicate and work on interdisciplinary and multicultural teams. Engineering work in a globalised world is not limited to just technical problem solving but also involves teamwork and communication with individuals both within and beyond national boundaries [11], [12]. However, none of the participants noted developing these skills as developing an engineering way of thinking. Hence, it is important that curricular experiences are designed in ways that help students not only develop these skills but also see these skills as integral to engineering early on in their degree.

5.3 Future work building on this study

While the findings of this study shed important light on identity development among second-year chemical engineering students through engagement with their course curricula, they also open avenues for future research. A further analysis can be done to understand racial, gender, and institutional differences in students' professional identity development. Previous research has established that students' race and gender identities interact with the engineering environment leading to unique experiences for them. Analysing how students' race and gender identities interact with the engineering curricula can give deeper insight into students' professional identity development. Additionally, researchers have previously noted the presence of differences in the academic culture including teaching and learning processes in the same discipline at different institutes. Hence, comparing students' identity development at different institutes can provide a deeper understanding of the role of academic curricula in their professional identity developed.

Analysis can also be done to understand how students' engineering ways of thinking change over time as they get more exposure to their curricula. Data are currently being collected from the participants, who are in their third of the degree. These data can be analysed to understand a shift in their identity over the year. Additionally, further analysis can be done to understand how different curricular experiences help students develop engineering ways of thinking.

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Student Entrance Knowledge, Expectations, and Motivation within Introductory Programming Courses in Portugal and Serbia

L. Alves
Instituto Politécnico de Bragança, Escola Superior de Tecnologia e Gestão,
Departamento de Informática e Comunicações
Bragança, Portugal

D. Gajić
University of Novi Sad, Faculty of Technical Sciences,
Department of Computing and Control Engineering
Novi Sad, Serbia

P. Rangel Henriques
Universidade do Minho, Escola de Engenharia, Departamento de Informática
Braga, Portugal

V. Ivančević[1]
University of Novi Sad, Faculty of Technical Sciences,
Department of Computing and Control Engineering
Novi Sad, Serbia

M. Lalić
University of Novi Sad, Faculty of Technical Sciences,
Department of Computing and Control Engineering
Novi Sad, Serbia

I. Luković
University of Novi Sad, Faculty of Technical Sciences,
Department of Computing and Control Engineering
Novi Sad, Serbia

M. J. Varanda Pereira
Instituto Politécnico de Bragança, Escola Superior de Tecnologia e Gestão,
Departamento de Informática e Comunicações
Bragança, Portugal

S. Popov
University of Novi Sad, Faculty of Technical Sciences,
Department of Computing and Control Engineering
Novi Sad, Serbia

P. Correia Tavares
Instituto Superior de Engenharia do Porto, Departamento de Engenharia Informática
Porto, Portugal

[1] Corresponding Author
V. Ivančević, e-mail address: dragoman@uns.ac.rs

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ABSTRACT

Programming is a skill needed across various disciplines and it is becoming more valuable for many job positions. However, students still appear to struggle in introductory programming courses. Academic achievement in programming may be influenced by numerous factors and may vary across countries, as observed in a previous study focused on Portugal and Serbia. In the present study, factors generally related to achievement and attrition, namely student entrance knowledge, expectations, and motivation, were examined as possible reasons behind achievement issues in introductory programming. An anonymous questionnaire that comprised closed-ended items was given to students enrolled in introductory programming courses at technically oriented higher education institutions in Portugal and Serbia. After data cleansing, response data from 678 students were quantitatively analysed to identify overall characteristics of the investigated groups, as well as differences between the groups from the two countries.

The students generally had numerous expectations and motives regarding introductory programming, but their reported entrance knowledge of programming was generally at low levels. On average, the groups from the two countries were similar. The main differences include higher entrance knowledge for students from Serbia and slightly higher expectations for students from Portugal. These findings form a basis for further inquiry into causes of previously observed student performance variations between Portugal and Serbia. As there are many commonalities between the students from these countries, we may work on novel instruction methods and tools that would be useful for programming teachers and enrolled students in both countries.

1 INTRODUCTION

Computer science skills, including programming, are becoming more important in various industries [1]. As a result, higher education institutions (HEIs) are under great pressure to provide students with a wider and more advanced set of competences. As opposed to the projections that the demand for programming skills will grow [2], there have been indications of university students generally struggling with programming in introductory computing courses [3].

Similar trends have been noticed in practice by teachers in Portugal and Serbia, which eventually led to the start of a bilateral research project between the two countries in 2018. This project initially focused on analysing teaching and achievement in programming education and it was soon observed that the two countries considerably differed in student pass and assessment rates within introductory programming courses [4]. In some cases, the pass rates were below the global average pass rate for such courses. These findings, together with the general goal of having more competent graduates in both countries, have prompted a new inquiry into student characteristics and attitudes relevant for academic achievement and the study of programming.

The present study investigates student entrance knowledge, expectations, and motivation as factors that could be used both to explain the observed differences and influence adoption of new competences by students. The following research questions are examined:

- What are the overall entrance knowledge, expectations, and motivation of students enrolled in introductory programming courses in Portugal and Serbia?
- How do students enrolled in introductory programming courses differ between Portugal and Serbia in terms of their entrance knowledge, expectations, and motivation?

These questions were answered by conducting a survey at HEIs in Portugal and Serbia, including HEIs that participated in the previous study [4], and analysing collected data using multiple data analysis methods.

2 RELATED WORK

Student entrance knowledge, expectations and motivation were the three main factors explored in the present study as there is considerable research about their relations with academic achievement and attrition.

In engineering education, students who persisted in engineering had greater personal, academic, or experiential exposure to engineering as opposed to students who switched to other fields [5]. Learning programming before university could be associated with higher initial academic achievement in ICT-related studies [6]. There is additional evidence of a weak positive relationship between programming performance at the university level and previous computer experience, albeit without statistical significance [7].

Unfulfilled student expectations may lead to various disappointments and even withdrawal from higher education [8]. Students may have expectations towards course content, in particular its academic rigour and alignment with industry perspectives [9]. Furthermore, expectations may vary with gender, as demonstrated in a survey of student perceptions of a computing-related programme [10].

A varied set of reasons may be behind enrolment in higher education and selection of a particular degree. In a study concerning motivation of students in computing-related studies, the compulsoriness of a programming module was the main reason for taking the module, much stronger than learning or actual module content [11]. However, the need to motivate students in programming has already been recognized [12]. Moreover, a positive relationship between intrinsic motivation and programming performance was discovered for a group of students in an introductory programming module [13].

3 METHODOLOGY

3.1 Overview

A quantitative research design was used in the present study. A survey was developed to investigate student entrance knowledge, expectations and motivation in introductory programming courses at four technically oriented HEIs: three from Portugal and one from Serbia. Collected quantitative data were first processed and then analysed using quantitative methods.

3.2 Survey

Students were surveyed by using an anonymous questionnaire in English. The questionnaire consisted of 21 close-ended items, here grouped into four categories:

- CAT0: four introductory items about student background, e.g., current study programme and previous education;
- CAT1: three items about entrance knowledge related to programming, e.g., familiarity with algorithm concepts and knowledge of programming languages;
- CAT2: six items about expectations regarding the introductory programming course, e.g., to learn a programming language and to develop software; and
- CAT3: eight items about motivation regarding programming, e.g., preference for using algorithms to specify reasoning and fulfilment in finding a solution.

For each item, exactly one response was to be selected. A 5-point response scale (1 – Null, 2 – Reduced, 3 – Medium, 4 – High, 5 – Excellent) was used for the CAT1 items, while a 3-point response scale (1 – Disagree, 2 – Neutral, 3 – Agree) was used for the CAT2 and CAT3 items.

The survey was conducted at the participating HEIs in the middle of the winter semester of the academic year 2018/2019. In total, there were 736 respondents (407 in Portugal and 329 in Serbia).

3.3 Data processing

The initial data set was based on 22 variables and contained 736 records, one record for each respondent. One variable denoted the country of the respondent, while the remaining 21 variables denoted responses to the 21 questionnaire items.

All records that contained an invalid response value for some item not related to study programme enrolment were excluded from the data set. A response value was considered invalid if the respondent provided a response value not listed in the questionnaire, provided multiple response values, or did not provide any response value at all. After record exclusion, 678 records remained in the data set: 389

records of respondents from Portugal and 289 records of respondents from Serbia. This somewhat strict exclusion criterion was adopted because it facilitated the subsequent analysis process. The analysis considerably depended on three derived variables, whose derivation required clean records across 17 initial variables. The exclusion criterion was regarded as acceptable also because a high number of the initial records were retained after the exclusion (approximately 92%).

3.4 Data analysis

For the purpose of detecting overall differences in responses between Portugal and Serbia, the data set was extended by adding three new variables: *Mean Entrance Knowledge*, *Mean Expectations*, and *Mean Motivation*, which correspond to averaged responses to the items in the categories CAT1, CAT2, and CAT3, respectively. Overall differences in responses were first examined by comparing means (M), standard deviations (SD), medians (Mdn), and distributions of the variables *Mean Entrance Knowledge*, *Mean Expectations*, and *Mean Motivation*.

Differences in responses between the two countries were evaluated by statistical testing. Independence between the country variable and each item response variable from the item categories CAT1, CAT2, and CAT3 was tested using the two-tailed Fisher's exact test. As the test was applied 17 times, i.e., once for each considered item response variable, the Bonferroni-Holm method for *p* value adjustment was used to control the error of the first kind in multiple testing [14]. In each testing, the null hypothesis was that the distribution of responses to the analysed item did not differ between Portugal and Serbia. The result of individual testing was considered statistically significant if the adjusted *p* value was below the 0.05 level. Mosaic plots were used to visualise distributions of responses to the items for which statistically significant results were obtained.

All analyses were conducted using the *R* language and environment for statistical computation[2], the integrated development environment *RStudio Desktop Open Source Edition*[3], and the following additional *R* packages with their dependencies[4]: *tables*, and *RColorBrewer*.

4 RESULTS AND DISCUSSION

4.1 Overall responses to items

As evidenced by descriptive statistics reported in *Table 1*, respondents in Portugal and Serbia possess low entrance knowledge of programming (M = 2.25, Mdn = 2.00, Scale 1–5), but have many expectations (M = 2.71, Mdn = 2.83, Scale 1–3), and motives regarding programming (M = 2.63, Mdn = 2.62, Scale 1–3).

The largest difference between the two countries is in mean entrance knowledge, which is higher in Serbia, followed by the difference in mean expectations, which are

[2] R: The R project for statistical computing, URL: https://www.r-project.org
[3] Open source and enterprise-ready professional software for data science - RStudio, URL: https://www.rstudio.com
[4] The comprehensive R archive network, URL: https://cran.r-project.org

only slightly higher in Portugal. However, the differences in overall responses between Portugal and Serbia appear to be small. This may also be observed in *Fig. 1*, which contains notched box plots for the respective variables.

Table 1. Descriptive statistics for *Mean Entrance Knowledge*, *Mean Expectations*, and *Mean Motivation* for Portugal and Serbia

Country	n	Mean Entrance Knowledge (Scale 1–5)			Mean Expectations (Scale 1–3)			Mean Motivation (Scale 1–3)		
		M	SD	Mdn	M	SD	Mdn	M	SD	Mdn
Portugal	389	2.14	0.84	2.00	2.72	0.34	2.83	2.64	0.29	2.62
Serbia	289	2.38	0.94	2.33	2.70	0.26	2.67	2.62	0.24	2.62
all	678	2.25	0.89	2.00	2.71	0.31	2.83	2.63	0.27	2.62

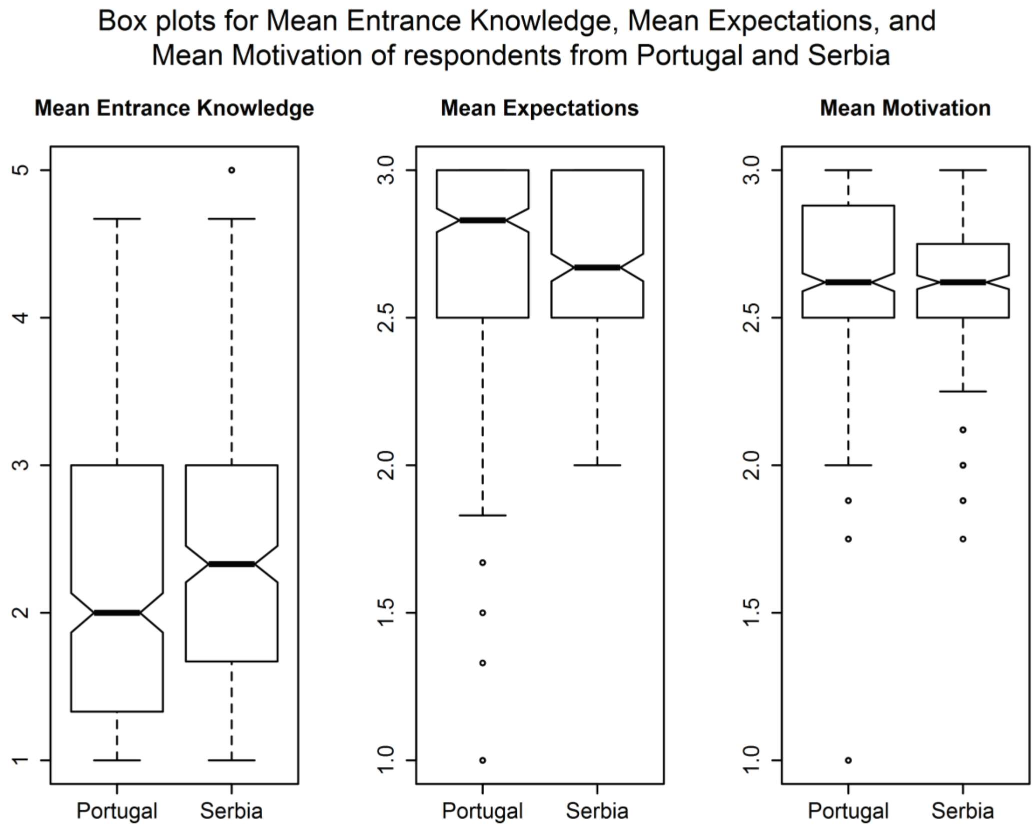
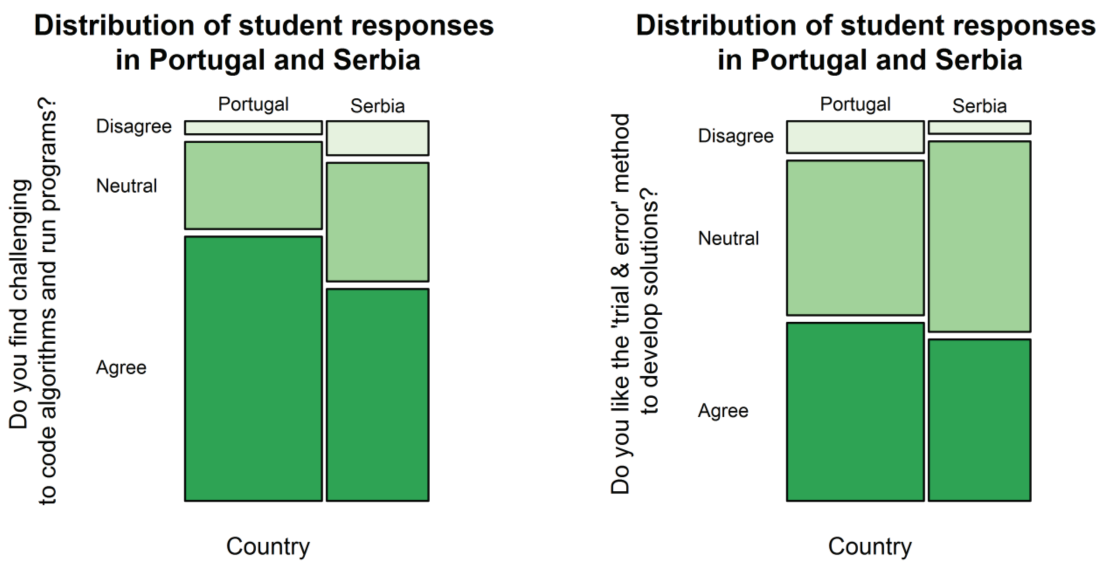


Fig. 1. Distributions of *Mean Entrance Knowledge*, *Mean Expectations*, and *Mean Motivation* for Portugal and Serbia

4.2 Responses to particular items

Responses significantly differed between Portugal and Serbia only for the following two items from the motivation-related category CAT3: *Do you find challenging to code algorithms and run programs?* (adjusted p value = 0.002) and *Do you like the 'trial & error' method to develop solutions?* (adjusted p value = 0.049). Distribution of responses to these two items is visualised in *Fig. 2* using mosaic plots.



a. *b.*

Fig. 2. Mosaic plots for responses in Portugal and Serbia to the items (a) “Do you find challenging to code algorithms and run programs?”, and (b) “Do you like the 'trial & error' method to develop solutions?”

The main difference in responses to the two items is somewhat greater overall agreement of respondents from Portugal with statements about finding algorithm coding and program running challenging and having a preference for the trial and error method when developing solutions. In the large majority of analysed items (15 out of 17), variation in responses between respondents from Portugal and Serbia was not statistically significant, which further supports the observation that respondents from these two countries are generally similar in terms of their reported entrance knowledge, expectations, and motivation.

5 CONCLUSION

Surveyed students from Portugal and Serbia reported low entrance knowledge in programming, but high expectations regarding their introductory course in programming and high motivation regarding programming in general. There were small differences in overall survey responses between the two countries, in particular higher entrance knowledge in Serbia and slightly higher mean expectations in Portugal. Responses to individual items were significantly different between the countries only for the motivation-related items about the challenging aspect of programming and the usage of the trial and error method in solution development.

Demand for high-level skills is increasing in the European Union (EU), so EU-level priorities for action include excellence in skills development and support for effective and efficient higher education systems[5]. Solid programming skills are needed today in many professional fields and are commonly taught in engineering education. Nevertheless, the results in the present study suggest that students in both Portugal and Serbia reach higher education with low programming knowledge despite having high motivation, which supports earlier doubts regarding previous education in computing [4]. Improving early education in programming requires vast effort, but there are some corresponding actions at both national and international levels, such as the digital competences initiative *Portugal INCoDe.2030*[6], introduction of a digital competences framework in Serbia [15], and the *EU Code Week* movement[7].

As shown in a prior study about introductory programming courses, academic achievement may considerably vary between Portugal and Serbia [4]. It appears that previously observed differences in pass and assessment rates, which are higher in Serbia as opposed to Portugal, cannot be readily explained only by differences in student entrance knowledge, expectations, or motivation, because the surveyed students from Portugal and Serbia were fairly similar in these respects. Students from Serbia reported slightly higher entrance knowledge, but this also might only partially explain considerably higher pass and assessment rates in Serbia.

Further research would be needed to investigate other potential explanations of the achievement discrepancy, e.g., student sociodemographic factors and prospects of starting a career, and differing course content and requirements. Teachers might only have limited options to combat the present achievement trend on their own, such as redesigning the course or applying novel teaching methods and tools. For these reasons, the present study is to be followed by more extensive surveys of students and an investigation into recommendations for programming teachers.

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[5] EUR-Lex - 52017DC0247, URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017DC0247
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A demographic picture of academics teaching on engineering programmes in Ireland and their Approaches to Teaching (ATI).

U Beagon
TU Dublin
Dublin, Ireland

Prof B Bowe
TU Dublin
Dublin, Ireland

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Keywords: Engineering academics, Approaches to Teaching, ATI

ABSTRACT

This paper presents the results of an online survey (n=293) carried out on academics teaching on engineering programmes in Ireland in 2017/18. The primary purpose of the survey was to provide a selection pool for interviewees in a separate phenomenographic study, however the survey also provided some interesting findings. Previously, there has been little published data on the diversity of personnel teaching on engineering programmes in Ireland and this paper aims to provide an insight.

In addition to collating the demographics of the survey respondents, and their background experiences in academic and industry, the Approaches to Teaching Inventory (ATI) [1] was also used as part of the survey. The results show that the respondents were more likely to use a Conceptual Change/Student Focussed Approach (CCSF) to teaching than an Information Transfer/Teacher Focused (ITTF) approach in the context of the modules they considered. Finally, diagrams are presented which show relationships between the Approaches to Teaching (ATI) responses and the level of programme being taught, the length of academic experience and any academic qualifications in teaching.

A study of demographics and attitudes of engineering staff was undertaken in Australia in 2010/11 [2] and we hope that both these results may encourage other countries to undertake a similar survey so that we may compare and contrast between different countries in order to better understand the diversity of our engineering academic community.

1 INTRODUCTION

The paper reports on an aspect of a larger phenomenographic study which aims to describe the qualitatively different ways that academics approach teaching professional skills in engineering programmes in Ireland. As part of the selection process for interviewees for the phenomenographic study, an online survey was circulated to all academics teaching on engineering programmes in Ireland. The main aim of this survey was to undertake purposive sampling of interviewees, but some of the data collected also provided some interesting findings in relation to general demographics of academic educators and their approaches to teaching, both of which are presented here.

1.1 Demographics

A phenomenographic study aims to identify the qualitatively distinct ways in which people conceptualise or experience a particular phenomenon. A phenomenographer looks for variation and hence seeks to interview a varied range of people. In this case, the researchers aimed to interview academics teaching on engineering programmes in Ireland, but realised very quickly that there was no central database of academic profiles nor published material which could be used to select appropriately differing interviewees and hence an online survey was used for this purpose. Ireland is not alone in the dearth of information about engineering academic staff and work undertaken by Cameron, Reidsema and Hadgraft [2] sought to collate similar information in an Australian context. The purpose of their study was to identify challenges, opportunities and barriers for change management within engineering education, but they collected demographic information, previous industry experience and they also used extracts from the ATI to highlight attitudes to teaching.

Although it was not the main aim of the Irish survey, the demographic results are nevertheless considered worthy of publication, to showcase the diversity of those teaching on engineering programmes in Ireland.

1.2 Analysis

It is important to bear in mind that no statistical analyses have been carried out within this study, all results presented are based on a comparison of frequency counts.

2 ACADEMICS' APPROACHES TO TEACHING PROFESSIONAL SKILLS

One aspect of diversity that was interesting from the aspect of the phenomenographic study, was how academics differ in their teaching practice. The theory of academic approaches to teaching provides a lens through which to consider this aspect. Prosser, Trigwell and Waterhouse [3] purport that the academic's conception of teaching has a direct influence on how the students learn and have created an Approaches to Teaching Inventory (ATI) survey instrument [1,3,4]. This instrument was used within the survey and highlights how an academic approaches teaching in a particular context. The research work that led to the creation of the Approaches to Teaching Inventory resulted from a phenomenographic study of first year university science teachers [3,4]. The analysis yielded five qualitatively different approaches to teaching (A-E), which are summarised in *Table 1.*

Table 1. Approaches to teaching (from Trigwell, Prosser and Taylor, 1994 [4])

	Strategy		
Intention	Teacher-focused	Student/Teacher Interaction	Student focused
Information transmission	A		
Concept acquisition	B	C	
Conceptual development			D
Conceptual change			E

Approach A: A teacher-focused strategy with the intention of transmitting information to students.
Approach B: A teacher-focused strategy with the intention that students acquire the concepts of the discipline.
Approach C: A teacher/student interaction strategy with the intention that students acquire the concepts of the discipline.
Approach D: A student-focused strategy aimed at students developing their conception.
Approach E: A student-focused strategy aimed at students changing their conceptions.

The ATI was revised in 1999 and the wording of some of the inventory items was updated to accommodate more flexible learning situations than those of first year university science teachers [1]. The original five sub scales were reviewed and a two factor subscale was now proposed, representing two fundamentally different approaches to teaching; Information Transmission / Teacher Focused Approach (ITTF) and Conceptual Change/Student Focussed Approach (CSSF).

2.1 Recent research – Approaches to Teaching Inventory

The original ATI was developed with first year physics and chemistry science teachers and the limitations of the research were highlighted as being relational and not necessarily the same for all disciples and contexts. It has since been used in a range of situations to relate approaches to teaching to other aspects of the teaching environment such as class size and teaching workload [5], impact of a teaching development programme [6], and disciplinary content [7,8,9]. Mean values of the CCSF and ITTF approach scales were analysed per discipline in these studies and showed statistical differences between discipline groups. Higher CCSF scores were found in the ‘soft’ disciplines (arts, humanities social science etc,) compared to the ‘hard’ disciplines which have a greater use of the ITTF approach (engineering, science, medicine) [9].

2.2 ATI – Criticism of conceptual foundation and procedures used

There has been criticism about the use of the ATI in scenarios where it was not originally intended and in the conceptual foundation and procedures which were used in its development [10]. For example, it is postulated that in two of the five categories, only one teacher’s voice may have been used to support the construct and since the gender of the 24 teachers was not identified, it is likely that 80-90% of interviewees were male and the scope of variation one could extract with such a gender bias is questioned [10].

2.3 Survey circulation

The survey was distributed to academic staff teaching on engineering programmes in all Higher Educational Institutions (HEIs) in Ireland. Staff listings were obtained from published staff contact details on each of the HEIs websites and this gave an estimate of approximately 1,000 relevant academic staff. Responses totalled n=273 giving an approximate response rate of 27%.

Whilst it is difficult to say whether the respondents are a representative sample, responses were received from each of the HEIs contacted and there was a varied range of discipline profile, academic qualifications, industry experience and age. Perhaps the only anomaly is that only 12.6% of those contacted to complete the survey appeared to be female based on their name, but as the results show in the next section, 22% of respondents were female. This is perhaps explained by the fact that the researcher is also a female engineering academic and female respondents may have been more likely to respond to a survey circulated by a fellow female engineer.

Fig. 1 and *Table 2* show the breakdown of gender and age of respondent profiles. The majority of respondents were male (n= 197) and 16 respondents selected “Other /

Prefer not to say". No respondent indicated an age of less than 25, and less than 8% of respondents indicated an age of below 35 years old.

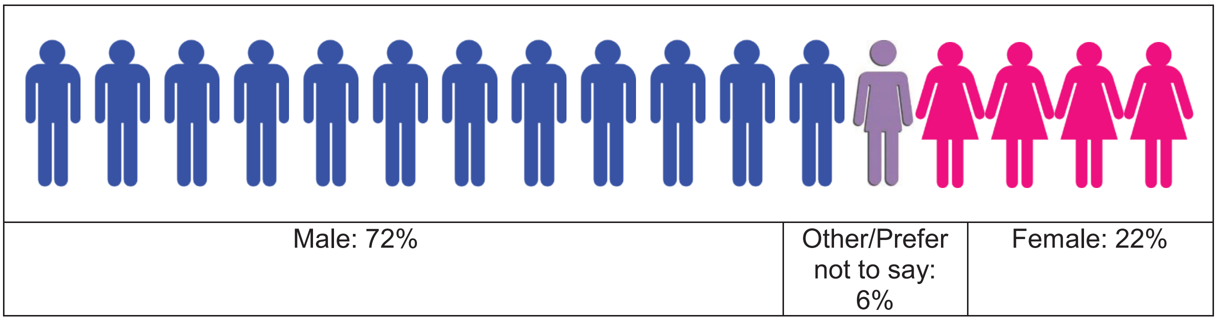

Fig. 1. Gender identification selected by respondents

Table 2. Age of respondents

Age	**<25 years**	**25 – 34 years**	**35-44 years**	**45-54 years**	**55 or older**
Number of respondents (%)	0 (0%)	21 (7.7%)	84 (30.8%)	114 (41.8%)	54 (19.8%)

2.4 Educational Qualifications

Respondents were asked to select all of their academic achievements. This was to identify those members of staff who had gained a PhD and those who had undertaken an educational qualification such as the Postgraduate Diploma in Third Level Learning and Teaching. *Figures 3 and 4* indicate the percentages of respondents who have gained various qualifications and those whose qualifications are in 'Engineering', 'Engineering and Education' or 'Other'. There was a wide range of qualification types selected by respondents with 87% (n=268) having an engineering qualification of some type. Respondents who answered 'Other' (n=39) indicated qualifications in the following broad categories; Science and Mathematics (n=23), Architecture and Construction (n=10), Business / MBA or Economics (n=3), Arts and Sociology (n=3).

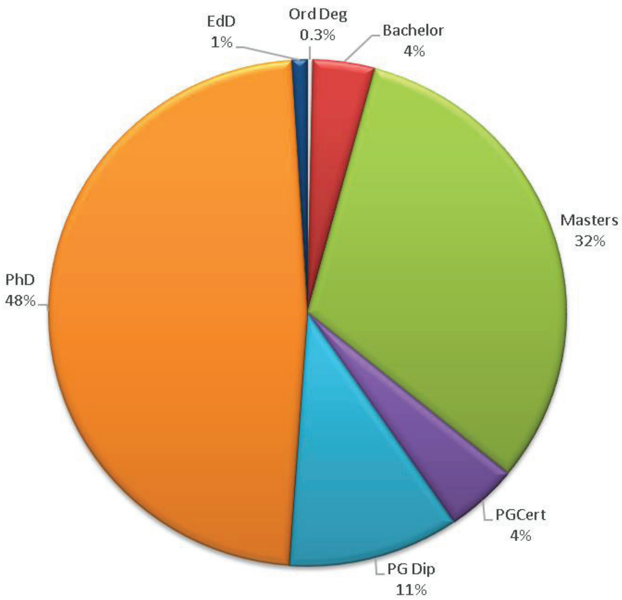

Fig. 3. Highest Level of Qualification

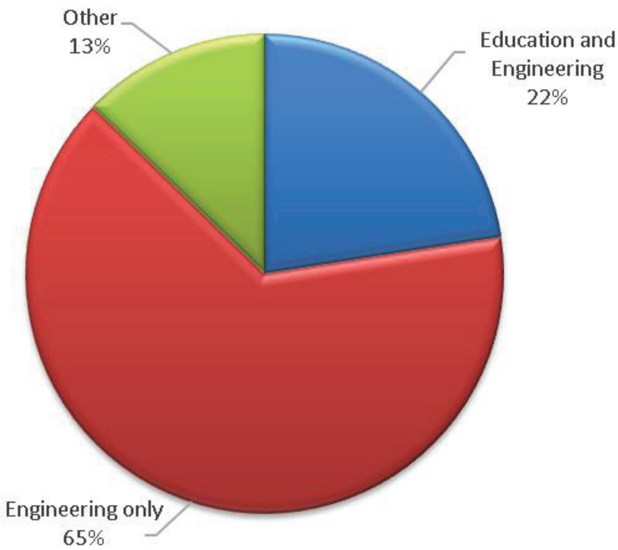

Fig. 4. Types of qualification gained

There was also a wide range of additional qualifications noted for those who selected 'Engineering' as a primary qualification. These included specialist subject areas such as regenerative medicine and software engineering, however 26 of the engineering respondents (8.5%) also indicated they had obtained either an MBA or Business/Management qualification.

2.5 Academic Experience

Respondents were asked to indicate the length, type and number of teaching hours they work in order to obtain a good range of interviewees with a selection of academic experience. *Figures 5 and 6* show the variation in responses to length of time working in academia and type of role selected.

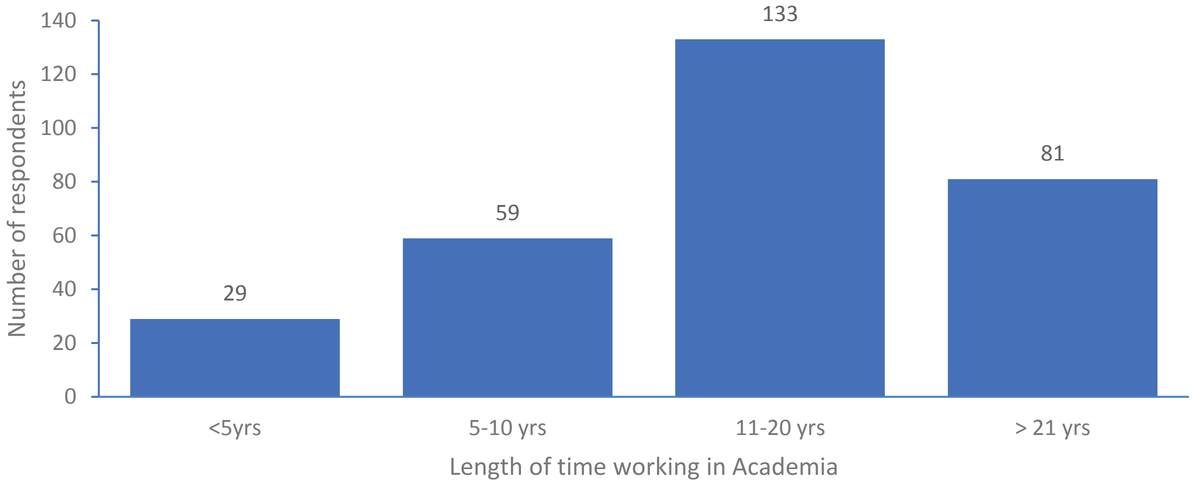

Fig. 5. Length of time working in academia

Type of role	Percentage of respondents	Graphical interpretation
Mainly Administration / Management	11% (n=32)	
Mainly Research	14% (n=43)	
Mainly lecturing	75% (n=221)	

Fig. 6. Type of role in academia selected

Third level education in Ireland is typically delivered within both Universities and Institutes of Technology (IOT). Respondents from each sector were asked to indicate their teaching hours and *Figure 7* shows the disparity between each sector with the clear majority of respondents in the IOT sector teaching greater than 15 hours per week. This is typically 6-10 hours per week for the University sector, 35% of which consider themselves 'mainly researchers' compared to only 5% of IOT staff selecting this option.

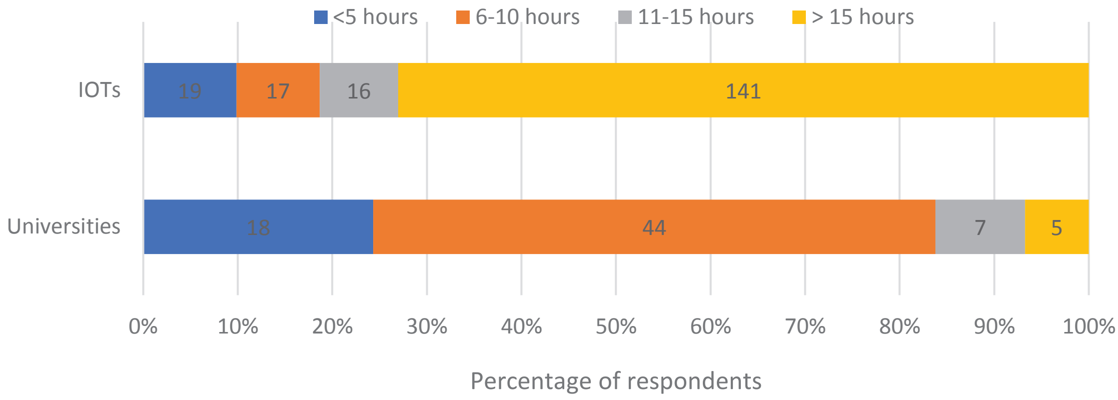

Fig. 7. No of teaching hours differentiated by University and IOT.

2.6 Industry Experience

Respondents were also invited to comment on their previous industry experience, the type of role they held and whether they were involved in the recruitment or training of new graduates. Many respondents have held roles in industry, as indicated in *Figure 8,* with 34 academic staff still working or consulting in industry.

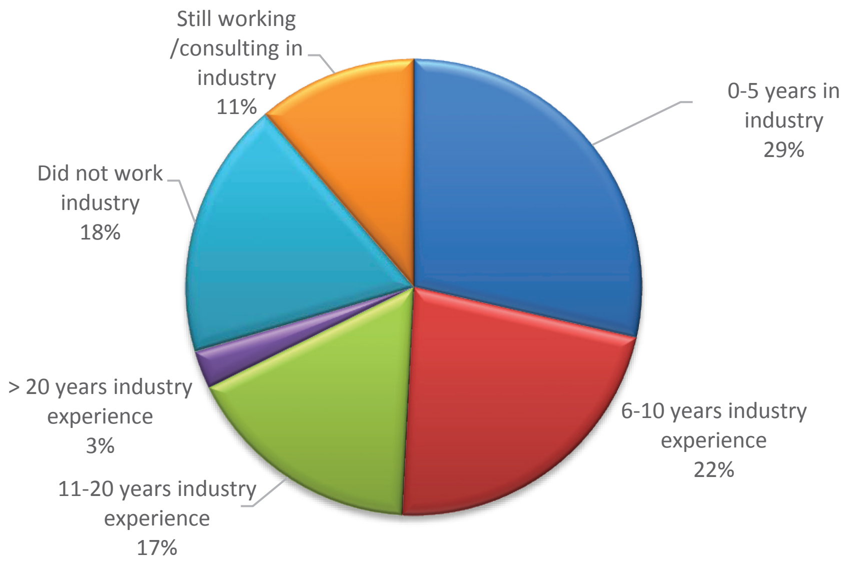

Fig. 8. Range of industry experiences noted by survey respondents.

The University sector holds proportionally more of the 53 respondents who have never worked in industry (38% of University responses compared to 13% of IOT responses). Conversely, approximately the same percentage (12%) of IOT staff and University staff are still working or consulting in industry. It is important to consider here that academic staff who are undertaking research projects with industry input may have answered the “still working / consulting in industry” option in this question.

2.7 Membership of professional bodies

Approximately 60% of respondents indicated that they were members of professional bodies, of which 38% are members of Engineers Ireland. Of the Engineers Ireland Members, more than half are Chartered Engineers or Fellows as indicated in *Figure 9.*

In order to become a Chartered Member, applicants must show evidence of specific objectives, many of which are aligned to practicing as an engineer. Those with Chartered or Fellowship membership therefore, would typically indicate a level of industry engagement and experience. Seventy-six percent of respondents indicated that they had contributed to an Engineers Ireland Accreditation in the past 5 years.

Type of Engineers Ireland Membership	**Percentage of respondents**	**Graphical interpretation**
Fellow	14.0% (n=16)	
Chartered Member	41.2% (n=47)	
Ordinary Member	40.4% (n=46)	
Associate Member	2.6% (n=3)	
Other (Graduate, Student, Affiliate)	1.8% (n=2)	

Fig.9. Type of membership of Engineers Ireland noted by survey respondents.

3 FINDINGS IN RELATION TO SPECIFIC RESEARCH QUESTIONS

The survey findings were also reviewed to assess the research questions;

- What is the relationship (if any) between approaches to teaching and the level of programme being taught?
- What is the relationship (if any) between approaches to teaching and educational qualifications of respondents?
- What is the relationship (if any) between approaches to teaching and educational experience?

3.1 Scoring of Approaches to Teaching Inventory

The Approaches to Teaching Inventory [1] used in the survey included 16 questions with statements pertaining to how an academic might approach teaching. The outcomes can show whether an academic has a Conceptual Change / Student Focussed (CCSF) approach or an Information Transmission/Teacher Focussed (ITTF). The respondent was asked to consider just one module, the one with which they have most contact time and so it is acknowledged that the responses are contextual; that responses for a different module may give a different score. The questions were in the form of statements, for example; "In teaching sessions for this subject, I deliberately provoke debate and discussion", or "It is important to present a lot of facts to students so that they know what they have to learn for this subject" [1]. Respondents select from 5 options from 'only rarely' (scored as zero) to 'almost always' (scored as 4). Hence the lower and upper bound scores are zero and 32, as each inventory scale has 8 associated questions.

All responses were scored and the results for the CCSF and ITTF calculated for each respondent. The following plot (*Figure 10*) shows the range of scores with each point representing the CCSF and ITTF score for one respondent. Whilst statistical analysis was not carried out, the trend line indicates that when one becomes more aligned with a Conceptual Change/Student Focused model, the score on the Information Transfer/Transmission Focused reduces.

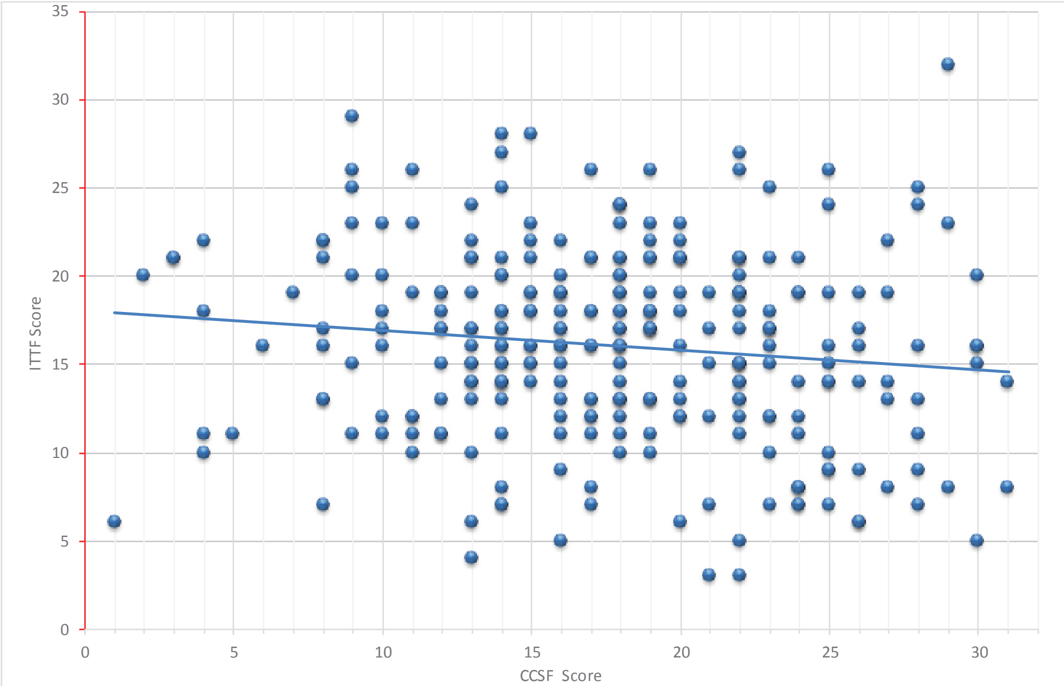

Fig.10. CCSF and ITTF scores for each respondent.

Figure 11 shows the CCSF and ITTF histograms overlaid with distribution curves, based on frequency. In this instance both scales have been scored positively. This result shows that on average there are higher CCSF scores meaning people tend to score higher on the CCSF scale compared to the ITTF scale. This suggests that most engineering academics in this sample are more inclined towards a Conceptual Change / Student Focussed model of teaching approach, albeit within the midrange of the scale and contextual to the module they considered when answering the question.

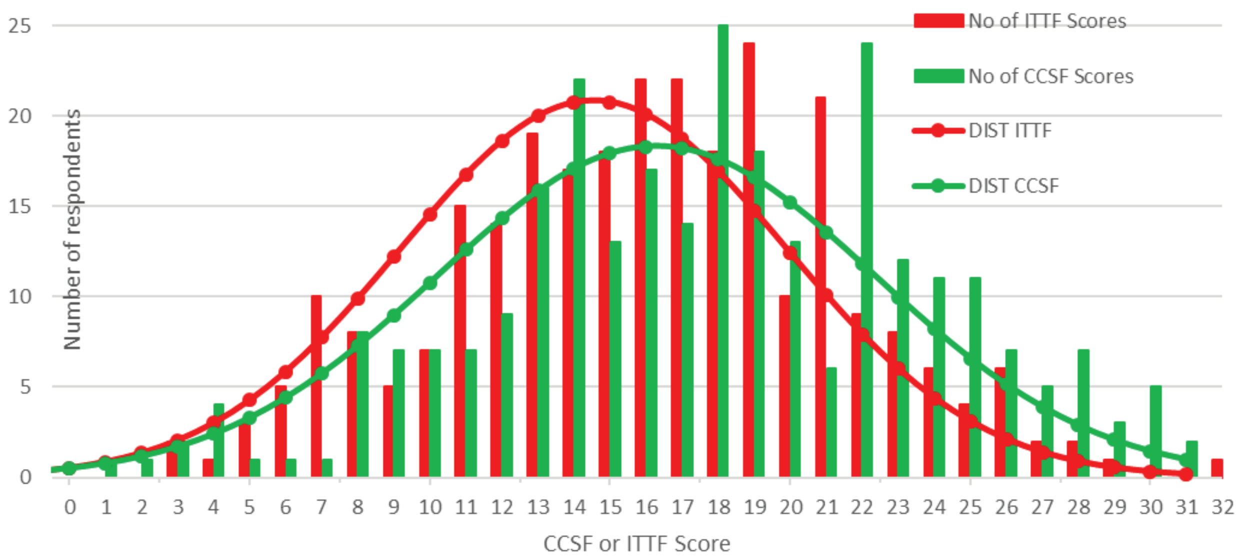

Fig.11. Histogram showing the number of each CCSF and ITTF scores.

In Ireland, the National Framework of Qualifications describes the various levels of academic programmes which include a Level 6 Higher Certificate, Level 7 Ordinary Degree, Level 8 Honours Degree, Level 9 Masters Degree and Level 10 PhD [11]. It appears from the results in *Figure 12*, that an ITTF approach can be quite common when teaching Level 6 and 7 students, which were typically described as large classes within a lecture theatre setting. A CCSF approach was more likely to be used in Level 8 and 9 modules which typically included a mixture of group work, studio classes, tutorials and laboratories. Both Problem Based Learning and Project Based Learning were also mentioned specifically in regard to a CCSF approach. *Figure 12* shows the spread of ITTF and CCSF approaches by Academic Level of programme.

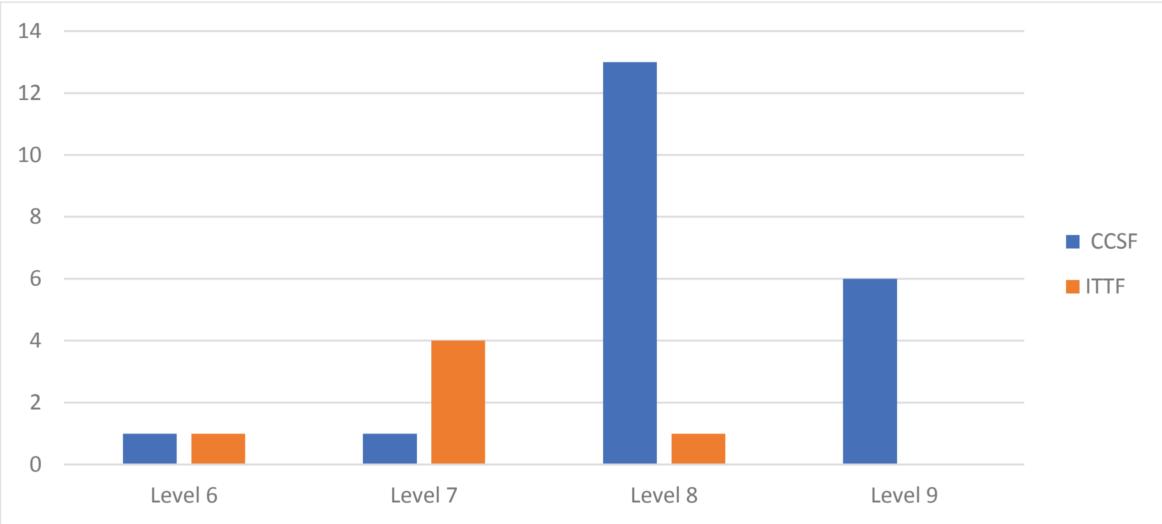

Fig.12. CCSF and ITTF scores for the modules selected by each respondent.

3.2 Approaches to Teaching Inventory scores versus Educational Qualifications

The next question sought to ascertain if there was a relationship between those academic staff with CCSF approaches to teaching and any evidence of an educational training record. Various thresholds were considered within the CCSF scale to identify those academics with a pronounced CCSF score. Table 3 shows the number of respondents who exceeded the thresholds in each of the ITTF and CCSF scales.

Table 3. Number of respondents exceeding various thresholds

Threshold Value	No of respondents who exceeded threshold in ITTF scale	No of respondents who exceeded threshold in CCSF scale
Greater than 20	60	93
Greater than 26	6	22
Greater than 28	2	10
Greater than 30	1	2

On this basis, a threshold value of 26 was chosen as providing a sensible selection of respondents for this question, which resulted in 22 CCSF and six ITTF scores greater than the threshold. Of the 22 CCSF allocations, eight had obtained educational qualifications (36%). Of the six ITTF allocations, two respondents had obtained Educational Qualifications (33%) approximately similar to the CCSF case, suggesting that the mode of teaching may be more attributed to context than knowledge of pedagogical approaches which may be gained through an Educational Qualification.

3.3 Approaches to Teaching Inventory scores versus Educational Experience

The next comparison sought to confirm if there was a relationship to show that as an academic gains experience through teaching a range of classes under different conditions and on different levels that their approach to teaching moves towards a CCSF approach. *Figure 13* shows the distribution of length of experience against those respondents who have been allocated a CCSF approach or a ITTF approach greater than a threshold score of 20. The threshold of 20 was used in this case to provide a more robust number of data points. However, this also means that in some cases a respondent had both an ITTF score and a CCSF score of greater than 20. In effect they use a combination of the two approaches and they are noted as 'Both' in this graph.

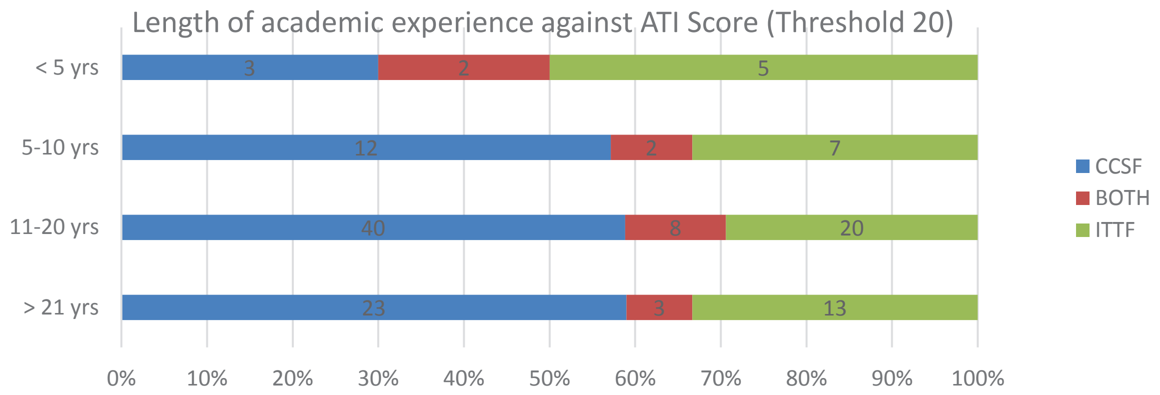

Fig.13. Bar chart comparing those who achieved a (> 20) threshold ITTF and CCSF score against their length of experience in academia.

Whilst the values for members of staff with more than five years experience do not change considerably, it would appear that that those with less than 5 years experience are more likely to have an ITTF approach.

4 CONCLUSIONS AND FURTHER WORK

This paper presents a snapshot of the demographics of academics teaching on engineering programmes in Ireland and provides a basis for ongoing collection of data to show trends in future years. Of particular note is the percentage of female academics (approximately 12% according to the lists provided on HEI websites) but 22% female respondents to the survey. This compares to 17.2% female respondents to the Australian study [2].

The findings in this paper show that there appears to be a contextual relationship to the Approaches to Teaching responses (ATI)and the type and level of academic programme being taught. There is no obvious relationship between evidence of an educational qualification resulting in a tendency towards a CCSF approach, suggesting that the teaching approach may be more aligned to the context of the teaching situation rather than pedagogical knowledge of the lecturer.

It also raises further questions about the relationships between academics' experience in academia and industry and how that influences the approach to teaching used in each context. Whilst conclusions cannot be drawn from the findings presented here, there are several aspects of the teaching context and the academics' experience which can be investigated further in an interview situation, which will inform the main phenomenographic study.

The output of this survey shows a picture of the diversity of academics teaching on engineering programmes in Ireland, and it raises some additional research questions in relation to academics in other countries in Europe and around the world. Further work could include;

- How do Irish engineering academics compare with other academics with regard to gender diversity, academic and educational qualifications and industry experience?
- How do Irish engineering academics compare with other academics with regard to the number of hours they teach and/or their split between teaching and research activity?
- How do Irish engineering academics compare to other engineering academics with regard to the CCSF and ITTF scores noted here?
- Is the relationship between teaching approach (CCSF/ITTF) and level of programme also notable in engineering programmes in other European countries?

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A phenomenographic study to investigate what we mean by the term "Professional Skills" – preliminary findings

U Beagon
TU Dublin
Dublin, Ireland

Prof B Bowe
TU Dublin
Dublin, Ireland

Conference Key Areas: Impacts of demographics in tertiary education, Diversity in Engineering Education, Strong demand for democratic involvement in educational processes

Keywords: Professional Skills, Phenomenography, Engineering Education

ABSTRACT

Recent calls for reform of engineering education have highlighted the importance of treating the engineering education system holistically; not only looking at developing curriculum components nor proposing new teaching pedagogies to enhance graduate skills. One aspect of this holistic view, which has not been given due cognisance is the impact that academic conceptions can have on the experience of the student in the educational system.

The authors propose that academics teaching on engineering programmes do not share a common understanding of what we mean by "professional skills", nor assume the same teaching and learning processes which develop these skills. It is unlikely that large scale reform of engineering education will be successful until we better understand and therefore allow for variations in conceptions of what we term here, "Professional Skills".

This paper reports on preliminary findings of a PhD study; a phenomenographic study of academic conceptions of the term professional skills in engineering graduates in Ireland. These preliminary results show that there are at least four qualitatively different ways in which the academics interviewed, conceive of the term professional skills. It is hoped that the results will enable academics to better understand how their own conceptions are similar to, or how they differ from their colleagues and so can enable them to better see how their own strategies can help reform engineering education.

This paper presents preliminary findings and hopes to generate discussion at the conference to help define, debate and shape the findings of the overall study.

1. INTRODUCTION

Engineering graduates in today's world face a global industry where professional skills are as important as the intellectual prowess gained by obtaining a degree itself. The importance of these skills is abundant in literature, yet so too is an ongoing barrage from industry that Higher Educational Institutions (HEIs) are not developing sufficient professional skills within students [1].

This occurs against a background of accrediting bodies who have adopted programme outcomes which require employability/professional skills to be integrated into the curriculum. There is also evidence that many educators have attempted to employ innovative strategies, such as Problem Based Learning to expose students to opportunities to practice these skills. Why therefore, is there still a gap between what industry wants and what HEIs provide and whose fault is it? Industry may be demanding more than an academic can deliver, in an already overcrowded curriculum with dwindling funding, particularly in an Irish context [2-3].

The author's interest in preparing engineering students for a successful career in industry stems from personal experience of recruiting, mentoring and managing graduates in civil and structural engineering consultancies. The range of skills, abilities and values of each graduate was varied, and it became apparent that academic achievement, whilst important, was not the defining skill for achieving early responsibility or promotion within the company. More often, the graduate who could communicate well and self-direct his/her work was given more responsibility and opportunity.

1.1 Influence of Accreditation Bodies and Industry

Accreditation requirements for engineering programmes serve as a framework for programme design. Several accrediting bodies including Engineers Ireland (EI), and the Accreditation Board for Engineering and Technology (ABET) require degree programmes to include outcomes, which incorporate what may be considered professional skills [4-5]. These skills include; self-directed working, teamwork, multidisciplinary working, ethics, communication with the engineering community and with society at large. The EI programme outcomes have been developed in consultation with employers and should therefore address concerns about professional skills from an employer's perspective. Employers in Ireland however, still report that they are not satisfied with the level of competence of engineering graduates in non-technical skills. [1]. This suggests therefore, that although there are processes in place which should ensure that students have opportunities to develop these skills, there is a disparity between what the accreditation paperwork requires and the skills that students actually develop. One area where this disjoint may occur is in the classroom and may be influenced by how the academic teaches or how the students learn.

1.2 Literature Review

Whilst there were no studies identified as part of this literature review on the definition of the term Professional Skills, work completed by Barrie [6] sought to describe the term "Graduate Attributes". This phenomenographic study was carried out amongst multiple disciplines in various universities in Australia. The work concluded that not only did academics have a variety of understandings of the term graduate attributes, that they had differing conceptions of how these attributes were taught and learned. Barrie produced an outcome space which shows relations between academic conceptions of what graduate attributes are and how graduate attributes were developed. Four hierarchal understandings of generic attributes were identified as;

1. **Precursor Conception** (necessary basic precursor skills but irrelevant as they are a prerequisite for university entry)
2. **Complement Conception** (Useful skills that Complement or round out disciplinary learning)

3. **Translation Conception** (These are the abilities that let students translate, make use of or apply disciplinary knowledge in the world
4. **Enabling Conception** (They are enabling abilities that infuse university learning and knowledge)

The conceptions identified above were taken from utterances in the range of transcripts that were collected from the interviewees. These results in themselves provide a unique understanding of the different conceptions that academics have in relation to generic graduate attributes. However, Barrie then reviewed the transcripts again, this time to identify relationships between the understanding of what graduate attributes were and how those academics conceived how students were meant to develop those skills. This work enabled him to present an outcome space showing the different approaches to teaching generic graduate attributes, which is available in the Barrie [6] paper. Whilst this research work follows a similar topic of interest to Barrie [6], there are several key differences. The term professional skills is used and not generic graduate attributes. Moreover, rather than considering generic graduate attributes as an outcome of university education, this study looks at professional skills of engineering graduates only, and the interviews are with academics teaching on engineering programmes only, rather than a multidisciplinary study. Finally, Barrie's work was carried out in Australia and this study concentrates on academics teaching on engineering programmes in Ireland [6].

1.3 Terminology

At this point, it is timely to explain why the term "Professional Skills" was used in this study. Terms such as; graduate attributes, soft skills, employability skills, key skills, transferable skills, transversal and generic skills are all used within the engineering education literature and are each meant to convey a list of skills that graduate engineers should have upon graduation [7-13]. Whilst there are many different definitions for skills and attributes, reference to the National Science Foundation funded project to develop a taxonomy of keywords for engineering education research is referenced here [14]. The final version of the taxonomy, available at http://taxonomy.engin.umich.edu/ has 454 terms arranged in 14 branches under 6 levels. As part of the validity exercise, a keyword analysis was carried out on a subset of articles and *Figure 1* below is a reproduction of the word cloud for the most commonly used terms in the keyword frequency analysis. The term professional skills is highlighted here, in absence of other terms such as graduate attributes and so on, and this gave validity to the decision to use the term "Professional skills" in this study.

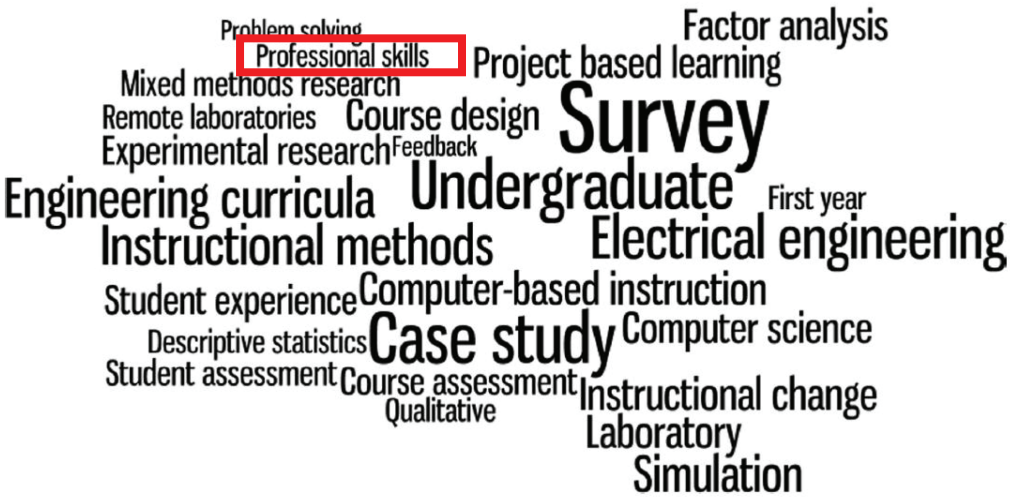

Fig. 1. Word cloud for keyword frequency analysis carried out as part of the validity exercise of the taxonomy project [Extracted from 14].

2 RESEARCH QUESTIONS

The research questions centre around the experience of the academic in the classroom, although we are also interested in factors which may have influenced how the academic contemplates the relative importance of professional skills. We also hope to relate our research outcomes to work carried out by Trigwell, Prosser and Taylor [15] which looked at academics' approaches to teaching and to Barrie [6] which investigates academics conceptions of graduate attributes.

The overall research study aims to investigate relationships between different objects of interest as shown in Figure 2.

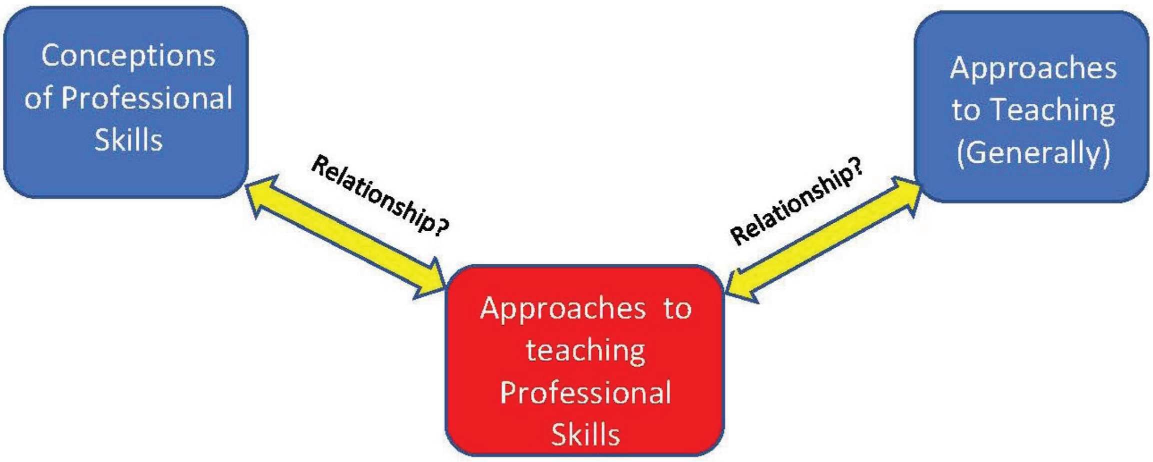

Fig. 2. Overall concepts and relationships to be investigated as part of this study

The overarching research question is;

- What are the qualitatively different ways that engineering academics approach the teaching of professional skills in engineering programmes in Ireland?

Sub-questions include;
- What are the qualitatively different ways that engineering academics **conceptualise** what is meant by professional skills in engineering? *(Preliminary results reported in this paper)*
- What are the qualitatively different approaches to teaching (generally) that engineering academics use in engineering programmes in Ireland? [20]*
- What are the qualitatively different approaches to teaching **Professional skills** that engineering academics use in engineering programmes in Ireland?
- How do academics manifest their conceptions of professional skills through their approaches to teaching professional skills?
- What is the relationship (if any) between approaches to teaching generally and approaches to teaching professional skills?

*results from this part of the study are presented in paper reference [20].

3 METHODOLOGY

3.1 Brief description of Phenomenography

The aim of the study is to build an understanding of academics' conceptions, perceptions and experiences of teaching professional skills. It is not to prove a hypothesis, to look at a particular case study nor a particular group of people. A descriptive method of enquiry was needed. Three research approaches were considered appropriate for the study; phenomenology, phenomenography and grounded theory. We determined that phenomenography would best answer the research questions.

Phenomenographers seek qualitatively different, but logically and hierarchically interconnected descriptions that a group of people experience in relation to a particular context [16]. Ference Marton, the original proposer of the term phenomenography, relates action and experience [17]. It follows that if we want to understand how people **handle** certain situations then we need to investigate how they **experience** those situations. "A capability for **acting** in a certain way reflects a capability **experiencing** something in a certain way. The latter does not cause the former, but they are logically intertwined" [17, p.111].

Phenomenography is proposed as an ideal fit for this research study for two reasons. Firstly, we believe that there are varied ways in which academics perceive, conceptualise and experience teaching professional skills. It is the variation we are interested in, not the commonalities which would be typical of a phenomenological study. The second reason is that a phenomenographic study is usually context bound. It refers to a particular instance that the interviewee is asked to reflect upon. We intend to investigate their experiences in relation to a particular context (teaching engineering students in Ireland) and not as an idea of teaching professional skills in the abstract.

3.2 Rationale and use of phenomenography in this research

This study aims to effect change in the way students are prepared for industry, particularly in relation to professional skills. This aligns well with the origins of phenomenography which was based in an educational setting. The study, while arguably based in education, focuses not on students but on the experiences and conceptions of academics. There is merit in this approach as it is argued that previous research studies in science education have sought to develop prescriptive solutions to problems in teaching and learning and that this is not effective, that descriptive results are much more powerful [18]. Phenomenography allows us to look at how academics approach their teaching in a natural setting and how these approaches affect the outcome for students. Research output in a descriptive form will allow academics to reflect critically on their own practice, which can account for their own individual perceptions [18].

Despite initial assertions to the contrary [17,19], phenomenography can be considered a research approach, and the researcher uses whatever research methods most appropriate to the study. In this instance, we undertook a two-phase approach. Phase One comprised an online survey, the primary purpose of which was to collect background information on the participants forming the population sample. The survey responses set the context for the research and informed the interview questions for the main phenomenographic study, which was undertaken in Phase Two. Some interesting results emerged from the survey and are presented separately in [20].

3.3 Research Participants

It was important that the interviewees selected for the data collection were appropriate to the purpose of the research, by representing a large cross section of views about the research topic. A purposeful sample of research participants have been selected for interview, based on a range of attributes which emerged from the survey data. It is intended that 20 interviews will be completed as part of the data collection. To date, four pilot interviews have been carried out, of which two were considered worthy of inclusion in the main data bank. This paper reports on preliminary findings from the analysis of those two interviews.

3.4 Analytical Methods

Phenomenography aligns with a subjective ontology, where the researcher interprets the outcome of interviews with people. It is accepted that the people will construe the world in different ways, as opposed to there being one truth. In fact, in phenomenography, researchers do not make any assumptions about reality, nor do they intend that their research outputs represent the **truth**. The findings of a phenomenographic study are presented in outcome spaces; hierarchically ordered sets of categories of descriptions, identified by qualitatively different variations of experience of the phenomenon. Researchers aim to present outcome spaces that reflect the phenomenon, but researchers can only provide more or less complete outcomes, not right or wrong outcomes [21].

Through uncovering variation, we hope to identify different **categories of description** which show **themes of expanding awareness** of how "professional skills" is conceptualised by academics. The hope is that the outcome spaces can show academics that there are **more complete ways** of conceptualising professional skills and as part of the larger study, how we can teach professional skills. It is hoped that this new-found knowledge of more complete ways of understanding how to teach professional skills will encourage greater adoption by academics, even within technical subject areas.

4 PRELIMINARY FINDINGS FROM PILOT INTERVIEWS

Although only two pilot interviews have been analysed, the authors believe there were some interesting themes uncovered and would like to present preliminary findings of one of the Categories of Descriptions; that of “What do academics understand by the term Professional Skills”. These findings are still in infancy but outline the current understanding of the phenomenographical process of analysis. We hope to discuss these further upon presentation.

Four preliminary categories of description have emerged from the two interviews and there is no attempt here to put them into hierarchal order yet;

W. Professional skills as the skills needed to succeed in the workplace.

X. Professional skills as being something that a person learns, where the person is the object of focus.

Y. Professional Skills as an umbrella term that includes Technical skills

Z. Professional skills as being an enabler to undertake Technical Skills

Each category is now described with accompanying quotes to explain how the category emerged.

W. Professional skills as the skills needed to succeed in the workplace.

This is described from the aspect of what is needed to succeed in the workplace or in professional life. The focus is work and industry and what is needed to be an engineer in industry, rather than on the person themselves. The interviewees relate professional skills to the ‘profession’ of being an engineer, where industry is the object of focus.

> *“Well I suppose you know we've mentioned the whole question of the skills that they'll be able to use when they go out into industry in terms of CAD, in terms of different things like that” Person D*

> *“how can students actually perform when they enter industry. And I think different sectors would look at that different ways. And it will depend very much on what your first role within the company is.” Person D*

> *“So it could be everything from writing a grammatically correct, well presented email. To chairing a meeting, to giving a presentation. I would see all of those things as skills which are potentially very useful in the workplace”. Person C*

X. Professional skills as being something that a person learns, related to the person.

This category, which also references professional life has the person at the centre. The skills are something that a person learns, connected to the person and whilst there is mention of professional life, the object of focus is the person themselves.

"I suppose, I think of skills as things that are learnt. So say it's anything that a person learns, at any point in their life, which is useful in a professional context. So that's used or would be useful within their professional life". Person C

"I mean the most important ones - they are more like meta skills… it's more like effective learning strategies and it's more about just recognizing the importance of meta cognition. So I spend time talking about this in class. So it's not ……. I don't mean these are such airy fairy things that they're not actual…... It's just I don't know if they are skills so much as their sort of philosophies that I would want students to embrace". Person C

Y. Professional Skills as an umbrella term which includes Technical skills

This category relates professional skills to technical skills, where technical skills are specifically mentioned within the description of professional skills. In this case, professional skills is an umbrella term which includes technical skills.

"There could be specific technical skills which are going to enable them to take on certain responsibilities within their professional lives. And so I think they're definitely professional skills. Then there's a whole other side of things which aren't maybe as specific to engineering but they are skills which are going to be useful in a professional workplace in the general sense". Person D

Z. Professional skills as being an enabler to undertake Technical Skills

This category also relates professional skills to technical skills, but describes professional skills as a subset of technical skills, and an enabler of technical skills. The ability to be an engineer and present or communicate technical CAD drawings or a technical report requires professional skills. In this category, the emphasis is on being an engineer and being able to undertake technical work, but with professional skills as a subset of skills, as an enabler.

"I would look at it as being a subset of skills…would be professional". Person D

"When the engineer goes out, they need to be able to communicate with people. I would say that communication is almost the price of entry. And then you can express that……. you can say well is that just being able to get up and talk to people, or is it actually being able to get up and present. Or is it actually being able to create a CAD model to express ideas". Person D

"So students and engineers need an ability to communicate. Part of that communication is obviously through CAD packages and SolidWorks, being able to look at a report being able to interpret it. Being able to say is this actually a good report or not". Person D

"And that's the point that I'm trying to come out……that even within communication you can have some parts of communication that are professional, technical". Person D

Once the relevant quotes have been extracted from the interview transcripts, the researcher must then define how the categories of description differ from each other, and this is achieved through considering the structural and referential aspects of each category. Whilst our analysis has not yet developed this far, several different aspects are coming to our attention.

- The object of focal awareness is industry – what industry wants, what the workplace wants.
- The object of focal awareness is the person - what the person needs to develop, skills that the person should develop for life.
- The object of focal awareness is in relation to technical skills; whether professional skills are inclusive of technical skills, separate to technical skills or an enabler for technical skills.

5 DISCUSSION AND CONCLUSIONS

It is recognised that the findings presented here were drawn from only two interviews, and this is why there has been no attempt to place them in hierarchal form. However, already there are aspects of these findings that relate to the outcomes of the study on Conceptions of Graduate Attributes [6]. Both the Complement Conception (Useful skills that Complement or round out disciplinary learning) and the Enabling Conception (They are enabling abilities that infuse university learning and knowledge) could be recognised in Category Y (Professional Skills as an umbrella term which includes Technical skills) and Z (Professional skills as being an enabler to undertake Technical Skills) here.

Equally importantly to note, is the aspect relating to the person or to industry which were not identified as structural or referential components of the Graduate Attributes study [6]. Although it is early to draw conclusions, this may be because of the emphasis of this study on engineering professional skills, as opposed to graduate attributes in general, which was the focus of the Barrie study [6].

We hope this paper presents the preliminary findings in a way which will allow us to generate debate at the SEFI conference to help us defend, define and refine the Categories of Descriptions uncovered as we move towards completion of the overall research study.

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Graduate Engineering Skills
A Literature Review
& call for rigorous methodological approaches

U Beagon
TU Dublin
Dublin, Ireland

D Carthy
TU Dublin
Dublin, Ireland

Prof B Bowe
TU Dublin
Dublin, Ireland

Conference Key Areas: 4th Industrial Revolution, Talent Management

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ABSTRACT

What sort of working world do our engineering graduates face? Engineering has become a global profession, where professional skills are as important as the intellectual prowess gained by obtaining the qualification itself. First, we must consider what skills are needed for engineers to meet the challenges of Industry 4.0. Academics who wish to engage in activities to enhance engineering education might therefore initially seek to identify which skills are most important and there is a wealth of literature addressing different viewpoints which adds further complexity to evaluating such studies.

This paper reports on two independent systematic reviews of literature to identify the most commonly discussed skills that engineering graduates require from the focus of different stakeholders. The first study audited 129 papers and identified the list of most commonly discussed skills, which was then condensed into a list of 17 professional skills. Independently, a review of the lists of skills used in 16 quantitative studies was carried out in relation to engineering skills requirements for graduate engineers specifically.

The results of both studies are compared to highlight the similarities and differences between the results of each method. The work also aims to highlight concerns over providing lists of skills in survey questionnaires without a rigorous research methodology. It is hoped that this paper will generate discussion and aims to raise additional research questions to initiate more in-depth research, into the differing views and contextual relationships of skills' listings.

1 INTRODUCTION

Professional skills, sometimes referred to as generic, soft or transversal skills in the context of this research can be defined as the skills which are valued by employers [1].

A review of literature on skills in engineering was carried out in 2006 which concentrated primarily on publications relating to the UK [2]. The author concluded that rather than clarifying the required skill set for engineering, the extent of literature published by variant organisations merely confused the definition and she concluded that further research is required. Concerns were also raised by Holmes [3] who summarised three problems with using lists of purported skills or attributes in surveys. The first is the provenance of such lists and he highlights than many studies use previously published ‘other lists’ in their research. He gives examples to show that the ‘other lists’ may not have been derived from a firm theoretical base, but as they are presented in a form with statistical analysis, it gives the impression of validity. The second is that responses to such surveys must be considered as opinions or perceptions, not facts. For example, whilst some employers may respond that a particular skill is important, it does not necessarily relate to action, i.e., that they use that determination when employing new staff. Finally, Holmes [3] warns against presenting data analysis from such surveys in a statistical form, using means and standard deviations, when there can be considerable variation in the respondent’s understanding of the question or meaning.

This paper reports on two systematic reviews of literature carried out by two researchers each working independently, to identify the most commonly discussed skills that engineers require. The reviews were carried out previously as part of other research projects and this paper has resulted from a reflection on those findings, so the intention here is not to replicate the reviews but to compare independent results.

The first study audited 129 papers and identified the list of most commonly discussed skills within those papers, which was then condensed into a list of 17 professional skills. Independently, 139 studies were identified and of those, a review of the lists of skills used in 16 **quantitative** studies was carried out in relation to engineering skills requirements for recent graduates. The frequency of appearance of each skill was counted and aggregated into a final list.

2 METHODOLOGICAL FRAMEWORK – LITERATURE REVIEW 1

Sources for review and the review process itself were identified using a staged process which is described further below. The aim was to adopt a process which can be replicated by other researchers and so an audit trail of decisions made is also provided.

2.1 Inclusion criteria

An initial scoping study led to the decision that a worldwide search be undertaken and all papers, conference proceedings, governmental and employer body publications be considered. The aim was into include as many stakeholder opinions as possible.

The final search terms were “engineering” OR “engineer” AND “graduate attributes” OR ”employability skills” OR “generic skills” OR “key skills” OR “core skills” OR “life skills” OR “essential skills” OR “key competencies” OR “graduate qualities” OR “graduate capabilities” OR “generic attributes” OR “soft skills” OR “personal attributes” OR “Employability” OR “professional competencies” OR “workplace skills” OR “work readiness” OR “professional practice” OR “transferable skills” OR “personal skills”.

The selection of databases included; Academic Search Complete, ERIC, British Education Index, Australian Education Index, Science Direct. Furthermore, searches were undertaken to include the publications of the Royal Academy of Engineering, The Institution of Civil Engineers, The Institution of Structural Engineers, the National Academy of Engineering and SEFI conference papers in 2015 and 2016. The initial search yielded 129 papers and this was considered sufficient for this study and therefore, the literature cited by the studies was not investigated further.

2.2 Filtering

Figure 1 provides a representation of the filtering process for the papers in study 1. Initially, each paper was screened to confirm that it related to both engineering and skills in the broadest sense. Twenty-three papers were excluded as the focus was on generic skills not specifically relating to engineering. A further eleven papers were excluded because whilst they did refer to engineering and skills there was no mention of specific skills requirements which was the purpose of this exercise. In total, 97 papers were included within the study, of which 72 papers were journal or research papers and 25 were publications from industry or government/ institutional organisations.

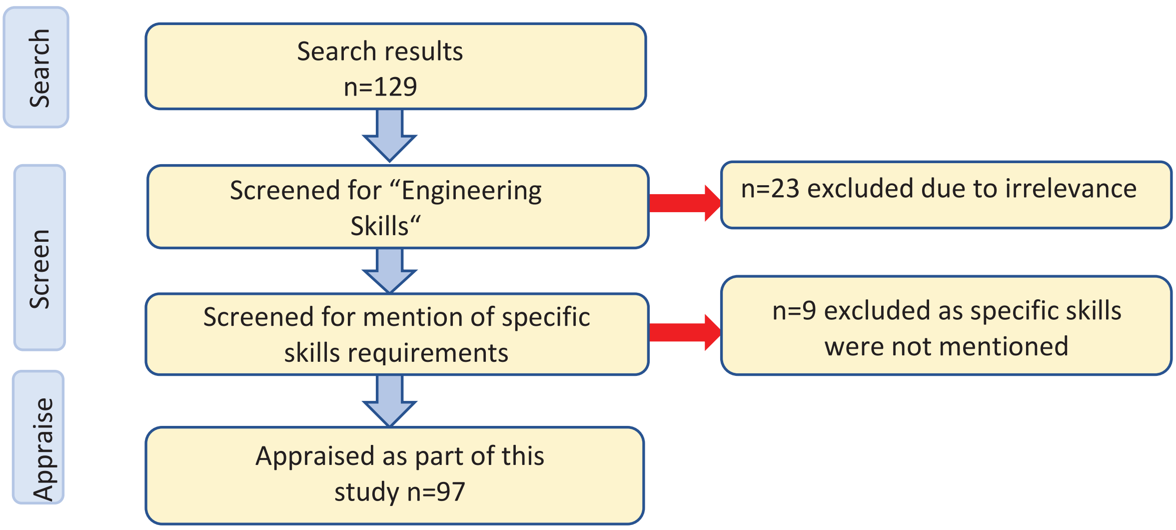

Fig.1. Flowchart of filtering process using in Literature Review 1

3 CODING AND ANALYSIS - LITERATURE REVIEW 1

The purpose of this study was initially to identify those engineering skills which were most discussed in papers produced between 2009 -2016 with a view to creating a list of skills for use in a follow up survey. Whilst the analysis of the data did not seek at this stage to produce qualitative findings, the coding process drew upon the General Inductive Analysis methodology as defined by Thomas [4]. This first phase of analysis 'open coding' resulted in 66 non-hierarchal categories, supported by definitions and inclusion criteria. In this analysis, the themes identified were not grouped into predefined categories, rather through a process of inductive reasoning, salient categories of meaning were derived from the data.

Each paper was analysed methodically and each mention of a specific skill was coded. The context in which a skill was mentioned was not considered. For example, both "However such teaching methods […] do nothing to develop transferable skills such as team working, communication skills or the ability to think 'outside the box'" [5, p.20] and "These students do not value the course's use of presentations in the development of their communication skills" [6, p. 212] were both coded under 'Communication' and the Bourn & Neal [5] citation under "Teamwork " too.

At this initial stage of coding an interpretative analysis was used. For example, both "…suggests that we need to pay greater explicit attention to such personal skills, and more generally to emotional intelligence within our curriculum" [7, p. 41] and a table which included graduate perceptions of their competencies which included "socioemotional" [8, p. 3787] were both coded under 'Emotional Intelligence'. In phase two, each of the 66 the categories were reviewed, refined, distilled, re-labeled and merged which resulted in 17 overall categories describing the skill set, which are displayed in Table 1 later in this paper.

4 METHODOLOGICAL FRAMEWORK – LITERATURE REVIEW 2

Both conference and journal publications were included in this study, while magazine articles and other such literature were omitted due to a lack of a peer review process. The goal was to identify the most commonly mentioned skills with reference to **graduate engineers**. In particular the focus was on the rational approach to the identification of these skills and so literature containing quantitative data was sought out such that only research papers containing ranked lists of skills were considered.

4.1 Inclusion Criteria

The initial search terms used were "engineering skills" AND "engineering competences" anywhere in the text, this proved to be an unmanageable amount of literature and so the search terms were narrowed to "graduate engineering skills" and "graduate engineering competences" searching in the title of the paper. This led to the identification of 138 journal and conference papers between 2000 and 2017.

The year of publication was chosen to start at 2000 due to the introduction of the ABET criteria, it is the authors view that the introduction of ABET has had a significant contribution to the volume of literature published in the area of professional skills since it's inception.

4.2 Filtering

Papers which did not contain quantitative data were excluded, along with papers which did not concern themselves with graduate skills or competences. This led to the appraisal of 4 conference papers and 12 journal papers for this study. The databases included; Wiley, Taylor & Francis and ASEE Peer. The process of searching, screening and appraisal is illustrated in Figure 2.

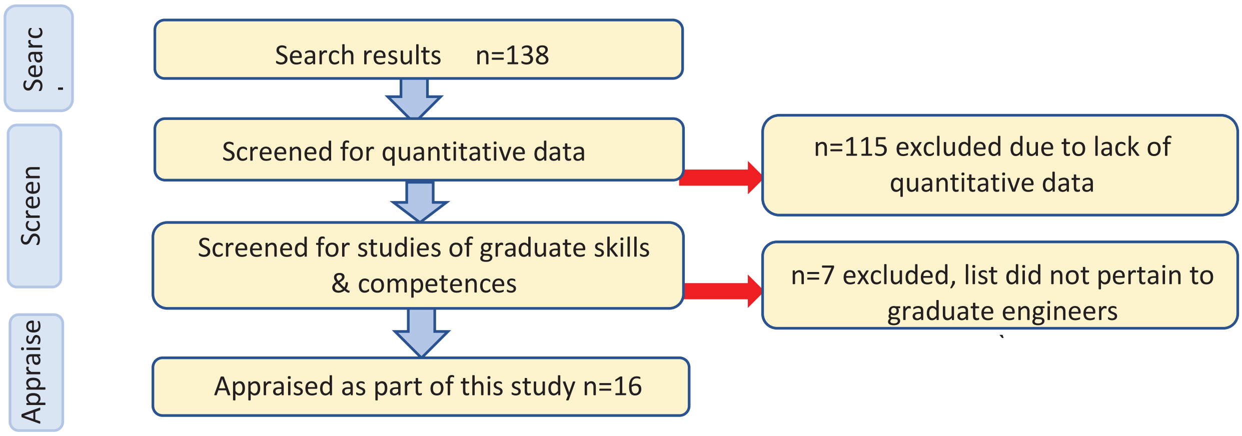

Fig. 2. Flowchart of filtering process using in Literature Review 2

5 CODING AND ANALYSIS - LITERATURE REVIEW 2

Papers containing ordered lists of skills which were either ranked or rated were extracted and aggregated into a final list of skills based on the frequency of use of each term and categorised using the European Skills Competences and Occupations (ESCO) [9] framework as a guideline. There are huge methodological assumptions being made to carry out this analysis, including that when an author refers to *teamwork* in one paper, that *teamwork* means the same thing in subsequent papers and so can be aggregated together. This is difficult to extract, given that in 16 papers, only 11 provide definitions of the skills they are referring to and only 9 made reference to the framework upon which the definitions were created. The other assumption is that these skills are culturally invariant, a more in-depth analysis would attempt to address socio-cultural differences in lists of skills.

6 RESULTS AND DISCUSSION

Both studies aimed to identify the list of skills which were most commonly mentioned in each systematic review. *Table 1* shows the most commonly mentioned skills in each Literature Review according to the frequency that each identified skill was mentioned.

Table 1. High level categories in rank order for the frequency of mentions.

Literature Review 1		**Literature Review 2**	
Skill	**Frequency**	**Skill**	**Frequency**
Character and Interpersonal Skills	433	Communication	29
Teamwork/Groupwork /Collaboration	249	Teamwork & Collaboration	18
Communication	195	Problem solving	18
Technical skills	189	Technical skills	16
Problem solving	130	Business/finance/entrepreneurship	16
Business Acumen	111	Planning & organising	16
Globalisation, Intercultural Skills	93	Ethics and sustainability	12
Self-Directed Learning/Independence	84	Cultural awareness	11
Project Mgmt/Planning/Organisation	67	Lifelong learning	10
Leadership	54	Professionalism	8
Practical application/Real life problem	37	Project management	8

Critical thinking	36	Social and political awareness	8
Research skills	31	Knowledge science, engineering	7
Foreign Language skills	19	Design	7
Risk Management	10	Interpersonal skills	5
General Knowledge	10	Leadership	5
Health and Safety	8		

6.1 Similarities and differences

The purpose of this paper was to compare two independent skills lists. At first glance, it is clear that skills such as Communication, Teamwork, Problem Solving, Technical Skills and Business are all highly cited and since both researchers used independent interpretive techniques, this suggests there is general agreement on these terms.

However, the differences in the two lists present a more interesting finding, and two examples are presented here; Character and Interpersonal Skills and Business Acumen.

6.2 Character and Interpersonal skills

In the first list, this was interpreted as having the highest number of mentions, whereas in Literature Review 2, this skill was located near the bottom, with only 5 mentions. As each researcher interpreted this differently, it led us to a discussion on what we mean as Character and Interpersonal skills. *Table 2* presents the subthemes which were coded within this category for both literature review 1 and 2.

Table 2. Sub themes allocated to the Character and Interpersonal Skills category in rank order for frequency of mentions.

Literature Review 1		**Literature Review 2**	
Character and Interpersonal Skills	**Frequency**	**Interpersonal skills**	**Frequency**
Ethics or Integrity	68	Interpersonal	2
Creativity or Innovation	67	Interpersonal skill	1
Social Responsibility	56	Personability	1
Sustainability or Environmental awareness	44	Personal quality	1
Adaptability/Change Management	32		
Emotional Intelligence	22		
Attitude to work	19		
Self discipline	12		
Self reflection and analysis	12		
Enthusiasm Motivation Curiosity	11		
Professionalism	11		
Decision Making	11		
Grit/Determination/Perseverance/Commitment	6		
Confidence	6		
Taking responsibility/Ownership/Accountability	3		
Self Awareness	3		
Work under pressure	2		
Maturity	2		

Here we can see differences in how each researcher interpreted each skills list. For example, ethics and integrity is included within Character and Interpersonal Skills in review 1, whereas it is pulled out as a separate skill under Review 2 and combined with Sustainability, which is included as another sub theme in Review 1. This raises the question; does each researcher conceptualise "ethics" as the same thing. In Review 1, it is aligned with integrity, suggesting personal ethics, internal to a person, yet in Review 2 aligned with sustainability, it suggests a relationship with the environment and society, the outside world. Professionalism is another example of where one researcher includes it as a sub theme of a larger conception, but another interprets it as a skill within itself.

6.3 Business Acumen

As an alternative example, *Table 3* shows the subthemes associated with Business Acumen and Business, Finance & Entrepreneurship.

Table 3. Sub themes in the Business category in rank order for number of sources.

Literature Review 1		**Literature Review 2**	
Business Acumen	**Frequency**	**Business Finance and Entrepreneurship**	**Frequency**
Entrepreneurship	23	Business & finance skills	5
Finance and Economics	19	Business skills	3
Customer Needs	13	Negotiation	3
Business etiquette	1	Entrepreneurship	2
		Finance	1
		Cost management	1
		Bargaining	1

The results of this analysis show that similar terms are included in both reviews, but in this instance, Literature Review 1 was much more confining in the terms associated with Business Acumen, than Business, Finance and Entrepreneurship in Review 2. Here, Review 1, defining the theme as Business Acumen, does not give justice to the expanse of the terms within the theme itself. It was not obvious that entrepreneurship was included within this category. This highlights the importance of accurate naming each skill taking cognisance of the range of terms within.

Here again, is another example of a difference in conception of a particular term. Negotiation, included here under Business, Finance and Entrepreneurship in Review 2 was also identified as a subtheme in Literature Review 1, but under the theme "Teamwork, Groupwork, Collaboration". Researcher 1 understands negotiation to be about people, changing people's minds, working with people to find a solution, whereas negotiation according to Researcher 2 is a business skill that can be learned.

The purpose here is not to suggest that one is more correct than the other, but to show the varying conceptions that researchers can have when creating lists of skills.

6.4 Conclusion

This paper came about from a discussion between two independent researchers who had undertaken literature reviews on skills listings for different purposes. When comparing these skills listings, it became apparent that both researchers had differing views on the conceptions of certain skills and this led us to write this paper to highlight our findings to other researchers.

This paper aimed to investigate the validity of using lists of skills in questionnaires and surveys. The results show, that whilst there may be some general agreement on some terms, there are also differences in how different researchers interpret those terms. As a result, using lists of skills in surveys adds an additional layer of complexity, as it is not only the researcher writing the list that interprets, but the survey participant too. This leads us to a call for more interpretive rigorous approaches to the use of skills lists in research studies.

We suggest that instead of using predefined lists of skills' terms in quantitative surveys, that each researcher takes the time to review the different conceptions of each term and that a description of the researchers understanding of the term is provided, to reduce the risk of a misunderstanding by any survey participant. The researchers involved in this comparative study have found it invaluable to discuss the different conceptions of some of these terms with someone with a different background and viewpoint and are now left with a more critical outlook on the use of lists of skills in quantitative surveys.

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Innovative monitoring of study time and performance and its efficiency in first-semester Calculus course for engineers

Szabolcs Berezvai[1]
Budapest University of Technology and Economics
Budapest, Hungary

Zsófia Pálya
Budapest University of Technology and Economics
Budapest, Hungary

Áron Hives
EduBase Educational Services LLC
Budapest, Hungary

Dániel Horváth
EduBase Educational Services LLC
Budapest, Hungary

Brigitta Szilágyi
Budapest University of Technology and Economics
Budapest, Hungary

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ABSTRACT

Calculus is the most important undergraduate mathematics course in engineering programmes at Budapest University of Technology and Economics, in which continuous study is essential for deep knowledge acquisition. However, it is common among students to study in a campaign-like way, so that they can succeed in the course without acquiring profound knowledge. The changing learning environment of the 21st century enables us to teach through methods utilising the technical tools of the age and integrating them into the learning process. In 2012, Institute of Mathematics at BME launched a new project aimed at teaching Calculus with an innovative method combining test-effect and online education that provides continuous practice for students with heterogeneous level of knowledge and learning strategy. Our goal was to examine practising behaviour of students during the semester and its effect on the midterm-test results. Using EduBase Online Educational Platform, from September 2018, we continuously monitored the

[1] Corresponding Author
Szabolcs Berezvai
berezvai@mm.bme.hu, ORCID ID: 0000-0002-6399-583X

practising of 115 first-year mechatronics and energy engineering students, their practising performance and time spent on weekly issued tests. The recorded learning patterns show that as the end of the semester approaches and duties increase, students are spending less time on practicing and focusing rather on topics not studied before. Additionally, statistical analysis proved that students who spread their total learning time out for several weeks were significantly more successful than their counterparts studying campaign-like. Moreover, we have established the learning-map for the group and introduced an efficiency function indicating the necessary level of practising to complete Calculus with profound knowledge.

1 INTRODUCTION

Learning means a relatively long-term change in one's behaviour due to experience. The knowledge gained from the basic subjects of engineer programmes must particularly be profound, as the professional subjects of the following semesters will be built on them. However, it is more and more frequently observed that secondary school students deal with a subject only before their knowledge is tested. Although there are several studies about the fact that campaign-learning before tests does not result in long-term knowledge, students often learn few days and nights before tests.

Since the pioneer memory researches of Ebbinghaus, it is well-known that time-shared learning is in long-term more effective than learning a huge amount of material in one block [1]. But the temptation is still there, as short-term learning in one block may result in good marks at the end. Bjork and Allen (1970) pointed out that the efficiency of time-shared learning may be explained by coding variability [1]. This means that during time-shared learning occasions, we process the information in a little different, more variable way. On the other hand, when we learn in one block, there is no such variability. According to Hintzman's theory of inappropriate processing (1974), when we learn in one block, reading the material more than once, after the first reading we do not pay as much attention to it as for the first time, therefore we can process it to less extent. Carpenter made examinations on how the time period between two blocks of learning influences our memory duration [2].

Concerning long-term knowledge, learning by tests or, in other words, learning by recalling is an effective method. Traditionally, testing is used for checking, evaluating the knowledge of students. However, testing can also be a way of learning, even if it is not the input of information but recalling it. Roediger and Karpicke's research (2006) proves that we can gain real, long-term knowledge through testing [3-4].

1.1 Challenges of Calculus at BME

In our research, we examined the learning habits of first-year students of mechatronics and energy engineer students at the Faculty of Mechanical Engineering of the Budapest University of Technology and Economics (BME) during Calculus 1 course. Regular subjects of Mathematics are some of the most important central basic subjects in most curricula in engineering BSc programmes. The educational experience of recent years shows that there is a wide range of mathematical knowledge of new university students. This is a great challenge for university lecturers of Mathematics, as there is not much time for them for a differentiated approach of teaching, for developing skills individually or in small groups. Apart from all of these, there is a change in the teaching and learning environment in the 21st century. All these facts together inspired us to find a new, innovative method. Our group developed a new methodology structure in the summer of 2012 that we put into practice in September 2012. Due to continuous developments, by September 2018 we were able to follow the learning habits of our students 'minute by minute', as all complementary material, all exercises were accessible for students by means of the EduBase online educational platform, which made continuous monitoring possible.

2 TEACHING METHODOLOGY

In the development of our educational system, learning and teaching methodology researches have played a great role, especially the results of researches on the positive effects of continuous testing on long-term learning (mentioned above).

2.1 Continuous retrieval-based methodology

So far, the pedagogical approach to the most effective way of gaining knowledge has been the repetitive way of learning. This means a continuous re-learning, based on the idea that through continuous repetition, information is being restored in our memory more and more deeply and systematically. However, experience shows that storing information this way is only a short-term success. In the long run, we keep forgetting things fast, and as the time goes on, we are able to recall less and less information. Very often learning 'word by word' in a rush is enough only for a test or an exam, right after that one starts to forget the freshly-learned information immediately. This method is not too efficient in the long run. It only checks what we know at the moment of testing, but it is not an effective way of gaining long-term knowledge [5-6].

Concerning all of these, the goals of our method were the following:

- Expanding our topics by practical issues
- Applying a test-based educational system
- Developing a student-centred motivational system
- Catching up and tutoring students
- Introducing online educational forms for regular and skill-developing subjects

An important element of our system is that we try to react to the changes of students' needs and of the external environment by continuous development and by recreating certain elements of the system. Based on our experience of several years we can declare that our system, which is based on frequent testing, which inspires continuous testing and which is completed with practical engineering applications, is well accessible for students. Moreover, it highlights links between different subjects more effectively and is efficient.

2.2 Expected learning time for Calculus 1

By now, it is technically possible to research the efficiency of the method from the student's point of view. Even the best method is inefficient if the student does not use it. The necessary quantity of learning to fulfil the requirements of a subject is important to get the credit for the competition of the course. At BME, the quantity of learning required from students (including lectures and seminars) is 30 hours/credit. In the case of Calculus 1, the required quantity of learning is listed in Table 1.

Table 1. Expected learning time for Calculus 1 course at BME

Activity	**hour/semester**
Participation in lectures	14 × 6 = 84
Preparation for seminars	14 × 2 = 28
Preparation for mid-term tests	2 × 14 = 28
Preparation for end-term exam	40
Total	*180*

This table clearly shows that two hours of preparation a week at home would guarantee continuous learning and gaining deep knowledge, but this quantity of learning is often not fulfilled due to campaign-learning strategy. With the help of our method, the quantity of learning at home is constantly ensured in the EdUbase system by issuing weakly homework tests.

2.3 Online platform – EduBase classroom

The online education was implemented with the unique testing and examination system of the cloud-based EduBase platform (see www.edubase.net) developed by our former tutors. Sine EduBase is device and platform independent, it provides a wide range of usability, customizable teaching and testing interface that covers the entire spectrum of examinations (e.g. home assignment, tests, exams), which can be shared by the instructor in a so-called digital classroom they have created.

In the present study, all the students were assigned to separated digital classrooms based on the tutorial courses. In the classroom, they received every week an online homework test to be submitted by the end of the week (i.e. Sunday 23:59). The competition of the homework tests could be abandoned at any time and can be continued later. Among the tasks, there were parametrized tasks, which were generated uniquely for each student. EduBase automatically evaluated the homework tests right after submission, and the students could view their performance and mistakes. After the deadline, the homework tests was opened again in practice mode, where students could solve the tasks again. Additionally, in this mode, students could see hints and steps of the detailed solution if necessary. According to the feedbacks, this practice mode was a great help for the students.

Thanks to the online tests, the time spent on each task could be precisely monitored both in homework and practice mode. Moreover, it was possible to follow the order of solution or when an answer was changed. Therefore, complete learning habits and performance was recorded for all students during the whole semester.

3 INVESTIGATED GROUP

In our study, we investigated the learning habits of a group of 124 mechatronics and energy engineer students at the Faculty of Mechanical Engineering at BME during the first-year Calculus course in the autumn semester of the academic year 2018/2019. A significant majority (88.7%) of the group was male (see Table 2.), while the proportion of women was only 11.3%, which corresponds to the usual.

Table 1. Participants of the investigated Calculus 1 course

	Men	Women	Total
Mechatronics engineer	72	10	82
Energy engineer	38	4	42
Total	*110*	*14*	*124*

Fig. 1/a shows the entrance point distribution. As in previous years, students have been enrolled with the highest entry points for engineering programmes in Hungary. It can be clearly seen that a large proportion (77 out of 121, 73,7%) of students achieved a score of 450-500 points (out of 500), which presupposes excellent graduation performance. Fig. 1/b and 1/c show the results achieved on the first and second mid-term tests. Calculus 1 also includes several materials which were covered in advanced high school classes of Maths. At the investigated Calculus course 100% of the students attended advanced Maths classes, thus the low rate of unsuccessful performance below 40% is in accordance with our expectations despite the effectivity problems of the Hungarian public education system. This statement is also supported by Figure 1/c, where the number of those who achieve good results is decreasing, although the ratio of topics covered in high-school remained the same. In case of Test 2, the increase of the burdens of students leads to an increase in the proportion of campaign-like learning, resulting in less successful performance.

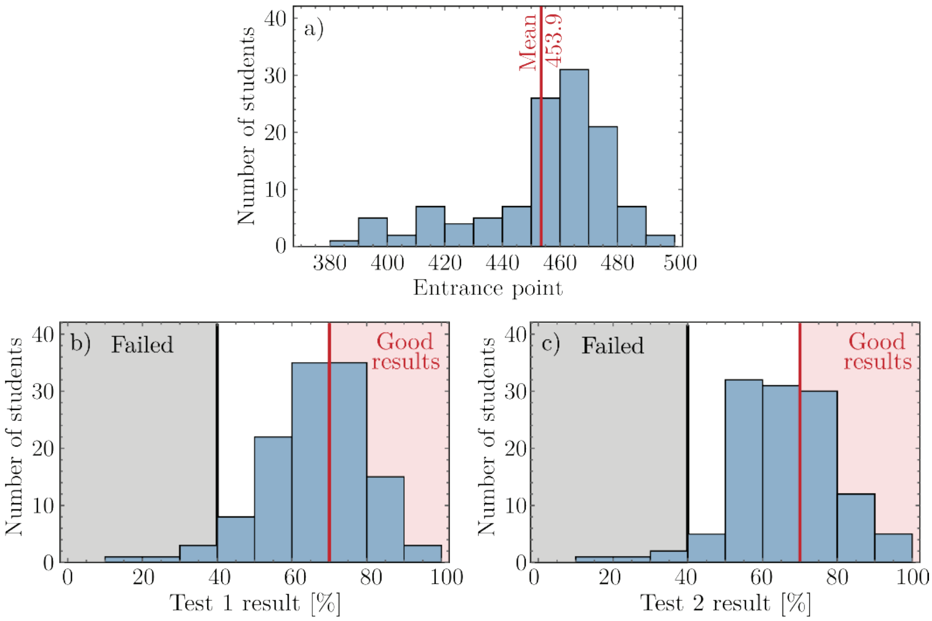

Fig. 1. Distribution of a) entrance points and mid-term test result for b) Test 1 and c) Test 2

4 RESULTS

4.1 Online learning habits

Analysing of the online activity for all students in EduBase, their learning habits could be summarised by the learning map in Fig. 2. The learning maps in Figs. 2/a and 2/b show that students practised mainly on weekends, one day before the homework submission deadline, which can also be explained by busy weekdays. Despite all this, using the online system we have achieved that almost every student had to deal with mathematics at least four times a week (2 lectures, 1 tutorial and the online practise), which supports segmented, retrieval-based learning.

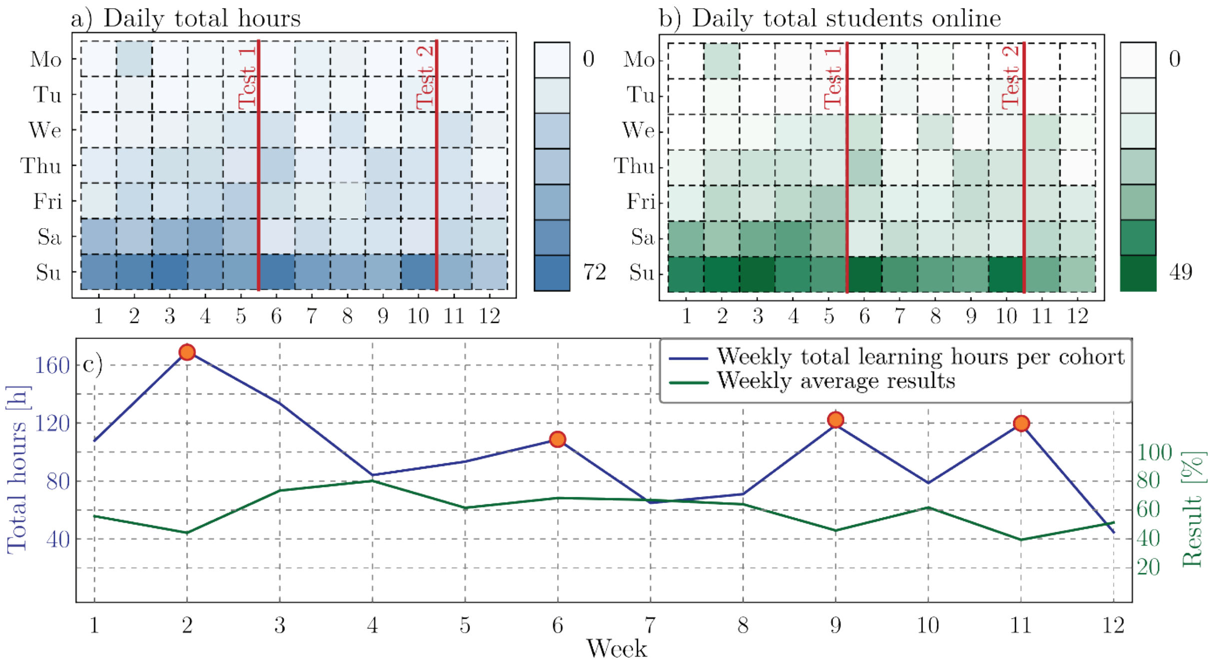

Fig. 2. Summary of online learning activity in EduBase classrooms during the semester

Finally, Fig. 2/c represents the variation of the total online time and the average score on the weekly tests. The orange dots highlight the homework tests on which students spent more time compared to the neighbouring weeks. These periods coincide with topics that does not form the part of the high school curriculum (see the red cell in Table 2.), thus the results are also modest. Considering the relation of the two curves, we can also see that for those parts of the material that have been studied in high-school (see blue cells in Table 2.), less exercise time is required, and better results are obtained. Note, that online activity decreased significantly in weeks 13-14, thus the corresponding data became irrelevant and not presented in Figure 2.

Table 2. Curriculum of Calculus 1 course

Material of Test 1		Material of Test 2		Material after Test 2	
Week 1	Spatial geometry 1.	Week 6	Limit of functions	Week 11	Integral calculus 2.
Week 2	Spatial geometry 2.	Week 7	Differentiation 1.	Week 12	Integral calculus 3.
Week 3	Complex numbers	Week 8	Differentiation 2.	Week 13	Integral calculus 4.
Week 4	Numerical series 1.	Week 9	Differentiation 3.	Week 14	Integral calculus 5.
Week 5	Numerical series 2.	Week 10	Integral calculus 1.		

4.2 Effect of campaign-like learning

In addition to the amount of online time, its distribution is even more significant. To quantify this during the semester, we have introduced the "non-campaign ratio" as $\kappa = 1 - T_{-1}/T$, for both mid-term tests, where T is the total learning time before the test and T_{-1} is the practise time in the last week before the test (the materials of Test 1 and 2 are listed in Table 2.).

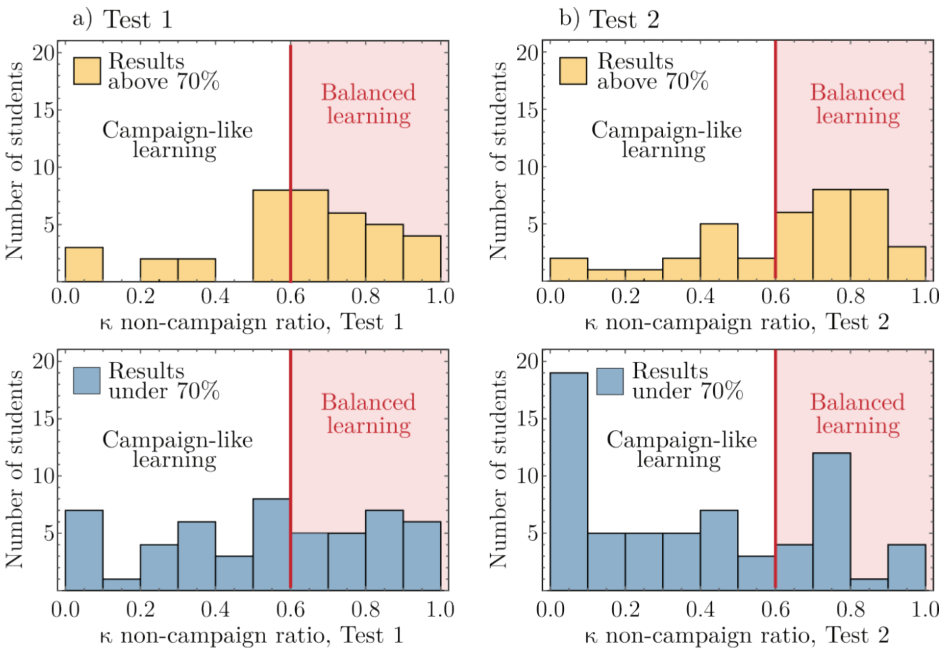

Fig. 3. Mid-term test results of students learning campaign-like and balanced way

The distribution of the non-campaign ratios is presented in Figs. 3/a and 3/b, respectively. In the figures, yellow histogram represents students with test results over 70%, while blue shows students below 70%. The critical value of the non-campaign ratio was set at 0.6 since below that value we considered the learning habit as campaign-like. When the campaign ratio is greater than 0.6, we assume that most of the learning time was spent not in the week before the test. It can be clearly seen that the majority of students with good results did not learn campaign-like. In case of Test 2, the inadequacy of campaign-like learning is particularly striking. Note, that the success threshold has been set at 70%, while according to regulations, each test above 40% is satisfactory for exam participation. Our experiences, however, showed that profound knowledge could be assumed only among students with good or excellent test results, namely above 70%.

In order to state that balanced learning strategy leads to better results, the semester data were investigated using one-way analysis of variance (ANOVA) with significance level of 0.05, where "*SS*" denotes the sum of squares, *"df"* the degree of freedom (one less than the number of elements), *"MS"* the mean square value, while *"F"* is the F-value according to the F-statistics. The analysis results are listed in Table 3, which shows that for both tests, the balanced learning distribution has better results with a significance level of 5%.

Table 3. Results of the ANOVA Analysis

Summary of data for Test 1			
	Campaign learning	**Balanced learning**	**Total**
N	44	76	120
∑X	2672	5025	7697.5
Mean	60.73	66.1184	64.146
∑X²	172656.2	345675	518331
Std. dev	15.5011	13.3815	14.3687

ANOVA Result details for Test 1				
	SS	**df**	**MS**	**F**
Between groups	806.5	1	806.52	4.005
In groups	23762.2	118	201.37	
Total	24568.7	119		

The f-ratio value is 4.00507. The p-value is .047658. The result is significant at p < 0.05.

Summary of data for Test 2			
	Campaign learning	**Balanced learning**	**Total**
N	57	62	119
∑X	3172	4235	7407
Mean	55.64	68.3065	62.244
∑X²	192614	299543	492157
Std. dev	16.9532	12.9723	16.2392

ANOVA Result details for Test 2				
	SS	**df**	**MS**	**F**
Between groups	4757.8	1	4757.77	21.11
In groups	26360.1	117	225.30	
Total	31117.9	118		

The f-ratio value is 21.11745. The p-value is .000011. The result is significant at p < 0.05.

4.3 Learning efficiency

In order to measure the efficiency of online learning, we have introduced the so-called learning effectiveness denoted as η, which can be calculated as $\eta = P_{total} / T_{total}$, where P_{total} is the total score achieved, while T_{total} the total time spent on each test. The learning effectiveness value is high if the student solved the online homework test with good results within a short time. This measure was obtained for each student for each online test, from which the average learning effectiveness was obtained for mid-term Test 1 and 2, respectively.

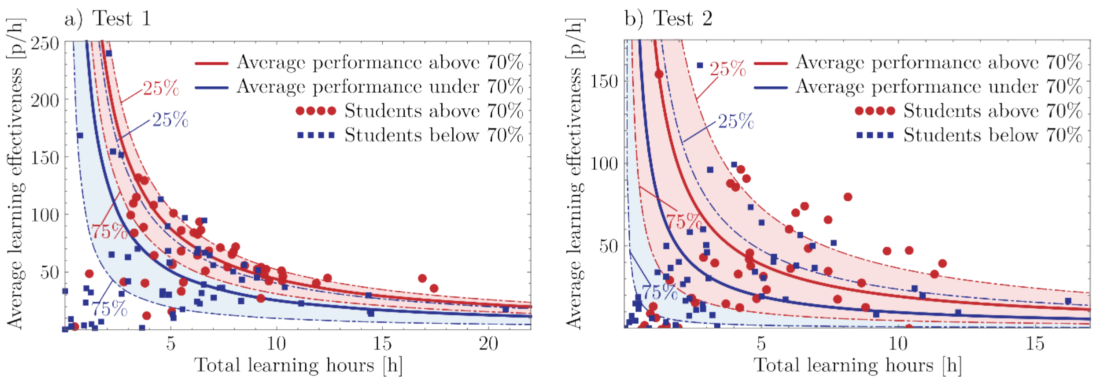

Fig. 4. Learning effectiveness as a function of total learning hours in case of Test 1 and 2.

Fig 4. shows the learning effectiveness as a function of the total learning hours for each student in case of Test 1 and 2. On the vertical axis, the average efficiency is presented. Students with results above 70% are represented with red, while under 70% with blue markers. The thick curves present the average learning performance for each group, while the shaded band around shows the middle quartiles of the students. It can be seen that those with good results show higher average performance. This figure also confirms that in this phase of learning, the high test scores are not the key factor, since same efficiency and performance can be achieved if one has difficulties with the homework test, but practises a lot.

The learning performance can also be represented by the pentagons, which helps to compare the individual performance with the average and pentagons also provide information on the extent of the balance of learning (see Fig. 5) [7]. On the segments connecting the centre point to the vertices of the pentagon, the results of each homework test are measured, from which a pentagon was combined for each student (see grey pentagons). The red and blue pentagons are the average of pentagons corresponding to students with results above and under 70%, respectively. Then, for each pentagon, the area/perimeter ratio (denoted as A/P ratio) was calculated and analysed. The distribution of these ratios is shown by the histograms. The theoretical maximum of this ratio is 0.405, and the more balanced the performance is, the higher the ratio is. It can be seen that the proportion of balanced performances are much higher among successful students. This is tendency is more significant for the period before Test 1, since in the second half of the semester the online activity decreased.

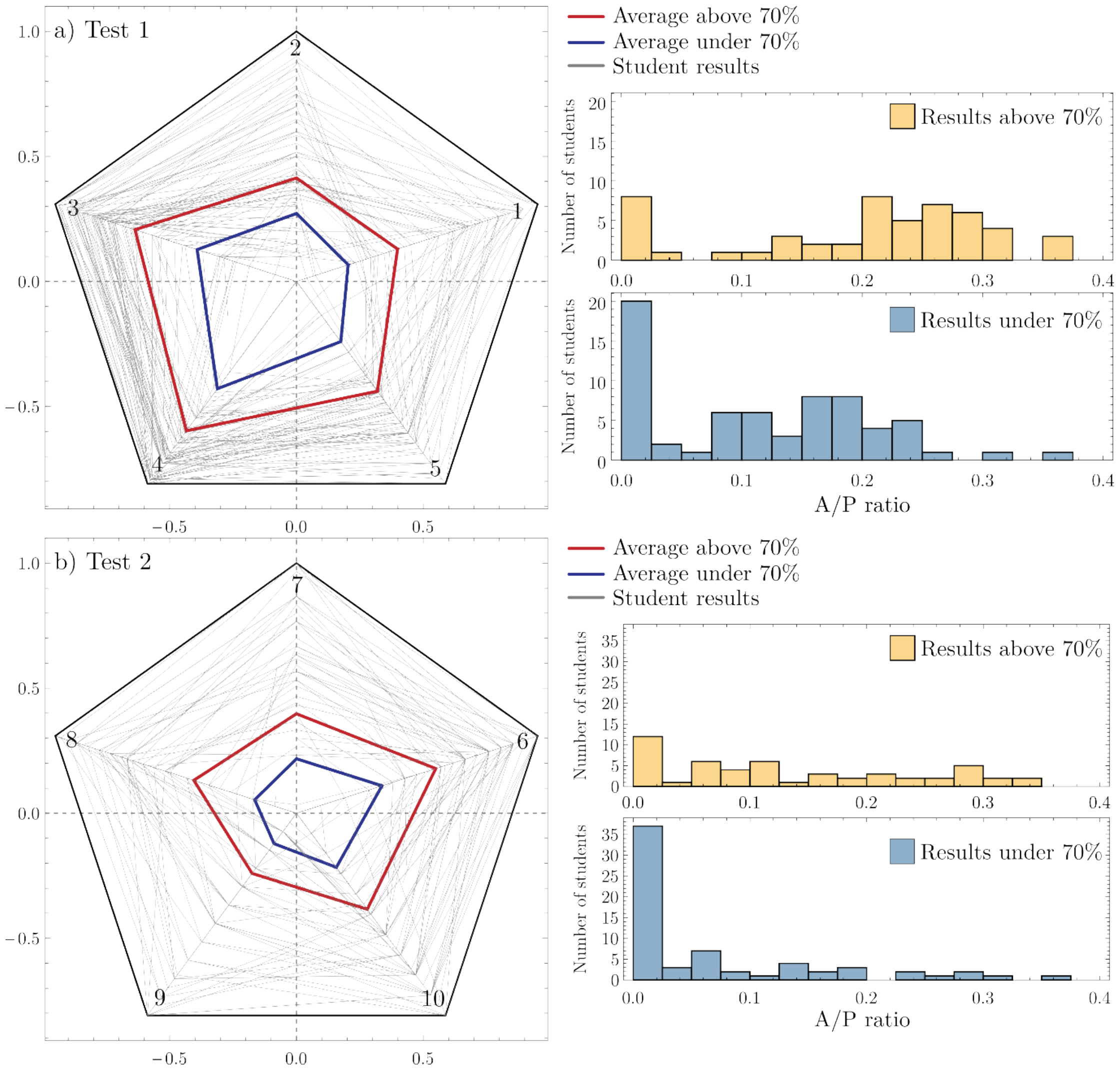

Fig. 5. Analysis of online learning performance using pentagons

5 CONCLUSIONS

In this contribution, we have presented an online teaching method which is capable of shifting the campaign-like learning habits of students towards to shared learning. All of this has been realized in a modern, innovative and student-favoured digital classroom, which requires no further time spent on teaching. It is also evident that even students with the right knowledge need to have the time to acquire the material of Calculus. We continue our research in the spring semester of 2018/2019, where topics that are new to all students is being processed.

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Learning of complex concepts

Engineering students' developing epistemic fluency in an electric circuit theory course

J Bernhard[1]
Linköping University
Norrköping, Sweden
ORCID: 0000-0002-7708-069X

A-K Carstensen
Jönköping University
Jönköping, Sweden

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Keywords: Learning of complex concepts, epistemic fluency, knowledge in action, lab-work.

ABSTRACT

An important aim in engineering education is that students should not only acquire knowledge, but they should be able to use this knowledge in action. I.e. they should develop professional capabilities for knowledgeable action and actionable knowledge.

According to Markauskaite and Goodyear professional knowledgeable action requires a holistic, fluent and co-ordinated use of semiotic and material tools, body and environment. Knowledgeable action requires the development of epistemic fluency that involves the ability to smoothly move between abstract, contextual and situated ways of knowing and the capacity to employ multiple epistemic tools. However, the epistemic complexity of knowledgeable action is often underestimated in engineering education. This epistemic complexity has been addressed by Carstensen and Bernhard who have developed the notion of "learning of complex concepts" (LCC-model) that models how students learn to master epistemic tools by "making links".

In this study we have used the LCC-model as an investigatory tool to analyse video-recordings from electric circuit theory courses. The aim was to gain an increased understanding in how students develop epistemic fluency. We will discuss critical features in the design of labs and in the use of real experiments, computer simulations, modelling and other semiotic and material tools in labs for students' development of epistemic fluency. The results of this study show that labs can be designed to facilitate students' development of epistemic fluency by making links.

[1] J Bernhard, jonte.bernhard@liu.se

1 INTRODUCTION

An important objective in engineering education is that students should *learn* to *use* theories and models. The aim is that students should not only acquire knowledge, they should also be able to use their knowledge and skills in action. Indeed, Mitcham [1] notes that design "constitutes the essence of engineering" since an engineer is "concerned with how things *ought* to be … to *attain* goals and to *function*" [2]. Thus, as pointed out by Skolimowski [3], science and engineering differ in important aspects. Simply put, the aim of science is to produce theories, laws and models that describe some aspects of (idealized) reality. On the other hand the aim of engineering is to design technical artefacts (i.e. products, processes or systems) and arrive at "artefact proposals" [4]. The proposed technical artefacts are human-made physical objects, but they are also intentional objects designed to perform some function in order to achieve some goals [5]. To be able to design, students should develop an understanding of the *relation* between theories and models, and objects and events, and to develop holistic, conceptual knowledge [6]. This is often seen as the fundamental purpose of lab work [7]. During lab-work, students are expected to *use*, or *learn to use*, symbolic and physical tools (such as concepts, theories, models, representations, inscriptions, mathematics, instruments and devices) in order both to understand the phenomena being studied, and to develop the skills and abilities to use the tools themselves [8], i.e. they should develop a holistic, fluent and co-ordinated use of semiotic and material tools, body and environment [9]. This requires development of epistemic fluency [9, 10] that involves the ability to smoothly move between abstract, contextual and situated ways of knowing and the capacity to employ multiple epistemic tools.

All this implies that students during their education should develop professional capabilities for "knowledgeable action" and acquire "actionable knowledge" as pointed out by Markauskaite and Goodyear [9]. It is important to note the two aspects of knowledge. *Actionable knowledge* means that the knowledge students (and engineers) posess should have such qualities that they are able to use it in professional action. On the other hand, *knowledgeable action* stresses that action should be based on knowledge – in a specific action it is not a simple task to understand which knowledge to use and adapt the knowledge to the situation at hand [cf. 11, 12]. A problem, according to Markauskaite and Goodyear [9], is that the "epistemic complexity of knowledgeable action is underestimated" and "higher education sometimes oversimplifies the epistemic qualities of professional tools". This epistemic complexity has been addressed by Carstensen and Bernhard who have developed the notion of "learning of complex concepts" (LCC-model) [13-16] that models how students "make links", and thus learn to master epistemic tools [17].

In this study we have used the LCC-model as an investigatory tool to analyse video-recordings from electric circuit theory courses. The aim was to use the LCC-model to gain an increased understanding in how students develop epistemic fluency.

This paper is organized as follows: Section 2 describes the background and the setting of the study; Section 3 describes the theoretical framework and the qualitative methodology used, i.e. video-recording, epistemic fluency and learning of complex concepts; Section 4 presents the findings of the current study; finally, Section 5 presents a short conclusion.

2 BACKGROUND AND SETTING

2.1 Setting

The empirical data analysed and discussed in this study was obtained in two consecutive years in an electric circuit theory course for electrical engineering students. The particular focus in this paper will be on students' courses of action in the first, original version, of a lab on the topic of transient response and students' courses of action in the re-designed version of the lab the following year. In previous publications the design and re-design of tasks using variation theory [18], the use of design science to develop theory and methodology concurrently with the designing of the lab [16], and the inclusion of simulations in the re-designed lab to achieve synergetic learning effects [19, 20] have been reported. In the present study a special emphasis will instead be on the question of students' development of epistemic fluency through their participation in the two different versions of the transient response lab.

2.2 The Lab: Transient Response

The circuit analysed in this lab is shown in Fig. 1a. Measured graphs for the current i(t) through the circuit are shown in Fig. 1b. The input voltage $u_{in}(t)$ is a 1 V step (practically achieved by a square wave with low frequency). *L* and *C* are kept constant and the value of *R* is varied.

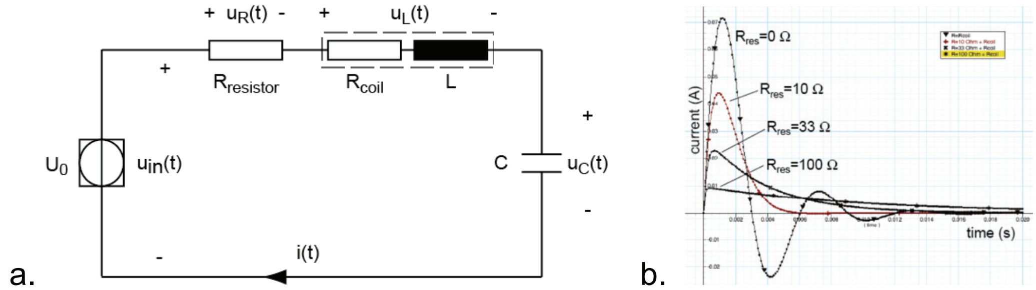

Fig. 1. a.) The electric circuit investigated in the transient response lab. R_{coil} is the internal resistance of the inductor. b.) Measured curves for the current i(t) for different values of $R_{resistor}$ (L=8.2 mH and C=100 μF) when the input voltage is a unit step.

The circuit in Fig. 1a is a second order system and if the current i(t) is taken as the output signal and the voltage $u_{in}(t)$ as the input signal the transfer function will be

$$G(s) = \frac{1}{L} \cdot \frac{s}{s^2 + \frac{R}{L}s + \frac{1}{LC}} \qquad (1)$$

The step response of the current through the circuit $(t > 0)$ takes the form $i(t) = a \cdot e^{-bt} \cdot \sin(c \cdot t)$ or $i(t) = a \cdot (e^{-bt} - e^{-ct})$, depending on whether the roots of the characteristic polynomial of eq. (1) $s^2 + s \cdot R_{tot}/L + 1/(LC)$ are complex conjugated or real. Thus, if *L* and *C* are constant, the form depends on the relative values of R_{tot} and $2\sqrt{L/C}$.[2]

One of the explicit tasks posed in this lab was for the students to make a curve fit to the measured graphs (See Fig. 2a.) of the current through the circuit for various values

[2] A third form is also possible: $i(t) = a \cdot te^{-bt}$ (critical damping). However, this occurs only if R_{tot} is exactly equal to $2\sqrt{L/C}$, which is very unlikely in practice.

of *R*. This basically comes down to find an appropriate mathematical expression to cause a calculated graph to give the same curve as the measured graph, and to show both in the same figure. It was possible to do this in the same computer program – *Data Studio*® – that was used to control the computer interface that generated the input voltage to the circuit and measured the current through the circuit and the output voltage.

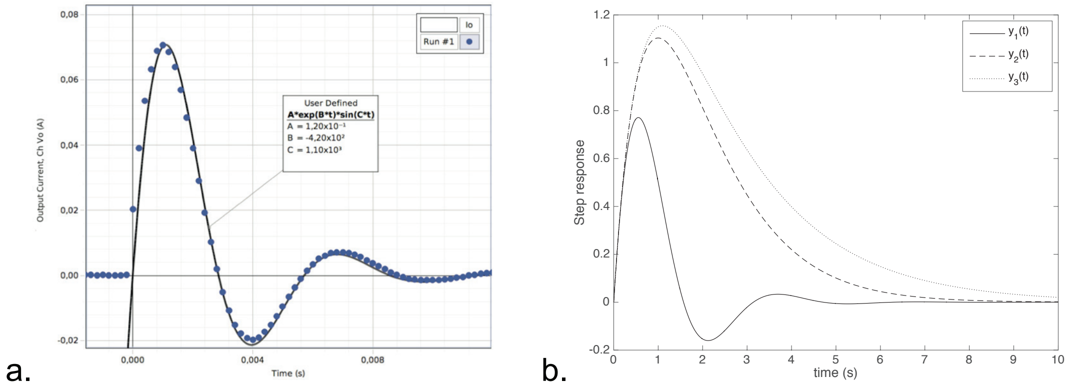

Fig. 2. a.) Fitting of a calculated graph (solid line) to a measured graph. The function used can be seen in the rectangle "User Defined" in the centre of the figure (In this case $i(t)=0.12e^{-420t}\sin[1100t]$ A) b.) Curves from Simulink-simulation for three different transfer functions (see Table 2 below).

From the curve fit students were expected to be able to determine the experimental values of R_{tot}, *L* and *C* for the circuit.

Table 1. Expected values for the roots of the characteristic polynomial of eq. (1) and corresponding expected values of i(t) for varying values of R_{res}, with *L*, *C*, and the step voltage constant. The resistance of the coil is assumed to be 6 Ω. Note that the frequency, ω_d, of the damped system changes with *R* and is not equal to ω_n.

R_{res} (Ω)	R_{tot} (Ω)	L (mH)	C (μF)	Roots of $s^2+\frac{R_{tot}}{L}s+\frac{1}{LC}$		$i(t)$ (A) (t > 0) (A)
0	6	8.2	100	$-366+1042j$	$-366-1042j$	$0.1170e^{-366t}\sin(1042t)$
10	16	8.2	100	$-976+517j$	$-976-517j$	$0.2357e^{-976t}\sin(517t)$
33	39	8.2	100	-272	-4484	$0.0290(e^{-272t}-e^{-4484t})$
100	106	8.2	100	-95	-12832	$0.0096(e^{-95t}-e^{-12832t})$

In a revised version of the lab simulations using Simulink® were used. In line with Variation theory [21, 22] the transfer functions were systematically varied. For example, three forms for the denominator were used

$$G(s)=\frac{N(s)}{s^2+2s+5} \tag{2}$$

$$G(s)=\frac{N(s)}{s^2+2s+1} \tag{3}$$

$$G(s)=\frac{N(s)}{s^2+2s+0.75} \tag{4}$$

with complex-conjugated roots [eq. (2)], a double root [eq. (3)], and two real roots [eq. (4)] respectively. As numerator 5, 3s and 3s + 5 were used. The step responses for some of the transfer functions are shown in Table 2 and in Fig. 2b. Note that the denominators in this case have rather simple roots easy to calculate by hand.

Table 2. Some transfer functions used in the Simulink simulations and the corresponding step responses (See Fig. 2b for graphs).

Transfer function	Roots of the denominator	Step response ($t > 0$)
$G_1 = \dfrac{3s}{s^2 + 2s + 5}$	$-1 \pm 2j$	$y_1(t) = \frac{3}{2} \cdot e^{-t} \cdot \sin(2t)$
$G_2 = \dfrac{3s}{s^2 + 2s + 1}$	$-1, -1$	$y_2(t) = 3t \cdot e^{-t}$
$G_3 = \dfrac{3s}{s^2 + 2s + 0.75}$	$-\frac{1}{2}, -\frac{3}{2}$	$y_3(t) = 3 \cdot (e^{-\frac{1}{2}t} - e^{-\frac{3}{2}t})$

3 THEORY AND METHOD

3.1 Data Collection

Video have been used to record and study students' courses of actions [23] during the two versions of the transient response labs (See section 2.2). I.e. we have analyzed what the students did do, what resources they used, what they made relevant, and how they oriented themselves towards the object of learning. Each lab-group (comprising 2-3 students) was recorded using a digital camcorder, obtaining a total of 80 h of video from the original and the re-designed versions of the transient response lab. The data was subsequently used to detect typical interaction patterns using the LCC-model (See section 3.3) and to study the development of epistemic fluency (See section 3.2).

3.2 Epistemic Fluency

A fundamental aspect of investigating how students learn and how they use knowledge in action is to study their deliberate use of epistemic tools in activities. An epistemic tool is a conceptual, symbolic or physical tool purposefully used as a "tool of knowing" [24]. Consequently, Markauskaite and Goodyear [9] have argued that one aspect of learning is "learning through mastering epistemic tools".

As already mentioned above a problem is that the "epistemic complexity of knowledgeable action is underestimated" and "higher education sometimes oversimplifies the epistemic qualities of professional tools". Rather, according to Markauskaite and Goodyear [9], professional knowledgeable action requires "fluent use of semiotic and material tools, body and environment". This requires, they argue, the weaving together, blending and co-ordination of conceptual, physical, epistemological and symbolic resources to establish an epistemic space. Thus, the concept of *epistemic fluency* [9, 10] is seen as involving "both an *ability to move smoothly* between the abstract, contextual and situated ways of knowing and a *capacity to employ multiple ways of knowing* provided by the senses, environment and imagination to construct actionable understanding" [9].

3.3 Learning of Complex Concepts Model (LCC-model)

The capacity to employ multiple ways of knowing has previously been investigated by Carstensen and Bernhard in the context of labs in electrical engineering [18]. From analysis of video recordings of students' courses of actions [23] they constructed what they called the "learning of complex concepts" (LCC-model) [13-16]. In this model identified epistemic objects are illustrated by circles and the links between these epistemic objects the studied lab-group were able to make during the lab are illustrated by arrows. Figures 3a, 3b, 4a and 4b below are made using the LCC-model analyzing students' courses of actions in the two versions of the transient response lab described above. The shaded circles in the figure represent epistemic objects located in the "world" of objects/events and the other circles the "world" of theories/models according to a categorization proposed by Tiberghien [25]. In the LCC-model learning can be seen as the making of these links by students. An implication is that learning, knowledge and understanding is not seen as an either/or thing. Rather, learning is seen as becoming "richer" the more links that are established and kept in focal awareness simultaneously.

4 RESULTS

4.1 First version of the transient response lab

As mentioned above, in section 2.2, one of the tasks in the lab was to make a curve fit to the experimental curves for $i(t)$ (see Fig. 1b and 2a) for varied values of R_{res} and from the curve fit determine the values for R, L, and C in the circuit. The fitting turned out to be a very difficult task for most students as it requires that the students identify what type of function the different curves in Fig. 1b correspond to. However, although the students in practice only had two functions to choose from they used all types of functions as an onset. Analysis of the videotapes revealed that students, the first year, during the lab mostly worked with one concept/entity (see Fig. 3a) at a time. Students avoided, or postponed, to do the necessary mathematics, i.e. mathematics was to a limited extent used as an epistemic tool. A more detailed analysis revealed that, when making curve fits, students only focused separately – one at the time – on the measured graphs, the calculated graph from the curve fit, and the function used to make the curve fit (See Fig. 3b). No links were made to the transfer function.

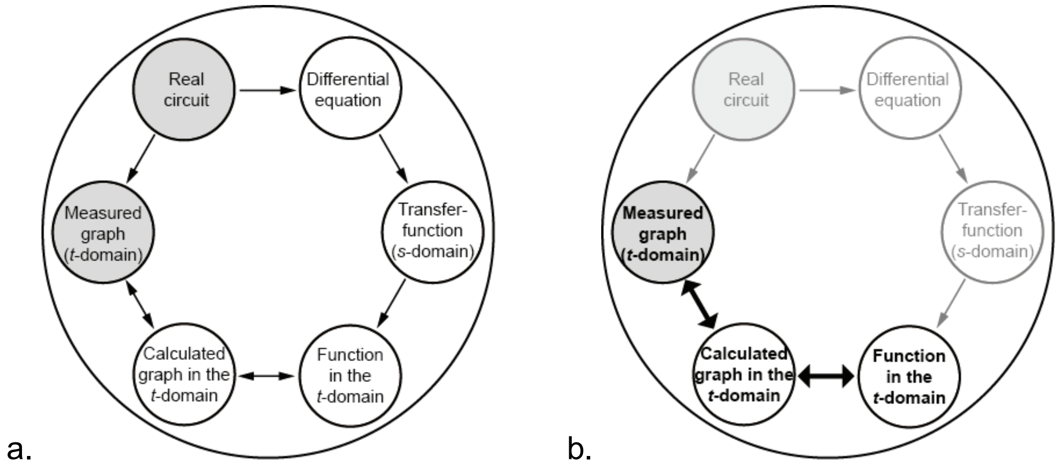

Fig. 3. a) Links made by the students in the first version of the transient lab. *b)* Students' focus when making curve fits using *mathematical functions* to model the response in the time-domain in the first version of the lab.

In the first version of the transient lab the task structure also followed the circular path displayed in Fig. 3a. Consequently, students' learning trajectories followed this pathway. As is discussed earlier students had difficulties to mathematically model the step response in an appropriate way and to draw conclusions from their model. Although the *intended* object of learning was that they should be able to make a link between the measured and calculated graphs this was not apparent in the task structure. Actually, as can be seen in Fig. 3a it was only possible for students to make links between the object/event and the theory/model world at two places.

4.2 Revised version of the transient response lab

Classroom observations and the video-recordings revealed that the students participating in the revised version of the lab, used the following year, worked in a rather different way as is indicated in Fig. 4a. The Simulink simulations enabled students to see where they were heading with the mathematics as the simulation outputs had similar forms as the experimental curves.

Our analysis is that the inclusion of simulations enabled the students to establish a triangular route between the *measured graph*, the *calculated graph*, and the *transfer function* and another triangular route between the *calculated graph*, the *function in the time-domain*, and the *transfer function* as is shown in Fig 4b. As a result the students were not afraid of the mathematics and started to calculate from the beginning. The discussions were centred on the underlying content of the lab. During the lab students noticed the relationships between different experimental graphs instead of looking only at one curve at a time. Throughout the lab they made links between the epistemic objects and at the end of the lab all the observed students had made the links displayed in Fig. 4a.

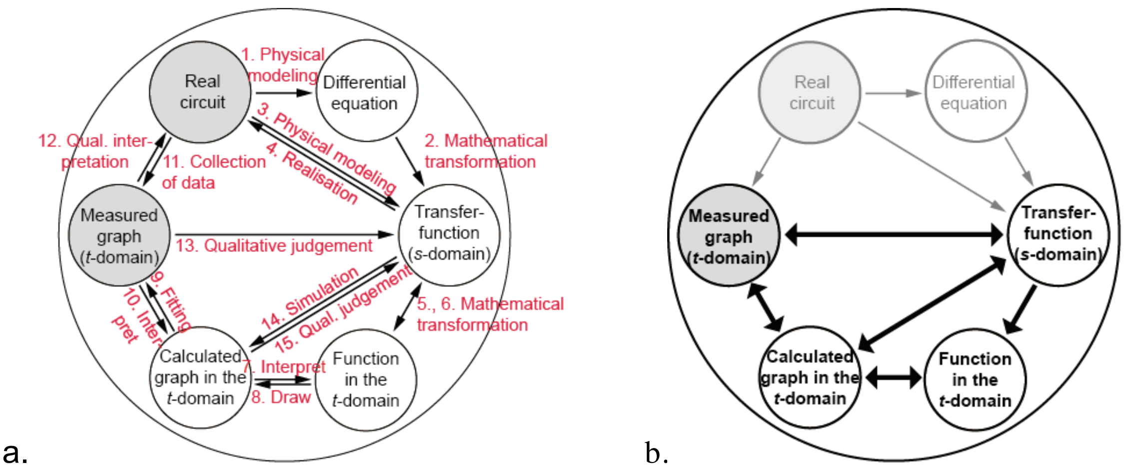

Fig. 4. a) Links made by the students during the revised lab. The numbers assigned to links refer to their entry in Table 3, and do not indicate any order in their establishment. *b)* Triangular routes enabled by the inclusion of simulations in the revised version of the lab.

To illustrate the complexity of the epistemic actions performed by the students in the revised lab the links displayed in Fig 4a have been labelled and assigned a number (This number is for representative purposes only and do not indicate any order in making of links. Indeed, the order in which links were established were different for different students.). In Table 3 a short description of what students typically do to establish the links in Fig 4a is presented.

Table 3. Short descriptions of the different epistemic actions students had to perform during the revised transient response lab to make each of the links displayed in Fig. 4a.

Link			Label	Short description of students' epistemic actions to make the link.
No.	From	To		
1	Real circuit	Differential equation	Physical modelling	Model the current through circuit using differential equations.
2	Differential equation	Transfer function (s-domain)	Mathematical transformation	Apply Laplace transforms to the differential equation.
3	Real circuit	Transfer function (s-domain)	Physical modelling	Model the circuit directly using Laplace transforms to obtain the transfer function in the *s*-domain (frequency domain).
4	Transfer function (s-domain)	Real circuit	Realisation	Use the transfer function obtained through fitting to the measured graph to calculate corresponding values for R, L and C.
5	Transfer function (s-domain)	Function in the time-domain	Mathematical transformation	Inverse transform the transfer function to obtain (possible) function in the time-domain.
6	Function in the time-domain	Transfer function (s-domain)	Mathematical transformation	Laplace transform the function in the time-domain to obtain the transfer function.
7	Calculated graph in the time-domain	Function in the time-domain	Interpret	Interpretation and judgement how the parameters of the function in the time-domain should be adjusted to fit to the measured graph.
8	Function in the time-domain	Calculated graph in the time-domain	Draw	Draw a graph of the time- domain function.
9	Calculated graph in the time-domain	Measured graph in the time-domain	Fitting	Fit the calculated graph to the measured graph.
10	Measured graph in the time-domain	Calculated graph in the time-domain	Interpret	Interpretation and judgement how the calculated graph should be adjusted to fit to the measured graph. Is the fit "good enough".
11	Real circuit	Measured graph in the time-domain	Collection of data	Connect sensors and measurement equipment to the circuit. Setup and run data collection.
12	Measured graph in the time-domain	Real circuit	Qualitative interpretation	Adjust setup of data collection to obtain as good data as possible.
13	Measured graph in the time-domain	Transfer function (s-domain)	Qualitative judgement	Judge and interpret the measured graph in relation to the transfer function
14	Transfer function (s-domain)	Calculated graph in the time-domain	Simulation	Use Simulink to directly obtain calculated graphs from transfer functions
15	Calculated graph in the time-domain	Transfer function (s-domain)	Qualitative judgement	Judge and interpret the calculated graph in relation to the transfer function

In this short paper it is not possible to give a full description of all the epistemic actions students had to do to make all the links presented in Fig. 4a and Table 3. Nevertheless, the empirical results summarized and presented in Fig. 4a and Table 3 clearly display the complexity of the actions students are supposed to perform to make links and to be seen as understanding transient response in an electric circuit.

5 DISCUSSION AND CONCLUSION

The results reveal that during the first version of the transient response lab students develop a quite limited epistemic fluency revealed through the few links students made as is shown in figure 3a.

On the other hand the results from the revised lab as presented in Fig. 4a and Table 3, indeed, reveal the truth in Markauskaite and Goodyear [9], statement about the "epistemic complexity of knowledgeable action". The analysis made, using the LCC-model, clearly presents the complexity of learning. It is also clear that the students have some mastery in the fluent use of epistemic tools. However, it is important to note that this epistemic fluency does not come by itself. It was a result of a deliberate re-design of the lab (See the triangular routes in Fig. 4b) with an intention to facilitate the integrated use of different epistemic tools, especially regarding making links transcending the object/event and theory/model worlds.

We argue that fluent use of epistemic tools involving the "fluent use of semiotic and material tools, body and environment" [9] is important for professional knowledgeable action in all branches of engineering. In another study [26] we have demonstrated how architectural engineering students are using practical epistemic cognition in a design project and that they had developed epistemic fluency. The students in that study used a wealth of bodily material resources as epistemic tools, in an integrated and seamless way, as part of their interactions to design an energy optimized building.

Finally, this study reveals the similarities between the idea of mastering of epistemic tools by "making links" proposed by Carstensen and Bernhard [17] and the notion of "epistemic fluency" by Markauskaite and Goodyear [9]. We propose that these similarities should further be investigated as we see a potential for mutual cross-fertilization between theories.

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A COMPARATIVE CURRICULUM ANALYSIS OF TWO PBL ENGINEERING PROGRAMS

A. M. Boelt[1]
Ph.D. fellow
Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Aalborg University
Aalborg, Denmark
Email: boelt@plan.aau.dk

L. B. Bertel
Postdoc
Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Aalborg University
Aalborg, Denmark
Email: lykke@plan.aau.dk

A. Kolmos
Professor
Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Aalborg University
Aalborg, Denmark
Email: kolmos@plan.aau.dk

N.R. Clausen
Ph.D. fellow
Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Aalborg University
Aalborg, Denmark
Email: nclausen@plan.aau.dk

ABSTRACT

This paper presents preliminary findings from an ongoing cross-faculty research project on the future of problem-based learning at Aalborg University. The research project consists of a baseline study and a number of sub-projects, this particular case being part of the former, where a curriculum analysis is conducted to infer how PBL competencies are framed in formal curricula on 13 different educations. This paper includes two of these curricula in more detail.

PBL is hailed as an innovative approach to learning with a focus on authentic problems and student-directed learning. The formal structure has, from its conception been regarded as highly adaptable, enabling institutional and societal ambitions to be aligned. Students working

[1] Corresponding author

with a PBL curriculum are expected to develop a variety of competencies, both specific disciplinary and vocational, but also competencies directly related to the actual pedagogical approach. These competencies are internally dubbed 'PBL competencies', and as part of a new institutional strategy, these are to be included in formal curricula explicitly stating the progressive development throughout the educational cycle. This paper provides a comparative analysis of current institutional framing of PBL competencies in two formal curricula from two bachelor programmes of engineering education at AAU (Nanotechnology, and Biomedical Engineering and Informatics). Conducting a theoretically directed content analysis, each curriculum is analyzed for categories and themes related to the aforementioned PBL competencies. The research results will give insights into how the progression of these PBL competencies are described in the formal curricula. Preliminary results point to a diverse inclusion of PBL competencies within the selected formal curricula with little evidence of explicit formulations regarding the progression of these competencies, especially on later semesters.

INTRODUCTION

This paper presents initial findings, a methodological approach and a theoretical framework for conducting a directed content analysis of problem-based learning (PBL) curricula exemplified in two cases of engineering bachelor programs, Nanotechnology and Biomedical Engineering and Informatics. The research is part of an ongoing multi-faculty research project PBL Future at Aalborg University called PBL Future, encompassing a baseline study, of which the curriculum analysis is a part of, and a number of sub-projects. This analysis is part of the baseline study and research how PBL learning outcomes are described in selected formal curricula on bachelor and master programs.

Formal curricula is an interesting point of departure when researching educational programs and can be understood as cultural artefacts socially constructed by numerous actors with different agendas [1-2]. These networks of action are situated in specific systems of reality from which the document get meaning. Traversing the boundaries of national educational spheres, international processes such as the Bologna Process has influenced the development and structure of the formal curricula to meet a set of standardized descriptors categorized as knowledge, skills, and competences enabling comparisons of educational programs across Europe [3]. One argument for this transition to learning goals is to reform and modernize 'Europe's antiquated education system' by moving from teacher-centered teaching to student-centered learning, and recognizing 'the use of learning outcomes as the only logical approach' [4]. However, at Aalborg University a student-centered pedagogical approach to learning has been practiced since 1974, so in what ways are the university in need of modernization? The principles of the approach remain alive and well, but there is an institutional desire to review the principles to keep them relevant in the future to meet requests of industry 4.0 or develop the much-anticipated competences of the 21st century.

Interestingly, Voogt and Roblin [5] notes in their comparative analysis of frameworks describing 21st century competences, that two of the frameworks highlight PBL as a pedagogical technique supporting the acquisition of these competences, but some students still struggle to conceptualize and vocalize generic competences developed in a PBL environment.

Our and colleges' experience as project supervisors shows that students use the learning outcomes stated in formal curriculum as a checklist for potential assessment when they are about to finalize projects. An unfortunate result might be learning directed to the test, which although participant-directed can put unconscious limitations on the work students pursue. From a strategic point of view however, descriptions of more generic learning outcomes in the formal curricula may prove a viable path to initiate students into the mystery of non-disciplinary competences. Researching formal curricula provides insights into how these are framed and described from an institutional perspective, and while the analysis naturally cannot illuminate us as to how the curricula are enacted, it can show us how and if the competences are present at all, and if so, how the development progresses over semesters.

In the following, we will briefly present the core tenets of the Aalborg Problem-based Learning model, the theoretical framework used to conduct the content analysis of the collected data, and the analytical constructs used to direct the analysis. Finally, we will present the initial findings of the research and discuss how these learning outcomes can be included in the formal curricula.

1 THE AAU MODEL OF PROBLEM-BASED LEARNING

Inspired by youth revolts and critical pedagogy in Europe, problem-based learning has been a central component of studying at Aalborg University since its inception in the 70's. Centered around authentic problems, students engage in problem-based and project-organized learning activities with high levels of autonomy and student-directed learning facilitated by supervisors and teachers [6-8]. The AAU model of problem-based learning is characterized by three core and interwoven clusters of learning principles [6]:

- **The learning approach**: An approach involving identification, analysis and solutions of authentic, practical or theoretical problems defined by students. Problems can vary in structure and complexity influencing the organization of learning activities, ranging from predefined cases to complex situated problems.
- **The social approach** to learning supports the learning approach, where learning is considered a collaborative social activity unfolding in interaction with peers, sharing and constructing knowledge together. Learning becomes an act of negotiation, the group setting the direction for their problem-solving.
- **The contents approach** is the last core principle, and covers selection of knowledge and skills. Working in a PBL environment is inherently interdisciplinary with learning spanning across multiple subject domains requiring the students to use a variety of sources and methods from different disciplines. Further, the learning is framed as a research process relating theory and practice enhancing students' understanding of the two when analysing and solving a particular problem.

According to Guerra [9] the presented learning principles, PBL fosters an environment in which students develop competences such as problem-solving skills, decision-making, self-directed learning, critical thinking, communication and teamwork. During the course of a project, students need to be mindful of project management, groupwork and collaboration, consequently developing learning strategies and gaining a diverse set of process competences while being socialized into a professional field and identity [7].

2 THEORETICAL FRAMEWORK

In this section we will present the theoretical framework directing the analysis and discuss epistemological considerations of conducting a content analysis of the formal curricula, also known as the intended curricula.

2.1 Curriculum Making

Curriculum making exists on multiple levels; institutional, programmatic and classroom. The institutional level consists of a nexus of culture and society, whereas the curriculum on a programmatic level consist of syllabus and subject construction, descriptions and structures of school, programs and approaches to teaching, and last but not least stating criteria for successful graduation. The final level is the enacted or mediated curriculum unfolding in a classroom [10-11]. This analysis is thus limited in scope because of its singular focus on the programmatic level. However, it contributes valuable insights into and important understandings of the construction and framing of the structures within which the curriculum is enacted and experienced.

2.2 A Directed Content Analysis

The content analysis is informed by Krippendorff's methodological approach [12], and can be characterized as a directed content analysis with code schemas established by theory or concepts before the first reading. Krippendorff argues that a content analysis must be transparent in its approach, suggesting to applicate five basic elements providing a transparent framework:

1. **Body of text:** Formal curricula
2. **Research question or hypothesis:** How are PBL competences presented in the formal curricula
3. **Context in which the text has significance:** An integrated problem-based and project-organized curriculum
4. **Analytical constructs to process text:** Descriptions of PBL competences
5. **Inferences intended to answer a research question**

Since meaning is brought to texts by an interpreter, there is no single meaning to derive from text and the same text can be subjected to multiple and different analyses depending on context. Thus, there is a link between the text and outside phenomena, i.e. meaning exist as something outside the actual text and according to Krippendorff the 'analysist must look outside the physicality of the texts' to fully grasp its meaning [14].

2.3 Cases and Body of Text

The cases in this analysis are two educational programs; BSc in Engineering (Biomedical Engineering and Informatics) and BSc in Engineering (Nanotechnology with specialization on Physics) or (Nanotechnology with specialization in Biotechnology), hereafter BIO and NANO.[2] Both are three-year programs with a workload of 180 ECTS. As expected the courses and subjects depend on profession, but both programs have a course introducing students to problem-based learning on the first semester, presenting methodology and underlying premises of the approach, but also topics related to project management, collective learning approaches and more. The result of this becomes evident when presenting the initial findings.

[2] These are official titles from formal curricula.

The data used in the analysis are two formal curricula. Both are organized according to the Dublin Descriptors describing expected learning outcomes in categories of either knowledge, skills or competences [3]. The selected curricula each refer to a number of official governmental papers and internal regulations, the anticipated overall competences profile of the finished bachelor students, overall description of courses, pedagogical framings and assessment among other things. Since curricula are as different as the social actors and institutional bodies who produce them, a decision has been made to limit the scope to course descriptions. The formal curricula were read, selecting matching criteria of the mentioned PBL competences and coded in NVivo. The units of analysis are learning outcomes defined either as knowledge, skills or competences.

Though PBL is contextual and exemplary in practice, formulated learning outcomes relating what could be considered as prior developed PBL competences to a specific professional domain has been excluded in the analysis. This is due to the fact that students have difficulties transferring knowledge between fields [13], and any inclusion of domain specific competences in the guise of PBL competences would in this context require students to have transferable competences unbeknownst to the analyst.

2.4 Progressive PBL learning goals

Based on the learning principles/approaches presented earlier, a research group at Aalborg University has deduced four distinct competences developed by students' doing PBL. The PBL competences can be divided into four categories:

- **Problem-oriented competences** gained by engaging in authentic and complex problems through exemplary practice, activating prior knowledge to construct new knowledge in a context that requires this skill [14].
- **Interpersonal competences** developed by collaborating and negotiating with peers during participant directed projects.
- **Structural competences** related to project management or to paraphrase Anderson in Jonassen [15]; competences to externalize the sequence of cognitive operations.
- **Metacognitive competences** reaching across all of the above, characterized by the relation between the individual student and their learning processes.

These competences can only be developed in a reflective practice connecting theory and practice. Disbanding this dialectic results in mere trial-error processes and is not considered reflective practitioners engaging in double looped learning cycles. The dialectic relation means that students' learning experiences are directly related to their PBL practice and the collective and individual reflection of these experiences [14]. It also means that knowledge and skills stated as learning goals are complimentary to the development of PBL competences, and hence included in the content analysis.

Progressive PBL learning goals are then related to the development of generic PBL competences over the course of the whole education, and making this progressive development explicit to students in terms of expected learning outcomes.

3 RESULTS AND DISCUSSION

The initial result of the analysis paints a similar picture of the two curricula: The majority of learning outcomes related to the development generic PBL competences are placed on the first semester with little evidence of progression in the course of the educational programs. In the following we will elaborate more on the results by looking at each year including examples of learning outcomes.

It important to note that learning outcomes are not quantified meaning that one goal can contain a number of sub-goals. The weighting of the coding is done in such a manner that the selected weight of each text string is relative to the rest of the text corpus from which it originates. An interesting side note, and a sting maybe is that many formulations are lifted almost word to word from the national qualification framework without any further relation to the actual context or course, problematizing our own unending quest and obligations to prevent plagiarism.

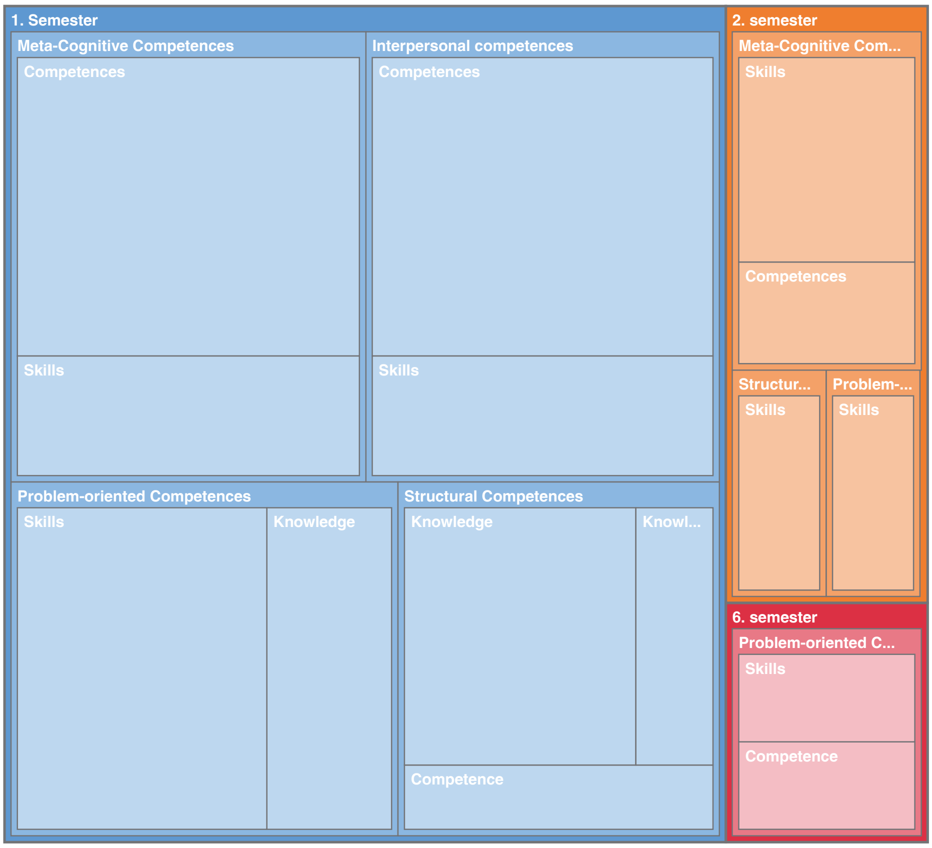

Fig. 1. Treemap of NANO

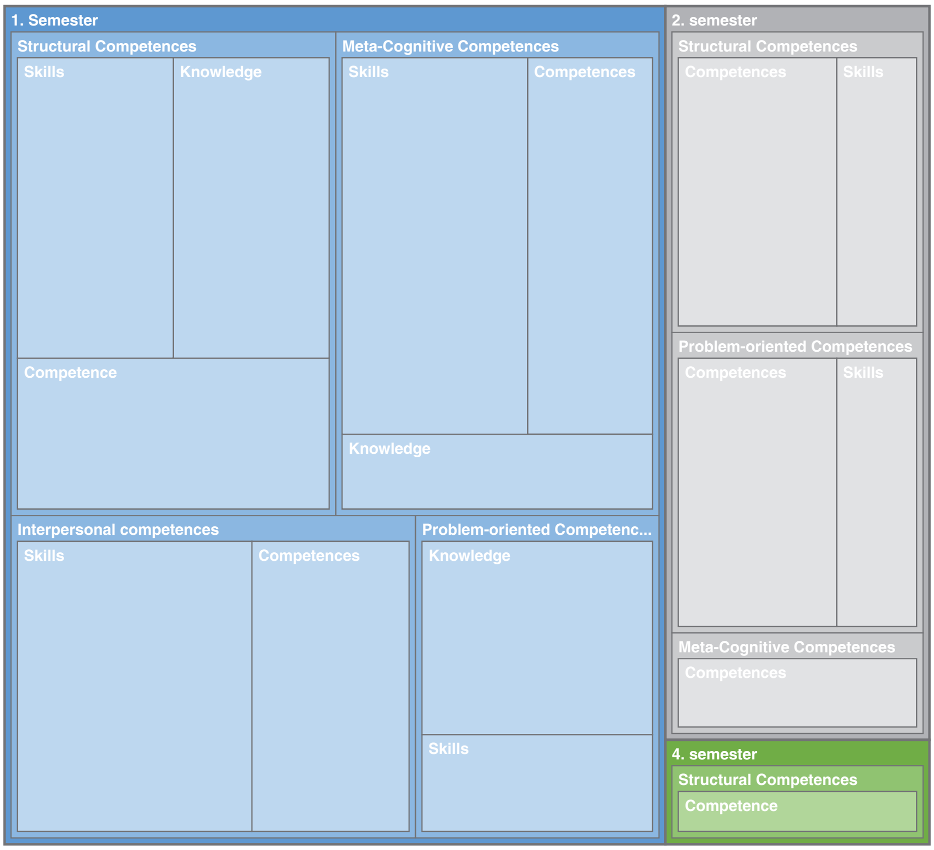

Fig. 2. Treemap of BIO

The treemaps shown in figure 1 and 2 show that the majority of learning outcomes related to the development of generic PBL competences are placed on the first semester. The intended learning outcomes are described using the Dublin Descriptors [3], but more often than not only two of categories. It should be noted that the colors displayed in the treemaps are byproducts of the coding in NVivo, and has no interpretative value.

BIO and NANO share a similar structure during the first year, where students are introduced to PBL in 5 ECTS course, and in three projects dubbed P0, P1, P2. For each of these projects the students must hand in a process analysis describing their group work, project management and more. Already at the 2. Semester the presence of learning goals related to generic PBL competences are more limited, and for both BIO and NANO there are no learning goals related to development of interpersonal competences.

On the second year, the third and fourth semester, BIO has learning goals related to the aforementioned PBL competences. The learning goal addresses development of structural competences during project work. It was surprising to find that none of the other PBL competences were present as generic PBL learning goals.

The formal curricula shows that students fairly early are establishing a membership in their specialized education [16], where PBL is described in relation to professional and contextual problems not readily transferable as generic competences across knowledge domains without aid from supervisors [13]. The supervisors are tasked with bridging the paths for transfer, but by emphasizing learning outcomes as the 'only logic step' for modernizing educational programs and institutions there is a chance that students may only seek learning experiences that only 'hugs' [17] a set target rather than opening up or encouraging abstractive thinking and development of metacognitive skills. A challenge when using explicitly stated learning outcomes in a PBL environment is ensuring student and teacher autonomy during the learning experience, but one could argue that using too explicit outcomes can affect the learning trajectory of students, rather than enabling themselves to navigate their path into both a university environment and a professional context.

4 CONCLUSION

Reading the formal curricula gives insights into the institutional framing of PBL competences, or intended curricula, but they do not tell us anything about the actual enactment of the curricula. The documents can serve as a basis for discussing institutional strategies and how the desired strategic ambitions of educational institutions can be implemented while maintaining a high degree of teacher autonomy, minimizing an instrumental approach. The bulk of generic PBL learning goals placed on the first and partly second semester stresses the important role that the supervisors play when it comes to helping students transfer competences across professional domains. According to Bernstein this can be difficult as the students on specialized educational programs develop subject loyalty in a self-perpetuating oscillating motion including teachers and lecturers. Of course, loyalty is by no means negative, but in this age of interdependency, loyalty needs to extend the borders of professional domains.

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Quality of Ethics Education in Engineering Programs using Goodlad's curriculum typology

Gunter Bombaerts [1]
TU Eindhoven 0000-0002-8006-1617.
Eindhoven, the Netherlands

Karolina Doulougeri
TU Eindhoven, Eindhoven, the Netherlands

Nienke Nieveen
Twente University, Enschede, the Netherlands

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ABSTRACT

Ethics education is part of many engineering curricula and at the same time a debated matter in terms of its goals, extent and educational approach. The quality of ethics education is, however, not prominently described in engineering education research (EER). To answer this gap, we perform a literature review that focuses on ethics education in EER. We analysed the data using a general quality framework that considers four elements of quality, i.e. relevance, consistency, practicality and effectiveness. We find that EER elaborates on the relevance of ethics education in three different ways: realisation of conceptual goals as honesty, integrity, or social responsibility; support of engineering concepts as complexity or risk; or instrumentally to comply with national educational standards. EER has little focus on consistency, except for the link with the entire curriculum. Also practicality is little developed, only on whether assessment is valid and reliable in ethics education. Teachers' perceptions of the instrumentality (is it helpful in teaching), congruence (does it fit the circumstances) and cost (is it feasible with the available time and resources) are less stressed. Debates on effectiveness in turn are prominent in ethics education and focus on the influence of: student characteristics and competences; course design; connection with the curriculum; and broader cultural aspects. We conclude that consistency and practicality are largely missing in ethics education in EER and that many implicit notions of relevance and effectiveness exist. This framework can make quality more explicit and impact the discussions on ethics education in EER.

[1] Corresponding Author: Gunter Bombaerts, g.bombaerts@tue.nl

1 INTRODUCTION

Few people would argue the importance of high quality engineering education and therefore the concept of "quality" has been discussed extensively in many places around the world. In literature on the concept of quality, two main perspectives can be found. The first emphasizes that engineering education should reach high standards of student outcomes. Within this line accreditation criteria have been developed and used, such as the Engineering Criteria 2000 (EC2000) by the Accreditation Board of Engineering and Technology (ABET) and ISO 9000 international standards. Both highlight learning outcomes and assessment and consider factors that concern the mutual recognition and global mobility of the engineering profession [1], [2]. A second line emphasizes meeting standards for the planning and acting of engineering education. This line considers factors that affect the quality of engineering education process, such as the importance of specifying clear educational goals and matching the educational and assessment methods adopted to these goals. Moreover, this line also considers the actual teaching processes of engineering education [3].

In this contribution, we introduce an evaluation framework that goes beyond both perspectives. The framework compares student outcomes with course intentions and the way the teaching and learning processes are being implemented. Moreover, the framework takes into account the expectations regarding course intentions, implementation and outcomes of different stakeholder groups, i.e. university-based curriculum (policy) makers, university teachers and students. Combining these responses and observations provides a rich basis for course (re)design and improvement.

We use this model for an exploratory literature research in which we do not aim to be exhaustive, yet want to sketch a first view how quality in ethics education in EER is currently described, what are the possible blind spots or specific emphases.

2 THEORETICAL FRAMEWORK FOR QUALITY

2.1 Course representations

Quality in ethics programs is rarely dealt with in a systematic way. Ocone [4] introduces a checklist as a practical tool for looking at ethics leadership (asking heads of department, course teachers and industry), visible ethics (effects on students) and actual ethics behaviour (observations in meetings). To interpret, understand and communicate about course-related issues, such as ethics course improvement matters, the curriculum typology by John Goodlad [3], is a valuable model to extend Ocone's approach. This typology distinguishes different representations of a course or curriculum: the intended, implemented and attained curriculum. First of all, a course can be described or represented by its *intentions*. Course designers, as well as other stakeholders will have their ideals when thinking about the aims of the course and what the course should look like. During the design process, course designers will make these ideals tangible by writing up the plans in a course guide and its accompanying teaching and learning materials. These formal documents usually do not (and cannot) cover all original ideals. Moreover, typically several redesign cycles are needed up until all course materials are ready to use. Next to its intentions, a course can also be represented by the way it is *implemented* in the teaching process by teachers/lecturers and others involved. Teachers may (and usually do) deviate in their perceptions of the original teaching and learning materials. They do this based on the characteristics of the students' group, previous teaching experiences and contextual factors. These perceptions will also affect the actual teaching and learning processes, the operational curriculum. For instance, teachers add illustrative examples, questions, dilemmas, etc. in order to assist students in their understanding and application of the topics at hand. Finally, the course can also be represented by the *attainment* of students. Based on their backgrounds, earlier experiences and interests, students, but also others involved, usually differ in the way they experienced the course and deviate in their performance outcomes.

2.2 Course quality

For clear communication about a course, the three representations and six forms (as summarized in *Table 1*) is of support. The same typology has also proven to be an aid in understanding relationships and discrepancies between the different representations of the course in practice. In this section, the typology is used to illuminate the notion of course quality [5], [6] and linked to four quality criteria: relevance, consistency, practicality and effectiveness. According to the logic of the framework, a high quality course should suffice for all of four quality criteria.

Table 1. Overview of curriculum representation and form with explanation and quality criteria.

<table>
<tr><th>Representation</th><th>Form</th><th>Explanation</th><th>Quality Criteria</th></tr>
<tr><td rowspan="2">Intended</td><td>Ideal</td><td>Vision (rationale or basic philosophy underlying a curriculum)</td><td rowspan="2">Relevance
Consistency</td></tr>
<tr><td>Formal</td><td>Intentions as specified in curriculum documents and/or materials</td></tr>
<tr><td rowspan="2">Implemented</td><td>Perceived</td><td>Curriculum as interpreted by its users (especially teachers)</td><td rowspan="2">Practicality</td></tr>
<tr><td>Operational</td><td>Actual process of teaching and learning (also: curriculum-in-action)</td></tr>
<tr><td rowspan="2">Attained</td><td>Experiential</td><td>Learning experiences as perceived by learners</td><td rowspan="2">Effectiveness</td></tr>
<tr><td>Learned</td><td>Resulting learning outcomes of learners</td></tr>
</table>

2.3 Relevance

As far as a good quality course in concerned, the course itself (the intended course/curriculum) must be well considered. All course elements (such as its goals, content, assessment strategies) should be based on state-of-the art knowledge and considered relevant to the course objectives. Largely this is comparable to the content validity of a course, referring to the question to what extend do experts agree on the essential parts of the course elements? Expert opinions of course can differ. For ethics courses, the distribution of what is relevant is large. Different experts and stakeholders might disagree on what the relevance for ethics (education) is to realize the universities mission and vision or for the future profession of engineering students.

2.4 Consistency

The course design itself should show consistency. This quality aspect bears a resemblance to construct validity and to the notion of constructive alignment [7]. Constructive alignment emphasises the need of clear linkages among the intended learning outcomes, the assessment tasks and the learning environment (teaching and learning activities) that students are required to engage in in order to reach the intended learning outcomes. In this contribution we refer to the need of coherence between all components of the course and the entire curriculum [8], including its rationale, the aims and objectives, content, learner activities, teacher role, materials and resources, grouping, location, time and assessment. Every subject has its own specifications and own interlinkages. For students and for many other teachers, the specifications of ethics education are sometimes difficult to understand.

2.5 Practicality

Already more than 40 years ago Doyle and Ponder [9] pointed at teachers' ability to make on-the-spot judgments about the practicality of a change proposal. The practicality that stems from this (and has been elaborated for instance by Janssen, Westbroek, Doyle and Van Driel, 2013) [10] refers to teachers' perceptions of the instrumentality (is it helpful in teaching), congruence (does it fit the circumstances) and cost (is it feasible with the available time and resources) of the proposal. Translating this into the framework at hand, this means that teachers should consider the proposed courses to be usable for their teaching practices. In our framework, we would add that teachers, tutors and assistants not only expect the context elements (materials, rooms, group sizes …) to be supportive but that this should also be their perception after actually having taught the courses. Practical courses show consistency between the intended and perceived curriculum and also between the intended and operational curriculum.

2.6 Effectiveness

Finally, the outcome of the course is important. Students' experience (the experiential curriculum) are usually measured in student satisfaction surveys, in some instances extended with focus group interviews to gain more in-depth data on their perceptions [10] And of course, high quality courses also show desired learning takes place and students pass the course by reaching its learning objectives. With effective courses, similarities exist between the intended and experiential curriculum and the intended and attained curriculum.

3 RELEVANCE CRITERION IN ETHICS COURSES

We see three subfields discussing relevance of ethics courses, which is a focus on conceptual goals, more topics related approaches and approaches that focus on complying with national educational standards.

3.1 Conceptual goals

Conceptual approaches in ethics education quality discussions aim for a cluster of interrelated concepts. Iona & Ursu [11] state values as the relevance of the ethics part in the curriculum: “The importance of introducing ethics in the technical education syllabus is undeniable, taking into consideration the fact that engineers are expected to reach the highest standards of honesty and integrity, especially because their actions have a vital, direct impact upon the quality of life!” Conway [12] enlarges this to “Teaching and learning strategies are needed that highlight the social and environmental context of technological activity, that encourage pupils to consider what determines the quality of their own lives and those of others, and that stimulates reflection on the values and beliefs which influence the priorities when value judgements are being made.” Bielefeldt and Canney [13] focus on social responsibility (SR) attitudes, Bekkers and Bombaerts [14] on ‘the role of the engineer of the future’ and Johnston and Eager [15] on social significance of engineering: “Recognition of the social significance of engineering education and engineering practice needs to be reflected in a much broader and more integrated approach to the construction of engineering programs generally, and to issues of professional practice and ethics in particular.” Feister, Zoltowski, Buzzanell, Zhu, and Oakes [16] analyse the reflexive characteristics of “how students interpret and make sense of their work in an engineering education context, and how this context may impact students' development and understanding of ethical decision making”. Finelli etal. [17] and Carpenter et al. [18] enlarge this concept to ethical development as a combination of knowledge of ethics, ethical reasoning, and ethical behavior. Other authors focus on professional responsibility [17], ethos of modern engineers as “lifestyle and professional identity” [19] and perspective-taking, moral efficacy, moral courage, and moral meaningfulness [20]. Lastly, some authors discuss the narrow focus of ethical systems discussed and the lack of universities openness to other ethical systems. Murrugara [19] for example shows that Chilean universities with existing ethics courses teach them using a philosophical or theological perspective, limited to occidental theories, and usually from a Christian point of view, not focussing on indigenous viewpoints. Verrax [21] points at three failures of common ethics education in France, i.e. ordinary versus disaster ethics, involving the public, and taking into account power relations.

3.2 Topics related approaches

A second set of publications frames the relevance of ethics in engineering education in more concrete and engineering related aims and concepts as professional codes [22] (Hess and Fore indicating that this is the most common ethics education approach in engineering programs in their study [23]), complexity, context and sustainability [24], risk [25], global perspective [26] or macro-ethical perspectives [27]. Also critical professional skills are considered important for the relevance of ethics education such as the students' technical oral and written communication, professional and working relations between team members, project and time management [28], adaptive expertise [29] or soft-skills [30].

3.3 Complying with national educational standards

A third set of articles defines relevance of ethics courses by their need to comply with national educational standards. Barry and Ohland [31] discuss accreditation requirements for the Accreditation Board for Engineering and Technology (ABET), the Computer Science Accreditation Board (CSAB) Engineering Criteria 2000 in the USA and course accreditation requirements of engineering education in Australia. Rowden and Striebig [32] propose a three hour unit on the economic and environmental impacts of product design is proposed for inclusion in the ABET accredited engineering program. Passow and Passow [33] propose to broaden "ethics" in the Washington Accord or ABET accreditation requirements to “responsibility”.

4 CONSISTENCY CRITERION IN ETHICS COURSES

Ethics education quality discussions focus far less on consistency and is never explicitly mentioned. If the issues is discussed, it is often in the debate about embedding or separate ethics courses. Even here, the focus is more on practicality or effectiveness. Another way consistency enters the quality debate is by the practice-what-you-preach principle. Farahani and Farahani [34] for example write about all staff’s task to show respect for the students’ safety and health, privacy, and showing trust, respect, tolerance and openness.

5 PRACTICALITY CRITERION IN ETHICS COURSES

Thirdly, practicality in ethics in engineering education mainly focusses on whether assessment is valid and reliable. As Goldin, Pinkus and Ashley [35] state it: “Assessment in ethics education faces a challenge. From the perspectives of teachers, students, and third-party evaluators like the Accreditation Board for Engineering and Technology and the National Institutes of Health, assessment of student performance is essential. Because of the complexity of ethical case analysis, however, it is difficult to formulate assessment criteria, and to recognize when students fulfil them.” Several instruments have been developed to answer this challenge: Student Engineering Ethical Development (SEED) survey [18] [22] [17] (Harding 2015 SEED-PA …), moral reasoning skills survey [35], Engineering Professional Responsibility Assessment (EPRA) [13][36], Schwartz value profile [37], and the Engineering and Science Issues

Test (ESIT), measuring “moral judgment in a manner similar to the Defining Issues Test, second edition, but is built around technical dilemmas in science and engineering”. [38]

Whereas these methods focus on the ethics part alone, other methods analyse the entire engineering competence development. The Academic Competence Quality Assurance framework [39] for example, measures all engineering competences, including “takes account of the temporal and social context”. All these approach consider the context-specific needs of different engineering disciplines in ethics education and leverages the collaboration of engineering professors, practicing engineers, engineering graduate students, ethics scholars, and instructional design experts. ([40] to add to the practicality of the ethics education in EER.

6 EFFECTIVENESS CRITERION IN ETHICS COURSES

We group our findings on effectiveness in student and course, curriculum and ‘university and beyond’.

6.1 Student and course

Johnston and Eager [15] state that “effective treatment of social and ethical issues should not be trivialized by superficial approaches to analysis and presentation. We […] suggest some practical ways in which both breadth and depth can be achieved, and to highlight problems we see as needing further attention.” Ooi and Tan defined effectiveness in an ethics workshop as “student’s theoretical understanding on engineering ethics and student’s perceptions on ethical/non-ethical behaviour through case studies.” [41] Bielefelt and Canney [13] found that change in social responsibility attitudes occurred more in courses treating themes as international, community, ethics, service learning projects, and development. Others refer to multidisciplinary project teams as core to work increase ethical decision making [16] or Schwartz value profile [37]. Alfred & Chung [42] report on the effectiveness of a “Simulator for Engineering Ethics Education” placing students “in first person perspective scenarios involving different types of ethical situations. Students gather data, assess the situation, and make decisions. The approach requires students to develop their own ability to identify and respond to ethical engineering situations. It is based on a mathematical model of the actual experiences of engineers involved in ethical situations.” Other research focusses on learning outcomes of the ethics education as intrinsic motivation [43] [], deep learning [44],

6.2 Curriculum

The curriculum is also seen as an important level for the effectiveness of ethics courses. Bielefeldt etal. [45] found that “only 30% felt that undergraduate students in their program received sufficient education on both the societal impacts of technology and ethical issues; only 20% felt this way about their graduate program.” May and Luth [20] found that “both embedded and stand-alone courses were effective in enhancing participants' perspective-taking, moral efficacy, and moral courage. Moral meaningfulness was marginally enhanced for the embedded module condition. Moral judgment and knowledge of responsible conduct of research practices were not influenced by either ethics education condition. Contrary to expectations, stand-alone courses were not superior to embedded modules in influencing the positive psychological outcomes investigated.” Drake *etal.* [46] advice engineering ethics to be “integrative, delivered at multiple points in the curriculum, and incorporate specific discipline context” to increase students’ moral reasoning and sensitivity to ethical issues. Literature focuses also on co-curricular experiences next to formal curricular experiences [17] and volunteer activities to increase societal responsibility [13]. Lin therefore advices engineering programs to “incorporate more explicit instruction about the social dimensions of engineering to support the development of socially responsible engineers.” Findings suggest that the number and type of co-curricular experiences have an important influence on ethical development. [18] [47] for example state that “industrial training has minimal impact in improving or developing students' ethical awareness. The impact is such because students who undergone industrial training may have observed certain behaviour that they thought are acceptable in a workplace; this may have changed the way students perceived their acceptance on the situations.” Barry & Ohland [31] state that “more courses or course time on professionalism and ethics will necessarily lead to positive engineering education outcomes. Much of the impetus to add more curriculum content results from a lack of conclusive feedback during ABET accreditation visits.”

6.3 External university

Effectiveness is also determined “beyond” the curriculum. Carpenter *etal.* [18] found that the institutional culture made a difference on how students behaved and how they articulated concepts of ethics. [19] found that “research work into the processes of forming the professional ethos of today’s generation of engineers, its complexity and challenges of its reform involves the creation of a public image of the engineering profession as a certain subjective picture of the world, the tracking of its structural and content dynamics in the course of professional training, as well as a study of the professional academic community and the transformation of its mission and strategy.”

7 CONLUSION

7.1 Discussion

Using our quality framework based on John Goodlad, our exploratory search shows that consistency and practicality are largely missing in ethics education in EER and that many implicit notions of relevance and effectiveness exist. Although relevance receive strong focus, it is often implicitly mentioned, it is unclear if the statements are the opinion of the individual scholar, a formal statement of the result or a clearly lived-by norm within the university organisation. We tend to believe that most principles mentioned in the literature are individual and still heavily debated within universities. Consistency is absent in the debate on ethics courses’ quality and little is written on practicality. The articles refer little to teachers' perceptions of the instrumentality (is it helpful in teaching), congruence (does it fit the circumstances) and cost (is it feasible with the available time and resources) of the proposal. Nevertheless, the practical application and therefore final quality, heavily rely on consistency and practicality. Many questions remain here. How can the consistency between courses contribute to ethics education quality? How does the practicality of measuring outcomes in ethics courses influence the education itself (multiple choice questions, difficulty to measure attitudes …)? Debates on effectiveness are again prominent in ethics in engineering education. However, also here, many questions remain. What about the effectiveness of the ethics education in light of student diversity (first year's vs last years, gender, ethnicity, religious backgrounds …)? How do engineers and companies see effectiveness of ethics education?

We showed that this framework made quality more explicit and impact the discussions on ethics education in EER. Further research should reveal how the criteria relevance, consistency, practicality and effectiveness can be better addressed to keep adding to the overall quality improvement of ethics education in EER.

7.2 Limitations

We are aware that we opened up a large debate in which a lot has to be said, far more than one single article. Our analysis therefore does not show our exhaustive research results, but aims only to be explorative and sparking off the ethics education quality debate. This means that for the relevance and effectiveness criteria, we know there is more in the literature. We did not focus on the role of companies in the ethics education quality debate. There is a debate on corporate social responsibility, but what does it imply for the companies role in ethics education in engineering curricula? We of course also acknowledge that we might miss parts of the literature. It might be possible that other concepts in ethics education in engineering curricula can show us wrong in that consistency is absent.

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COLLECTIVE INTELIGENCE IN ROBOTICS LABS: MAPPING THE FLOWS OF INFORMATION

M. Braga[1]
CEFET/RJ Federal Center for Technological Education
Rio de Janeiro, Brazil

C. Schettini
CEFET/RJ Federal Center for Technological Education/Militar School
Rio de Janeiro, Brazil

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ABSTRACT

Knowledge is the feedstock that students work with in STEM learning environments (labs of basic sciences, robotics labs, makerspaces, etc). When students are developing projects in these environments a huge quantity of knowledge is being spread, information is being stored in both people and devices, and a collective intelligence is also being created. The STEM environments should be spaces where the knowledge can flow easily among each one of these sources. However, there are many factors that can create bottlenecks for these streams. These flows and bottlenecks must be mapped by knowledge managers (teachers, mentors, etc) during the activities, aiming to improve its spread. The research from this case study in a robotics workshop aims to create ways to study and knowledge management in STEM environments. In this target, a group of students from different classes were gathered in a robotics lab for an introductory activity. The structure of the activity was an initial contact with robotics focused on learning both the programming and assembly of robots as well as the phases of development in an engineering project. All activities were recorded with cameras positioned in different points. The exchange of information was registered and inserted in software of Social Networks Analysis. The map allowed understanding in some features of the information flows established by the students. From this map it is possible to change the environment setting to improve these flows. This research can help to understand and change different configurations of all engineering education environments by improving their knowledge management.

[1] M. Braga
marcobraga@namelab.education

1 INTRODUCTION

The STEM learning environments are not static spaces. When students are working on an engineering project, knowledge is built through various flows of information that fill the entire space. The work in a robotics learning lab, for example, is naturally collaborative and complex. There is always interaction among students, between students and the professor, or between students and devices and or tools. Therefore, the interaction (learning) can happen among humans directly or between humans and artifacts, because the students acquire knowledge manipulating artifacts as robotics pieces, engines and software.

The knowledge flows can have different configurations depending on several factors like architecture of the lab, position of workbenches, and distribution of kits and tools. The mapping of these flows can furnish important information to improve the spread of knowledge in these environments.

The mapping of these flows can show the interactions among students, teacher, and artifacts. The intention of this work is to identify these good pathways and bottlenecks aiming to improve the knowledge management in these STEM environments. The results can stimulate the emergence of a collective intelligence among the students and aide in the creation of innovative environments for engineering project developments in schools and universities.

2 THEORETICAL FRAMEWORKS

This research is founded with the view that work in a STEM environment can be understood as being a network, where several actors (vertices in the language of graphs) play important roles in the exchange of information and by consequence in the learning. Two theories will be highlighted here that can contribute to the understanding of knowledge management in STEM environments, specifically in robotics labs: The Actor-Network Theory (ANT) and The Collective Intelligence.

2.1 The Actor-Network Theory

The actor-network theory emerged as a response to traditional sociological studies, where social relations were studied only among people. For the advocates of actor-network theory several artifacts play an important role in the social relationship that cannot be overlooked in these studies [1] [2]. In the modern world, the technological artifacts are not only mediators between humans; they also have the power to change these relationships. Verbeek [3] cites the example of the introduction of the microwave oven in American households in the final decades of twentieth century. In past times, dinner was a moment of conversation (information exchange) between members of families. Everyone sat at the table and talked about the day’s events in both work, and community; however with the advent of frozen food and the microwave oven, many families did not eat at the same time as heating the dishes was not done at the same time. The diffusion of information in the communities has changed. The microwave began to play a preponderant role in the social relationships of the communities. It has created a bottleneck in the dissemination of information from the community social network. This has also occurred with the massification of the use of smartphones. People stay constantly connected to their social network through cyberspace and far from people physically around them.

When students begin to develop projects in the Robotics Lab, they become part of a knowledge network. Their learning comes from several sources. Teacher and classmates take part of a small network inside the robotics lab, although this network can be enlarged by the use of smartphones that connected the students to other similar experiences through the internet. Today You tube is the most important source of information for students involved in engineering projects.

Each actor of this network should have a free connection with everyone else. This is the ideal condition for the spread the knowledge in the network. But we know that it not happen for several reasons. This is the goal of knowledge management in the STEM labs, identify the bottlenecks to eliminate its.

2.2 Collective Intelligence

Depending on the project, the students will need to seek information from different sources that have already researched that topic. This learning process is fundamental, because the first step is to gather information from knowledge storages where other networks have already deposited their projects (You tube, websites, visits of campus companies, etc). This first step connects them to several other networks who are working or have already worked with the same problem. At the end of the work, it is important that each team posts on internet their process and the final product. This kind of collaboration allows them to make their contribution so that this network can be expanded. This kind of collaboration is similar to the bazaar method of software development [4]. It allows for the emergence of collective intelligence (people working in collaboration, but not synchronically) and a collaborative intelligence (people working synchronically). In the robotics lab, the students can keep collaboration synchronically, each one of them exchanging knowledge with others.

Levy [5] wrote about the cyberculture and networks, developing the concept of Collective Intelligence (CI). For him, the knowledge is spread among several people and several data-bases. The intelligence is a function of coordinated work among people and between people and sources of knowledge. Because of this, people should count on different ways of connecting and several sources of knowledge storage in places with easy access. The great intellectual centers of Antiquity like Bagdad and Alexandria or in the Middle Age produced a good team of thinkers and large libraries.

The Collective Intelligence does not emerge naturally. It is fundamental to create a proper environment where people can work together focusing on the goals and sharing knowledge. The elements of the team should have complementary skills and competencies.

When teachers create teams for collaborative learning, it is not easy to preview what kind of collective intelligence will emerge from that activity. They can create a proper space in the STEM environment but what is going to happen from that point cannot be foreseen.

From a case study, we intend to understand some of the characteristics of a collaborative learning strategy and how the students learn to work in engineering projects. A network should emerge from a dynamic where the teacher, the students and several devices become actors of a process where knowledge may flow freely among all of them.

3 METHODS & RESEARCH DESIGN

The first challenge of this research is to understand how the students build their own processes of information exchange during the development of an engineering project. In the first moment, this construction is almost random. There are several factors that give shape to this process. The first of them is the design of the environment. The position of workbenches or the place where the tools and robot kits are stored can draw the first topology of network. The pedagogy used in the activity can create different ways of knowledge flows too. The students can be stimulated to stay at the workbenches interacting with their team or circulating through in the environment and interacting with several elements such as tools, devices, and other teams. Each one of these elements can be set up previously to enhance the flows of information. The set up established by the students during the activity should be studied by the teachers to understand what should be changed. From this first set up, it is possible to change the position of non-human actors (furniture, architecture, etc.) or the pedagogies, creating a new topology aiming to improve the flow of information. It is necessary to create a research methodology that allows to map the paths of where the information is traveling. For this, we will use the methodology of video analysis and tools of social network analysis. We can think of the interaction among teacher, students and artifacts as a knowledge network where information is being exchanged all of the time.

This workshop was proposed to students from middle and high school (7th, 8th and .9th grades). The goal was to introduce them to engineering work through a robotics introductory project. They needed to assemble a car and coding it for a lap in a circuit.

After the presentation of the proposal, 21 students enrolled in the workshop. However, only 16 students attended all work meetings. Each one received a number of ID. They could choose their team freely. For this reason, the number of students on each team is not the same.

The students chose their position in the workbenches according to their preferences (Fig 1). The teacher did not indicate positions.

The topology analyzed here was built in one of the first days of the activity. This activity was recorded on video for analysis [6]. Two cameras were used for recording the interactions of actors. The researchers watched the videos and noted the interaction for twenty minutes. They noted the number of interactions creating a spreadsheet. This data was inserted in the Gephi software which created the map of interactions.

This work is the first analysis of these interactions. The goal is to detect the creation of a Collective intelligence through the measurement of clustering coefficient in the network created by the lab.

The duration of the workshop was 4 months. The twenty minutes of observation was the first proof point. All other work meetings were accompanied by a researcher and were recorded in a field diary.

4 RESULTS

The first observation was the position chosen by the students for organization of the work. The teams chose workbenches near the teacher. The teacher is the reference in the traditional learning environments, but after the work started all the spaces were occupied.

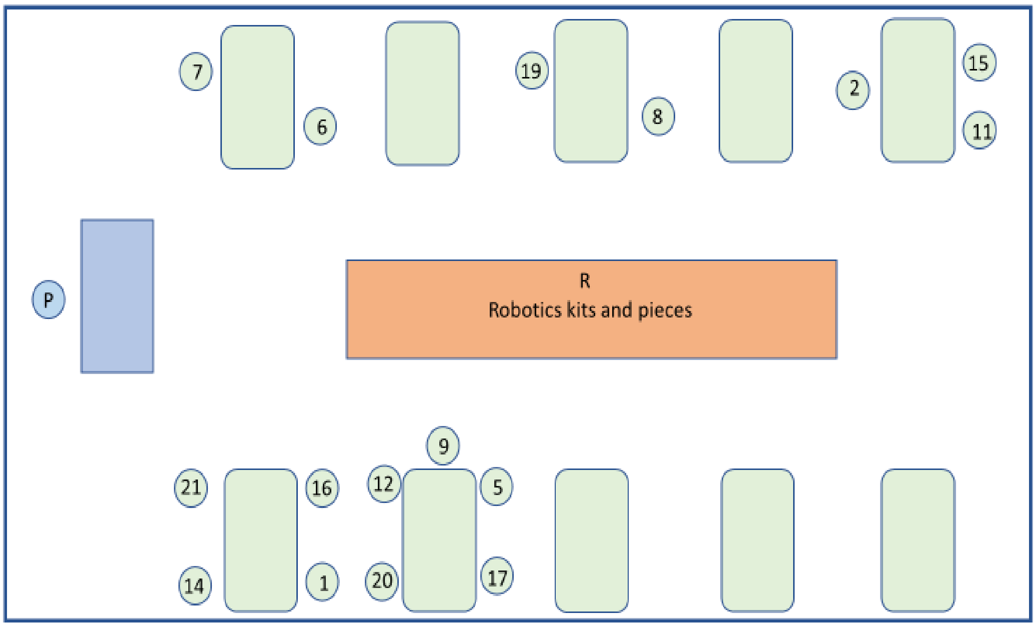

Fig. 1. Initial Lab Configuration

In the traditional lab each team worked from their workbenches with a great interaction among the students of the same team. However, the set-up of the environment blocked the interaction between teams. Braga and Guttmann [7] argued that when there is a common place in the STEM environments to take tools or general materials, the collaboration grows and there is higher interaction among all students. The teacher put a general workbench in the center of the environment with tools and pieces of the robotics kit to perform the role of a contact point among students. The intention was to promote the collaboration through the sharing of tools and robotic kit pieces. Each student could pick up a tool on the workbench and after using it would return it to the initial place so that other teams could use it too. This movement would induce the exchange of information at the workbench.

However, after removing tools from the central workbench, the students left it on the workbench of their own team. This situation created a new role for these tools and robotics pieces. The movement of students became more intense. They needed to pick up the tools from the workbenches of other teams. The tools and robotic pieces played a role of pollination of knowledge, because they allowed the students to move around the environment. They could see the work of classmates and suggest improvements or collect good ideas. The teacher or mentor could perform this role too, because the consults from them produced movement in the environment.

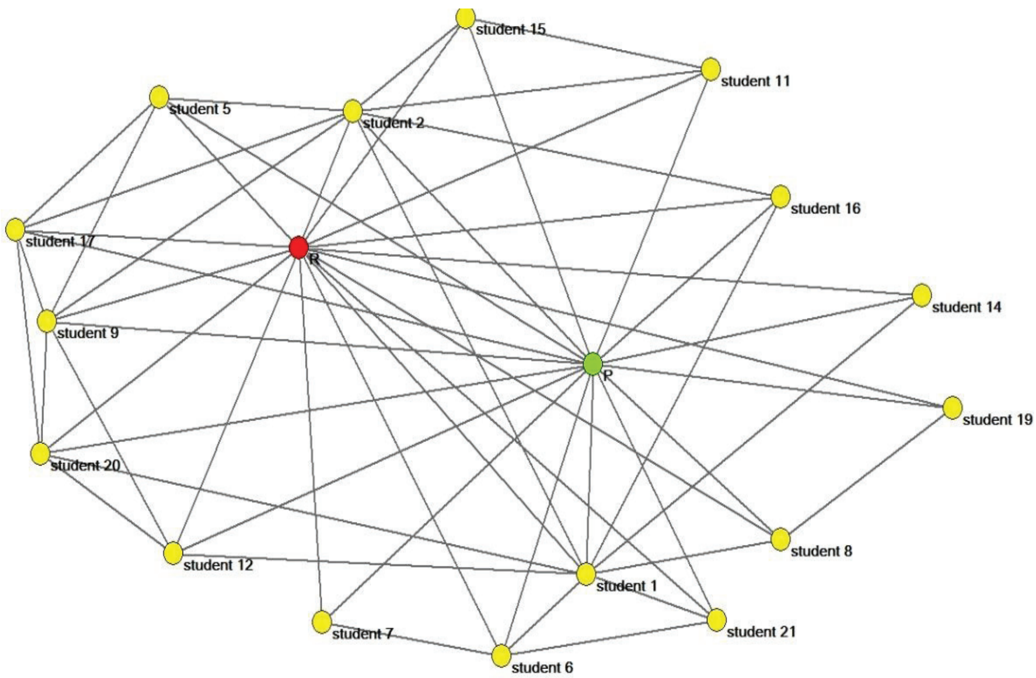

Fig. 2. – The network created during the initial activity. CC = 0,358

The network built in the Lab has 17 human actors (vertices), with 16 students and the teacher (P). The workbench with tools and robotics pieces is the non-human actor (R), making a total of 18 actors. The Collective Intelligence is built from the interaction of all these actors. Students sometimes need to interact with the teacher, and also with the tools and robotic pieces. When they choose a tool or a piece, they were thinking about the future actions and the basic needs to complete the task in their minds. Consequently, they are learning engineering.

In the ideal condition of interaction for the building a Collective Intelligence, each actor should interact with the other 17 actors. However, this did not happen, total interactions were not completed.

The Clustering Coefficient (CC) is the relationship between the real interactions (RIT), that is the interactions that really existed, and the total of possible interactions (TPI)[7].

$$CC = \frac{RIT}{TPI} = 0{,}358 \tag{1}$$

The data collected from the network indicates that only 35,8% of possible interactions happened. This number would be a good clustering coefficient for a network with a big number of actors. But for a small network it is not good.

The situation could have been more critical if the teacher and the workbench were excluded from the network.

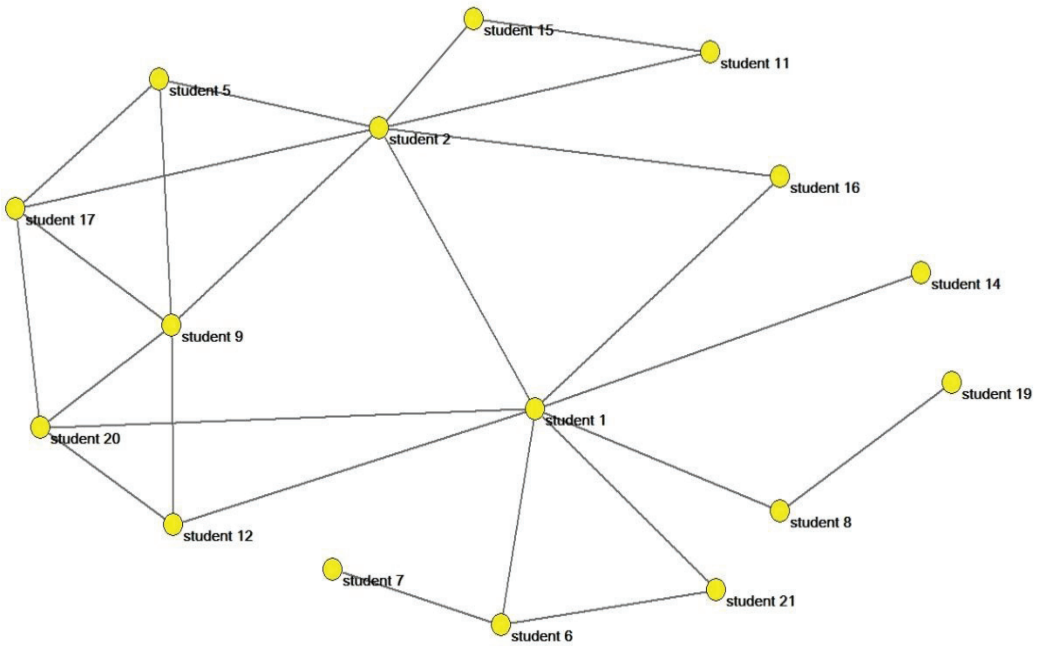

Fig. 3. The interaction without the teacher (P) and the robotics pieces workbench (R).

In this case, the clustering coefficient goes down to *CC = 0,2.*

Only 20% of possibilities of interactions took place in this network. It is not a good value for a small network.

5 DATA ANALYSIS

Some problems can be solved before the next activities in this environment with the improvement of interactions and to creating a more robust Collective Intelligence.

a) The teacher kept the centrality of the process. The activity is not a traditional class, but the teacher worked as a mentor for all students. All students-maintained interaction with the teacher, even those that were isolated from the other ones, like 7, 14 19.
b) The development of projects in workbenches can induce the students to work only inside their teams. Students 7, 14 and 19 stayed connected only with classmates of their own team. It can be a personal issue or a question of environment setup. They were in the points of lab that didn't allow great movements or easy interaction with other classmates. Other configurations of lab should be tested.
c) Students 1, 2 and 9 had the most connections with everyone. However, the big hub of this process was student 1. Student 9 had connections with students 5, 17, 20, 12 and 2, but four of them were on their own team. Only the student 2 was outside. Student 2 kept interactions with classmates 1, 5, 9, 11, 15, and 17, but 2 students were from their own team and the others came from only 2 other teams. Student 1 kept connections with classmates 2, 6, 8, 12, 14, 16, 20, 21. There are students in these connections from all teams. He is the hub of the network. This is an important issue for knowledge management because the hubs of knowledge networks are great information diffusers. Almost all information travelled through this hub. If the teacher needs to share relevant information with the teams, it important to know the pathway to implement this quickly.
d) Even the isolated students 7, 14 and 19 are so close to student 1. Student 14 is directly linked because they worked on the same team. Student 7 had the intermediation of student 6 and student 19 was linked through student 8.
e) Students 1 and 2 started the project in distant places in the lab. The central workbench had an important role in the connection between them. If this connection were blocked during the activity, we would break the network into two clusters with fewer connections between them. Therefore, the interaction between these two students was very important to spread information.

6 CONCLUSIONS

Other studies like this one should be repeated with other configurations of the lab. We used a traditional setup of the lab, with workbenches separated by teams. The number of workbenches was bigger than the number of students. Much of this space could have been used as a circulation area. Students 7 and 19 wouldn't have remained trapped between the benches. Student 14 seemed blocked by student 21 in the beginning of the activity however it didn't remain that way because student 21 circulated through the environment.

The best configuration would have been where the workbenches stayed in the center of the environment, without a part pull over the wall. It would have been necessary for each team to work on the workbench, but each student could have the capacity to circulate around it.

The central workbench with tools and robotic pieces played its role with efficiency. It produced the meeting of many students and the exchange of information.

The teacher also performed his function as a mentor. He attended the student requests and oriented them with solution for many problems.

This methodology is being used by us as a tool for knowledge management in the development of engineering projects, both in the pre-university engineering education and in undergraduate courses. The next step will be the introduction of concepts of knowledge management in engineering education from these results from this methodology. It will be necessary that they learn to manage their work to improve their Collective Intelligence in the development of projects.

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Mapping Current Curricular Changes in European Engineering Education

S.C. Brink
The Hague University of Applied Sciences
The Hague, The Netherlands

F. Georgsson[1]
Umeå University
Umeå, Sweden

G. Thomson
Aston University
Birmingham, United Kingdom

M.S.A. de Hei, E. Sjoer
The Hague University of Applied Sciences
The Hague, The Netherlands

W.F. Admiraal
Leiden University
Leiden, The Netherlands

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ABSTRACT

In Europe, there is a wide variety of curriculum designs in higher engineering education. Several international networks serve the goal of supporting the inherent need of higher education institutions to continuously improve their programmes, without per se offering a formal accreditation standard. In this paper, two such networks are considered: CDIO and SEFI. The curricular landscape across Europe and across the different engineering disciplines is mapped by means of a survey amongst the members of CDIO and SEFI. The results amongst 82 respondents show that the prevailing curriculum structure defined by focus, set-up and design is a fixed curriculum with flexible elements, focused on theory with skills woven in, and with a subject-centred curriculum, followed by another big group having a flexible curriculum with fixed elements, competency-based, and focusing on skills with theory woven in. Configurations vary based on region, engineering discipline and network membership.

[1] Corresponding author F. Georgsson, fredrik.georgsson@umu.se

Curricular changes in the past three years and coming two years focus mostly on assessment and examination, as well as pedagogics, interpersonal skills and curriculum flexibility. Certain engineering disciplines are more prone to curriculum change than others, such as Design Engineering and Information Engineering. Electric engineering currently shows significantly less curriculum change. When changing the curriculum design, learning goals, learning activities and learning vision are typically seen as a priority in engineering education. The most perceived barriers in the curriculum change process are staff competency and engagement for those about to make changes, and development time and costs for those having made recent changes.

1 INTRODUCTION

1.1 Mapping the state of the art in higher engineering education curriculum improvement

In Europe higher education institutions continuously work on improving the quality of their education in general and the curriculum designs of their programmes in particular, and engineering education is no exception to this. Content, didactics and organizational aspects of engineering education curricula are periodically evaluated and improved according to a set of quality criteria, determined on both national and international bases. Some are required by European laws and agreements or the national accreditation system, others are part of the institution's core policies or a strategic choice of a department or faculty itself. Currently, there is a wide variety of curriculum designs and innovations in European engineering education.

New educational science research insights seep into the aims of curriculum design improvements and its quality enhancement criteria. When looking at the proceedings of the international engineering education network conferences, certain trends can be seen, fed by both fundamental and more practice based educational research. For instance, 21st century skills have been extensively researched, initially resulting in many models of what these skills exactly are, extending to what pivotal elements a curriculum of the 21st century would need: cross-curricular key skills, learning through experience, learning outside the direct academic context, blended learning etc. (Mishra and Kereluik, 2011). An example of this is the role that reflection and critical thinking skills should play in engineering education, which has been acknowledged and redefined in the past decade (Buch and Bucciarelli, 2015). Kirschner et. al. (2006) found evidence for a higher effectiveness in learning by using guided, just-in-time instruction, in order to deal properly with expert-novice differences and critical cognitive load in students. This is the basis for curriculum models such as 4C/ID (Merriënboer et. al., 2002), and supports the emphasis on integration within a curriculum of offered knowledge and skills in authentic, complex projects within CDIO (Crawley et. al., 2011). Another trend that influences curriculum design is the role higher education institutions can play in open innovation networks (Hallenga-Brink and Vervoort, 2015), between education, research and the professional practice. From an educational point of view, this way students work with the work field during their studies, challenged to address topics such as sustainability, ethics, cultural differences and international communication. Another growing trend is the flexible curriculum, aimed to be better fit the entry level and individual learning preferences of students, the multidisciplinary nature of the near-future work field, and the speed with which society's needs and technological possibilities are developing (Sinke et. al., 2015).

Applying these research insights in engineering education has impact on the structure and design of the curriculum, and prompts alterations on one or more of the curriculum design axes as described by van den Akker et. al. (2006). Currently, there is no concise overview of what curricula in engineering education in Europe typically look like, nor of the specific changes that the engineering programmes currently work on when improving their curriculum designs. This research aims to map the curricular landscape and current changes in curriculum designs across Europe in the different engineering disciplines, regions and international networks.

1.2 Barriers in higher engineering education curriculum development

It is easiest to change a curriculum when there is a high sense of urgency and a high preparedness felt within the organization (Kamp and Klaassen, 2013). When internal concerns need solving and everybody feels the need to address these concerns, involvement will not be a problem. When there is a high urgency, but low preparedness amongst the staff, leadership commitment could be an important starting point instead. And when there is a low urgency but high preparedness, capacities of staff can be explored and facilitated in a bottom-up approach. To facilitate such continuous improvement practices, Professional Learning Communities (PLC) in any form serve their purpose to equip staff with the competency to make the needed changes. According to Verbiest (2002) PLCs are built on personal capacity, the individuals' ability to (re) construct and apply knowledge in an active and reflective manner, making use of up-to-date scholarly and practical theoretical insights, on collective capacity to do this as a group, with a shared vision as starting point, and on organizational capacity, having the cultural and structural conditions to support the development. Supportive, stimulating and shared leadership is also an important aspect of this organizational capacity.

The more radical the intended changes to a curriculum are, the more barriers will be experienced by the developers within the structure of their higher education institution, accreditation system and (inter)national laws (Hallenga-Brink, Carlsson and Georgsson, 2018). These barriers can result in delays and even cancelation of the intended curriculum developments. This research aims to map which barriers are experienced or foreseen in current engineering curriculum development in Europe, in relation to the different contextual settings of the higher education institutions (engineering discipline, region, phase of the change process).

2 METHOD

2.1 Survey amongst SEFI and CDIO members

In this research, two networks in Europe that function as international professional learning communities for engineering education are primarily considered: SEFI (Société Européenne pour la Formation des Ingénieurs) and the worldwide CDIO (Conceive – Design – Implement – Operate) which has active European and UK divisions. In 2019, SEFI has 113 institutional members, CDIO has 168 institutional members of which 69 are part of the European region. A total of 19 institutions are a member of both networks. CDIO offers a framework of guidelines plus a syllabus of learning goals to educate engineering graduates towards becoming professionals. SEFI has a thematic working groups structure and the Engineering Education Research journal. Both networks have an annual conference in which reviewed publications on educational developments are presented to share experiences and learn from each other. The proceedings of the last three years of both these SEFI and

CDIO conferences have been used as a source to list items on which to base survey questions on. An online survey has been generated and has been sent around via both networks' mailing lists, and their social media channels, to be filled in by heads of programme or other key figures within the programmes. In the survey, the code of ethics has been respected. Respondents were informed beforehand they can pull out of the survey at any moment. All respondents have indicated they give permission to anonymously process their input in the dataset.

2.2 Survey items

The survey contains several dimensions. The items have been on the SEFI and CDIO proceedings of the past three years, literature searches, and three earlier conference workshops by part of the authors on curriculum agility:

To describe what the curriculum designs of the different engineering programmes in Europe look like, their focus, set-up and structure have been specified. The main focus of a curriculum is typically either on Theory or on Skills. However, Theory Focused Curricula can have skills woven in and Skills Focused Curricula can have theory woven in, resulting in four items. The set-up of a curriculum can be described in four items: Fixed (subject supply driven), Fixed with Choice Elements (e.g. minors), Flexible with Fixed Elements (e.g. graduation project) or Flexible (student demand driven) (Georgsson, Carlsson and Hallenga-Brink, 2019). Thirdly, typifying the programme's curriculum design (Mulder and ten Cate, 2006) a distinction is made between Subject Centred, Learner Centred, Problem Centred, Challenge Centred, Project Centred, Work-Integrated Centred, and/or Competency Based curriculum designs.

Based on the conferences output, the SEFI proceedings of 2018, 2017, and 2016 and CDIO proceedings of 2018, 2017, and 2016, the following contemporary curricular changes became items in the survey: Cost effectiveness, Drop-out Rates/Non-Completion Rates, Curriculum Agility and Flexibility, Blended learning, Lifelong learning, Assessment and Examination, Graduation and Capstone Projects, Pedagogics (Active, Authentic, High-Impact etc. learning), Teacher Roles and Behaviour, Cocreation, Multi- and Interdisciplinary Learning, Talent Development of Students, Underachievement and Mediocre Student Work, Inclusiveness, Gender Equality, Cultural Diversity, Frequent Learning Disabilities (ADHD, autism, dyslexia), Personal and Interpersonal Skills of Students, Employability of Students, Internationalisation, World Citizenship, Industry Engagement, Research Engagement, Sustainability, and Ethics.

Didactic changes made to the curriculum are prioritized based on the curriculum design cobweb model as described by van den Akker et. al. (2006): Learning Vision, Learning Goals, Learning Content, Learning Activities, Learning Resources, Teacher Roles and Attitudes, Learning Groups, Learning Environment, Learning time, and Assessment.

The barriers for curriculum development were the result of workshops on flexible and agile curricula (Hallenga-Brink, Carlsson and Georgsson, 2018; Hallenga-Brink, Georgsson and Carlsson, 2019), indicated by twelve to sixteen engineering education practitioners on each occasion: Staff Skill or Competence, Staff Engagement, Student Acceptance, Senior Management Acceptance, Regulatory or Process Inertia and Blocks, Physical Infrastructure, Development Time and Costs, Operating Resources of the New Model, Passing Quality Assurance or Accreditation.

3 RESULTS

3.1 Respondents

There were 82 respondents describing distinct engineering programmes of 48 European universities to the survey. In Fig. 1 and Fig 2. the regional and engineering cluster distributions of the respondents are depicted.

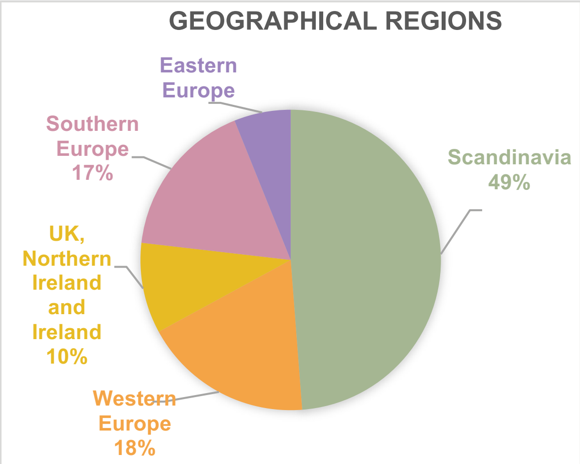

Fig. 1. Regional distribution of respondents

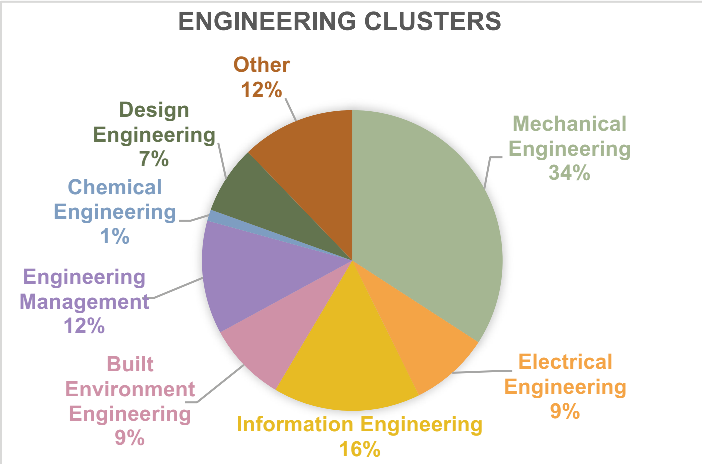

Fig. 2. Engineering cluster distribution of the respondents

3.2 Curriculum structure

A total of 43 out of 82 programmes have a Theory Focused Curriculum with Skills woven into it. Of these 43, 72% has a Fixed Curriculum with Choice Elements, and 18% has a Flexible Curriculum with Fixed Elements. When looking at the 33% of respondents that indicate a Skills Focused Curriculum with Theory woven in, 63% has a Fixed Curriculum with Choice elements, whereas 22% has a Flexible Curriculum with Fixed elements. 12% of all respondents has a solely Theory Focused Curriculum, and only 2% a solely Skills Focused Curriculum. Fig. 3 shows the curriculum design choices for each programme set-up. The Skills with Theory programmes work mostly with Project-based, Competency-based and Learner-based designs, whereas the Theory with Skills programmes work foremost Subject-based and to a lesser extend Project-based. Fig. 4 shows the same curriculum design choices, but now split per region. The percentages are calculated in regards to the number of respondents in each region. So, 80% of all Eastern European respondents mention a Competency-based Curriculum, whereas 80% of the Southern European respondents attribute a Subject-based element to their curriculum design. Scandinavia and Western Europe show a much more even pattern, although Challenge and Problem-based does not appear to be as common in the West-European programmes.

3.3 Recent and upcoming curricular changes

About 7% of the respondents has not made any curriculum changes in the past three years, nor are planning to do so in the coming two years. 76% has done curricular changes in the past three years. In the coming two years 35% will make changes.

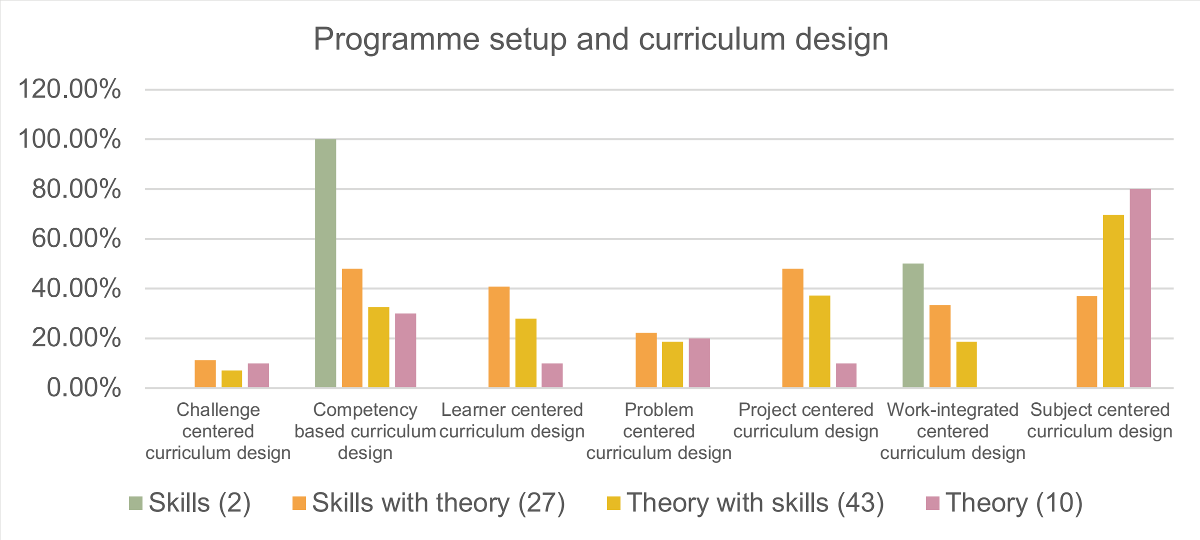

Fig. 3. Choices in curriculum design per type of programme set-up. The numbers in the legend correspond with the number of respondents.

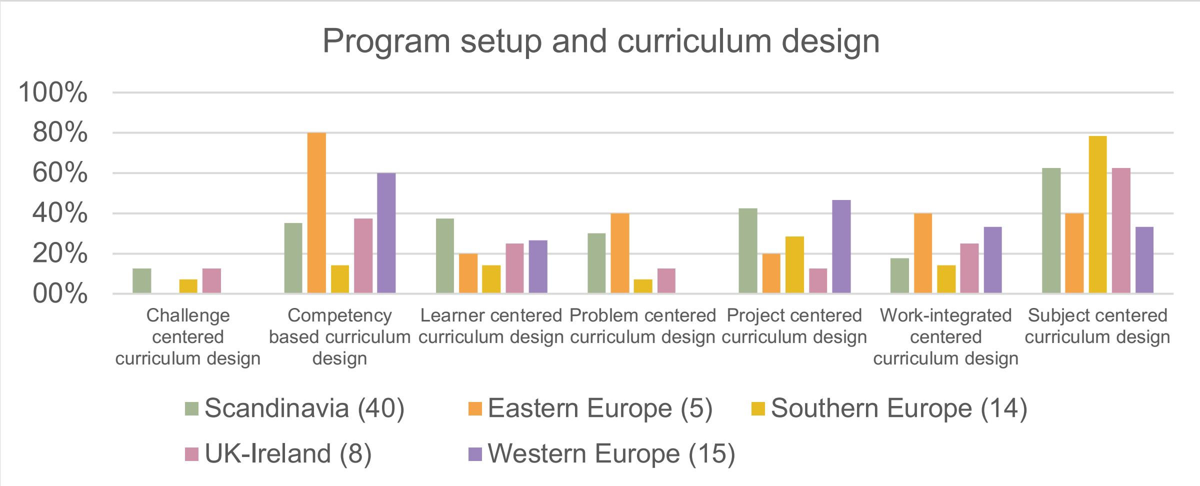

Fig. 4. Curriculum design per region. Note that programmes could indicate one or more choices to describe their design.

Fig 5. shows how different clusters within engineering education choose to make different changes in their curriculum. The changes are shown on a scale 0, no changes, to 3, major changes. On average the engineering programmes' level of change over all the 21 items is 0.98, which is just below Small Changes. Electrical engineering is significantly changing their curricula less (95% confidence interval), with an average of 0.60 ± 0.11. Design engineering programmes change most with an average of 1.20, but have a larger spread of ± 0.22 than Information Engineering, which has 1.18 ± 0.13. The item that is most often mentioned to be worked on by the programmes is Assessment and Examination, with an average of 1.27 ± 0.38, while Frequent Learning Disabilities yields the lowest average level of change of 0.35 over all programmes. There is one remarkable peak in the least chosen items: Design programmes work on changing the curriculum for underachievement and mediocre student results considerably more than the other disciplines. Pedagogics with an average of 1.22 ± 0.11, has the smallest spread as all disciplines mention it frequently.

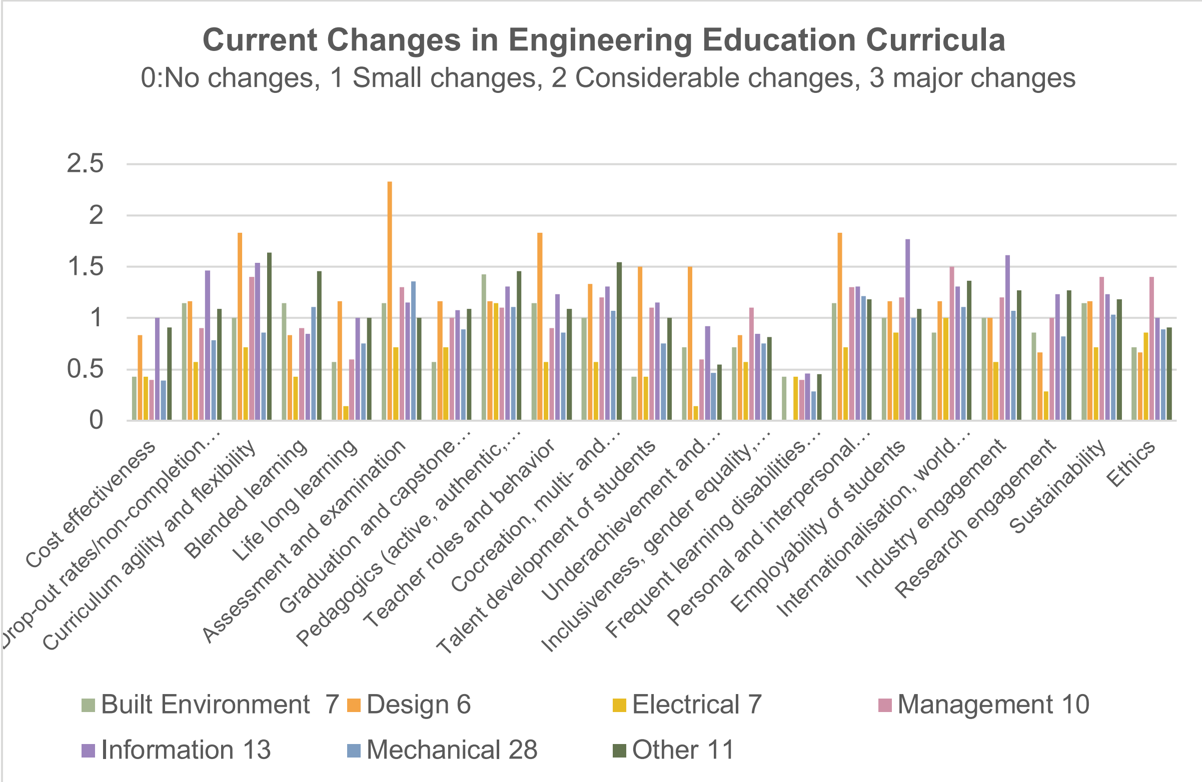

Fig. 5. Recent changes in curricula in European engineering education.

When looking at the chosen changes per region, the results are fairly homogenous per item, with the exception of Graduation and Capstone Projects, which has considerably more attention in Eastern Europe, and Assessment, which has more than average attention in the UK/Ireland. When looking at the respondents being either CDIO, SEFI or member of both networks, then CDIO-only members pay more attention to Assessment and Examination and Teaching Roles and Behaviour. Those not a member of either network pay more than average attention to Drop-out and Completion Rates. SEFI-only and combined CDIO-SEFI members remain close to the average attention paid to the different change items.

3.4 Barriers in the curriculum changing process

Fig. 6 shows a difference between the respondents that have carried out changes in the past three years and those that are planning on implementing changes in the coming two years. The largest difference can be seen in the expected barriers of Senior Management Acceptance and Regulatory or Process Inertia and Blocks. Those who have not implemented changes yet tend to expect these to be barriers, but this is not affirmed by those who have carried out changes. These differences are statistically significant at a 95% level.

In the category 'other barriers' individual respondents mentioned lack of top management support, balancing core knowledge and soft skills, the time a democratic changing process takes, scheduling conflicts and high numbers of dropout students due to industry employing them early.

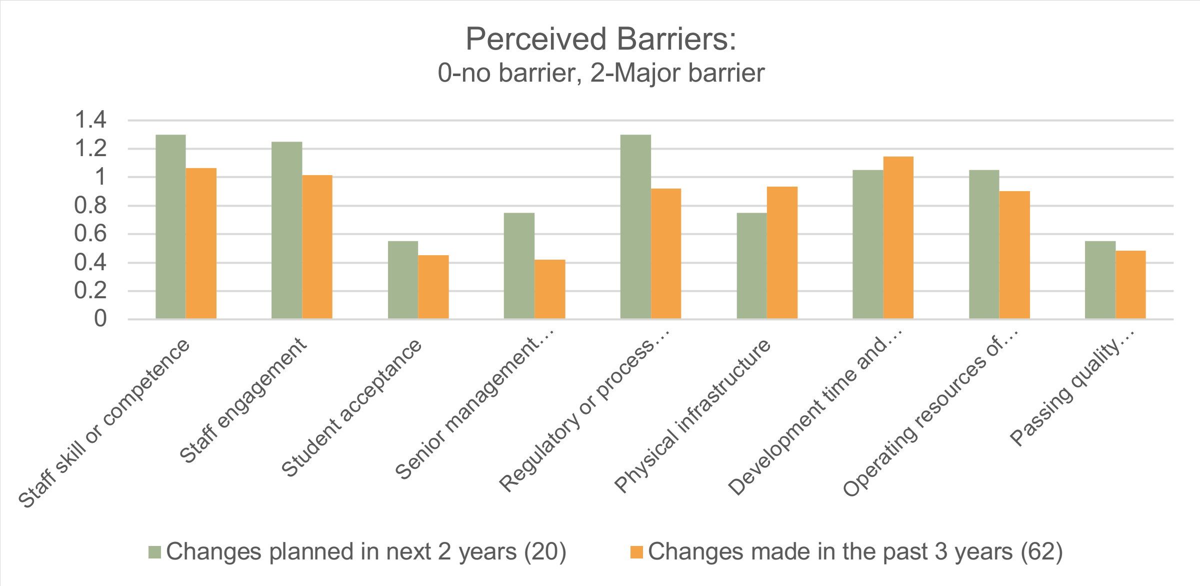

Fig 6. Differences in perceived barriers depending on phase of changing.

3.5 Priorities in the curriculum design development

In Fig. 7 the differences in priorities in curriculum design can be seen split by engineering discipline. Overall, 82% of the respondents stated that Learning Goals were continuously prioritized in curriculum development. Learning Groups and Learning Time were prioritized least as opposed to Learning Activities and Learning Vision. Especially the engineering disciplines of Built Environment and Design Engineering show different paths in the plot.

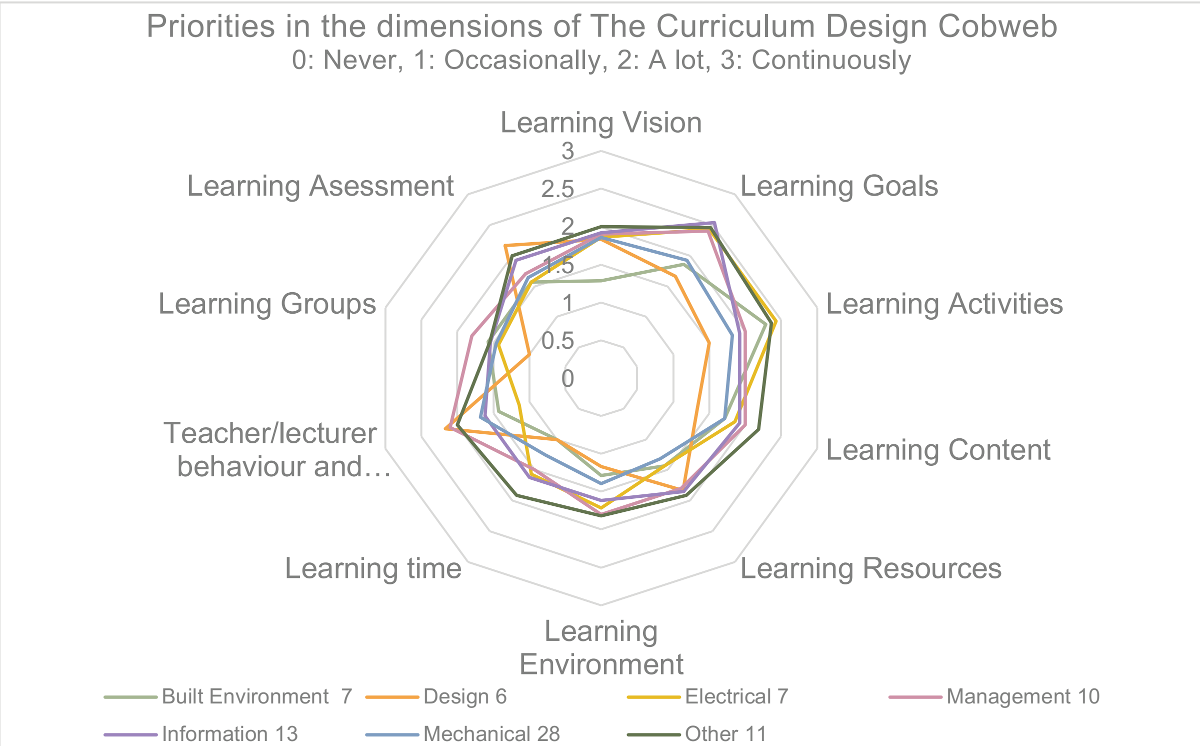

Fig. 7. The different engineering disciplines show different priorities in curriculum design.

4 CONCLUSION

In Europe the majority of higher engineering education curriculum designs are either Theory focused with Skills woven in or Skills focused with Theory woven in. The curriculum set-up that goes along with this is mostly Fixed with Flexible elements and to a lesser extend Flexible with Fixed elements and completely Fixed. None of the curricula were Flexible only. There was a spread in curriculum design of combinations where Subject-based, Competency-based, and Project-Based were most often mentioned. The biggest group of subject-centred curriculum designs were mostly found in Southern Europe, Scandinavia, and the UK/Ireland. Challenge-based curriculum designs are not common in Europe.

The changes European Engineering Education programmes make currently are mostly on improving Assessment and Examination, Personal and Interpersonal Skills, Curriculum Agility and Flexibility, and Pedagogics (Active, Authentic, High Impact etc learning). Learning disabilities and Cost Effectiveness were least mentioned. Electric Engineering made or planned the least changes to their curriculum from all the engineering disciplines. Design and Information Engineering made the most, with high peaks on Student Employability, Industry Engagement, Underachievement and Mediocre Student Results, Teacher Roles and Behaviour, and Assessment and Examination. CDIO-only members paid more than average attention to the latter two items as well. Drop-out rates were mentioned most often by those respondents who were not a member of SEFI nor CDIO.

On average, barriers most mentioned as majorly influencing the development process were Staff Skills and Staff Engagement by 83% of the respondents. A difference was seen between barriers anticipated by those about to make changes and barriers experienced by those who just made changes to their curriculum. Regulatory or Process Inertia and Blocks, Management Support, Staff Competence and Engagement all proved less of a barrier for the latter group, whereas Development Time and Physical Infrastructure proved to be more of a barrier to them.

When comparing the perceived barriers by network memberships the research showed that the more involved in engineering education networks the respondents are, the less barriers they perceive. Looking at the regional differences, the Scandinavian engineering programmes indicate less barriers overall than any of the other regions.

This research describes the vast map of curricular structures and changes made in engineering education curriculums in Europe. The results describe differences between geographical regions and clusters of programmes in how they approach curricular development. The results, however, are not allowing for drawing causal conclusion. For instance, the lack of focus on sustainability in eastern European engineering education might be explained by the fact that they implemented these issues a long time ago into their programmes or because it is yet to get attention. In order to analyse the data further, the number of respondents from different regions and programmes should increase.

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Barriers and enabling factors for engaging engineering students in research. A multi-perspective approach.

UB Bulmann, Ulrike
Hamburg University of Technology
Hamburg, Germany

SB Bornhöft, Sara
Hamburg University of Technology
Hamburg, Germany

DE Ellinger, Dorothea
Hamburg University of Technology
Hamburg, Germany

Conference Key Areas: New Complexity Quest in Engineering, Others
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Abstract

Industry 4.0 requires diverse, creative, and adaptable engineers, who solve complex problems based on innovation, research, and development. Thus, engaging students in research is a potentially high-impact educational practice. However, previous studies have shown that implementing students' engagement in research faces multiple obstacles that stress on the dimensions culture, resources in higher education institutions, structure of study programmes, academics' qualification and students' competencies. In engineering, however, little attention is spent on what academics and students perceive as barriers and enabling factors. This study highlights conditions for engaging students in research in engineering education. For this, we conducted six semi-structured interviews with students and academics at a German university of technology and analyzed those using thematic analysis. We found that interviewees perceive students' engagement in research differently and associate a wide range of activities. Together, they draw a manifold picture of its constraints. Beside common aspects, they identified the large amount of obligatory basic courses and the lack of practice in undergraduate programmes as hindering; a structure quite typical in German traditional engineering education. They also made various recommendations, such as supporting a culture for engaging students in research, appropriate facilities, and programme-based research skill development. Furthermore, they reported that academics need an open mind for topics of students' interest, while students are required to engage in extracurricular student-academic partnerships in research. Upon those findings, we argue for the need for further research and, subsequently, suggest formulating strategies by involving all stakeholders. This can potentially ensure developing future engineering talents at this university and beyond.

[1] Corresponding Author
UB Bulmann
ulrike.bulmann@tuhh.de

1 INTRODUCTION

Industry 4.0 desires diverse, creative, and adaptable engineers with sound technological skills who contribute to complex problem solving in society (see [1]) based on innovation, research, and development. Thus, engaging students in research is a potentially high-impact educational practice (see [2]), and its benefits in engineering education has been outlined elsewhere (see e.g. [3]). Various activities and strategies can be implemented to integrate research into teaching (e.g. [4], [5]). However, implementing students' engagement in research faces multi-dimensional obstacles and facilitating factors, i.e. regarding culture and policies as well as resources in higher education institutions, the structure of study programmes, academics' qualification and students' competencies, as observed by senior and junior academics (e.g. [6], [7]). Some studies summarized similar challenging and enabling conditions, that is, institutional, departmental and disciplinary conditions as well as course design and personal attributes (e.g. [8]). Brew and Mantai (2017) refer to other studies that stress the relevance of taking into account the various perceptions of research, teaching and learning, definitions, attitudes, actions and benefits of engaging students in research. In addition, disciplinary characteristics (see [4]) and contextual aspects of higher education institutions have to be considered (e.g. [9]). So far however, little attention has been spent on what both academics and students in engineering education perceive as barriers and facilitating factors. Following our first findings (see [7]), this qualitative study, conducted with three stakeholder groups at a German university of technology, discusses how academics and students understand research, teaching, and engaging students in research, what they perceive as barriers and enabling factors, and which ideas they have for enhancing students' engagement in research. Based on these results, a complementary quantitative study, conducted as a university-wide questionnaire, is planned.

2 MATERIAL AND METHODS

Engaging students in research is framed throughout this manuscript in a wider sense in the framework of the *extended research-teaching-nexus* model according to Rueß et al. (2016), which is based on the approach of Healey (2005). Therein, *research-based learning* in a narrow sense refers to a teaching format that enables students to experience the whole research cycle according to Huber (2009).

2.1 Context of this study

This study was conducted at a young German research-intense university of technology that offers a variety of engineering bachelor and master degree programmes. The university aims to grow in the next years with currently ~8000 students (~1500 first year students) and ~800 academics in six departments. Most academics are involved both in teaching and research. Connecting research and teaching is highlighted in the university's mission statement of teaching and learning. Engaging students in research is therefore an important part of implementing it. There are various teaching innovations for the different stakeholders in place, such as a qualification programme for research assistants for integrating research into teaching (see [7]), a facultative interdisciplinary project for first-year students, or an incentive programme for professors, who want to innovate learning modules or study programmes, all supported by the university's centre for teaching and learning.

2.2 Study methodology

In order to gain first insights into the views on research, teaching, engaging students in research as well as the perceived conditions at this university, data was gathered in the beginning of 2019 by six semi-structured interviews. Assuming that various stakeholders offer a valuable perspective, three different groups were surveyed, that is students, chief engineers, and professors. The position chief engineer is quite unique at the university and involves, apart from research and teaching activities, managerial functions within the respective institute. One-hour interviews were conducted with two students (S1, S2), two chief engineers (CE1, CE2) and two professors (P1, P2) that are open to teaching innovations. The sample represents a variation of gender (three female, three male persons), disciplines (process engineering; electrical engineering, computer science and mathematics; mechanical engineering; management science and technology; civil engineering), involvement in incentive innovations, activities in bachelor and/or master degree programmes, and some experience in engaging students in research. The participants were asked to:

(1) describe their understanding of research,
(2) define their understanding of teaching,
(3) explain typical situations in which they engage students in research (or were engaged in research as students), and what they perceive as benefits for students and academics,
(4) clarify what they perceive as barriers and enabling factors for implementing students' engagement in research, and
(5) formulate recommendations or visions with regard to students' engagement in research.

Subsequently, on the basis of relevant literature ([6], [8]), a five-dimensional category system for barriers, enabling factors and ideas was designed, including 1) culture, 2) resources, 3) structures of study programmes, 4) academics' qualification and 5) students' competencies. Then, the data was analysed using thematic analysis by two researchers. Here, one researcher proceeded interviewee by interviewee while the other researcher analysed the interviews question by question.

3 RESULTS

In order to understand how the interviewees perceive barriers and enabling factors and what ideas they have on how to engage students in research, it is necessary to consider their inherent conceptions of research, teaching and students' engagement in research. Therefore, these are discussed here first. Following this, the results on perceived barriers, enabling factors and ideas are presented.

3.1 Perceptions of research and teaching

The interviewees' general conceptions of research were quite similar, varying just in certain details. The participants, except P2, all described research as a series of activities to solve a problem, to answer a question or to give an explanation, while S2 and also P2 view discovering connections as important. Following Brew's (2001) concept of research, the interviewees are mainly oriented on the product or process of research, whereas the researcher as a person with personal goals seemed to be absent from awareness in the descriptions. Further on, interviewees referred to the following central aspects: a) research as generation of new knowledge (P1, P2, CE1, S2), b) research as similar to development (CE1, CE2, S1, S2) or, on the contrary, research as system innovation vs. development as technological innovation (P1), c) difference between research at higher education institutions compared to industrial research (P1, CE2, S2), d) holistic perception of research activities within a typical cycle (P2, CE1, CE2, S2) or focus on particular activities and phases of research (P1) and e) relevance of one's own research for society (P1, CE2 and S2).

The interviewees' teaching perceptions were also quite similar in some aspects, such as the teaching approach, but vary in others. All participants, except CE2, described teaching as knowledge transmission. In addition, P1, CE1, S1, and S2 mentioned the importance of students constructing their knowledge. Moreover, all interviewees, except S2, appreciated the development of both students' professional and personal competencies as being part of teaching. Additionally, interviewees drew attention to the importance of practice in teaching (P1, P2, CE1, S1) and emphasised employability as goal of teaching (P1, P2, S1).

3.2 Perceptions of engaging students in research

When asked about their perceptions of students' engagement in research, all participants elaborated on curricular activities and, in addition, three interviewees (P1, S1, S2) described extracurricular activities. The interviewees took all students into account when talking about engaging students in research, however four participants (P1, CE2, S1, S2) additionally described forms of engagement that were only offered to selected students. All interviewees' descriptions relate to particular phases of the research process, while two interviewees (S1, CE2) take the whole research cycle into account when engaging students. Two participants (P2, CE1) stated that research done by students is of minor quality, whereas one interviewee reported on treating students on eye-level and having experience in co-publishing with students (CE2). One interviewed student expressed the feeling of being treated as research partner (S1).

The development or improvement of certain competencies was seen as a main benefit for students, including professional competencies such as solving complex or real world problems (P1, S2), understanding differences between knowledge base and generation (P2), deep-learning (CE2), understanding connections between modules (S1), understanding limitations of technology and methods (S2). As aspects of personal skills, developing self-reliance (P1, S1, S2), critical thinking (P1), interest in research topics (CE2, S1), research skills (P2), time management, collaboration, communication and leading skills (S1) were mentioned. Furthermore, making friends with other students, getting to know institutes, and experiencing academics in their role as researchers (S1) were also indicated.

All academics highlighted that they gain joy when engaging students in research. Furthermore, advantages are the recruitment of suited students for student project work and theses (CE1, S1) or joint research projects (CE2), and building long-term networks (CE1). Additionally, S2 noted that academics can gain more empathy for students' competencies and can slip into other roles than the expert role.

The academics were asked to describe how they actively engage students in research in a typical teaching situation, whereas the students were asked to describe situations when they had been engaged in research during their studies. Interviewees' activities in engaging students in research took place mainly in three forms in the framework of Rueß et al. (2016): a) In lectures, academics present research results by describing innovative ideas (P1) or state-of-the-art-research topics (CE2); b) in brainstorming sessions in problem-based learning courses, students apply research methods (P1), simulations (CE1), programming tasks in small project works (S2), and c) students experience a research process in the framework of student projects or theses (P1, S1, CE2, P2). Interviewees' descriptions hint to individual, uncoordinated activities (P1, P2, CE1, CE2, S2) or activities that integrate students into a scholarly community (CE2, S1) according to Brew and Mantai (2017).

3.3 Perceptions of barriers, enabling factors, and ideas for improvement of engaging students in research

As a next step, the responses of the interviewees were categorized within the five-dimensional category system for barriers, enabling factors and ideas (see Chapter 2.2).

First, the cultural conditions foremost focus on strengthening the recognition of teaching. This includes more practice-orientation in engineering programmes, orientation on competence, treating students as partners as well as social engagement and industry co-operation (see *Table 1*).

Table 1. Perceptions of barriers, enabling factors and ideas for improvement of engaging students in research referring to 1) cultural aspects

#	barriers	enabling factors	ideas for improvement
1) culture	• the workload necessary for supervising research-based learning projects is not adequately accounted for in the teaching load (P2) • little practical work as integral part of study programmes in engineering (P1) • focus on professional rather than personal competencies and research skills (S1) • low failure tolerance (S2)	• teaching recognition, e.g. by awards, funding (P2) • culture of partnering with students as co-researchers (P1, CE2) • informal meeting culture between academics and students (P1)	• appreciative structure for academics' efforts in engaging students in research (P2) • teaching incentives for academics (S2) • joint problem solving projects with industry partners and communication of results, even if these question common practices (P1) • cooperative problem solving of students and academics (S1)

Second, resources named by the interviewees included efforts, staff number, infrastructure, incentives, and characteristics of projects in engineering (see *Table 2*).

Table 2. Perceptions of barriers, enabling factors and ideas for improvement of engaging students in research referring to 2) resources

#	barriers	enabling factors	ideas for improvement
2) resources	• low staff number (P1, P2, CE1, S1), e.g. for coordinating teaching activities (P1, CE1) • high workload due to other competing duties (P2, CE1, S1) • high efforts, e.g. for co-working with students at pilot stands (P1), providing new topics (CE1), updating lectures (S1) • limited current resp. real data (only published resp. simulated data are available) (CE1), due to confidentiality of industrial projects (P2) • lack of informal social space (P2)	• appropriate personnel at departments (P1) • investment in junior academics to supervise students projects (P2) • incentive structures, such as appropriate teaching load (P2) • staff network, e.g. for equipment loan (CE2), • more appropriate rooms and facilities, e.g. meeting places in every institute (P1), group and PC rooms (CE1)	• decentralized supporting staff with pedagogical and subject competencies (P1) • funding of staff for teaching innovations and/or module coordination (CE1) • unbureaucratic process to the provision of materials for students' experimental work (CE2) • modern infrastructure, such as maker spaces (S2) • database on vacant student projects (P2)

Thirdly, structural aspects of engineering curricula were also revealed, such as the hierarchical structure of curricula, the amount of basic courses, the relation of compulsive to obligatory courses, the workload of modules as well as their coordination. Other items were the amount of practical elements, the types of inquiries and assessments, the existence or amount of given credits, the space for students' interests, courses on methods of scientific working, and the number of extracurricular activities (see *Table 3*).

Fourthly, it was found, that conditions referring to academics' qualification for engaging students in research relate first of all to their personal competencies, rather than on their professional competencies (see *Table 4*).

And last, the following conditions for engaging students in research in terms of students' attributes were addressed: students' knowledge, research skills, affective-motivational aspects, their study focus, engagement besides courses and future prospects (see *Table 5*).

Table 3. Perceptions of barriers, enabling factors and ideas for improvement of engaging students in research referring to 3) structural aspects

#	barriers	enabling factors	ideas for improvement
3) structure	• uncoordinated modules (P1, CE1, S1, S2) • inappropriate credits for workload in students' projects (P1, S1) • few high quality practical work within curricula (P1, S2) • closed inquiries, complex assessment, little space in the standard curriculum, few possibilities to receive positive feedback on competencies (S1) • few choices on subjects or too many obligatory courses, too many basic knowledge courses, dominance of written exams (S2)	• clustered modules with an overall research topic (P1), pedagogically coordinated courses (CE1) • integration of non-technical, uncredited courses (S1) • more practical work in problem-based learning sessions (P1) • self-dependent work in courses (CE1) • open inquiries, proper assessment, well-structured team projects in the beginning and many subject choices in master degree programmes (S2) • appropriately designed courses regarding work-load, deletion of other modules, balance between basic knowledge and research integration in lectures, group projects, interdisciplinary topics(S1) • voluntary work of student groups at test stands with researchers (P1)	• hierarchical, scaffolded design of curriculum that integrates research (CE1) • integration of students' projects in curricula (S1) • integration of student projects with industry partners in curricula (CE1) • support for student projects based on their own questions (S1) • enable students to specialize (P2) • smaller projects and emphasis on particular research phases in the bachelor programmes and integration of research modules in the master degree programmes (S2) • will to strengthen students' research competencies combined with product development (CE1) • addressing current societal problems (S1) • courses on methods of scientific working (CE1)

Table 4. Perceptions of barriers, enabling factors and ideas for improvement of engaging students in research referring to 4) academics' qualification

#	barriers	enabling factors	ideas for improvement
4) academics' qualification	• not enough open-minded professors with regard to modern pedagogies (S1) • professors' expert role limits their empathy for students' hetero-geneous competencies and novice perspectives (S2)	• open-minded, interested academics (P1, P2, CE2) • academics engage in topics of students' interest (CE2) and are open to supervise projects of students' interest (CE2, S2)	• courage for offering open inquiry topics, address students' autonomy even in projects with given topics, clarify roles in a project, and motivate students to creativity and experimentation (CE2)

Table 5. Perceptions of barriers, enabling factors and ideas for improvement of engaging students in research referring to 5) students' competencies

#	barriers	enabling factors	ideas for improvement
5) students' competencies	• knowledge heterogeneity in the beginning of studies (S2) • uncertainty due to taking over responsibility for results, no experience in dealing with failure (S2)	• students who plan a research career (CE2) • students who already know methods of scientific working (CE1) • students interested in topics and practical applications (CE1, CE2) • students with frustration tolerance, creativity, readiness for risk-taking, courage (CE2)	• engagement in extracurricular activities, such as project teams (S1) • engagement in practical work at institutes (S1, S2) • active decision to select modules in the master's degree programmes with an emphasis on practice resp. research (S2)

4 DISCUSSION

4.1 Discussing perceptions of conditions for engaging students in research

Engaging students in research entails complex conditions, and these were confirmed in this study with various stakeholders at one German university of technology. Both academics and students provided pieces of a big puzzle. The findings correspond with research in other countries or disciplines. For example, room allocation, student-faculty ratio, workload, space in the curriculum, teaching efforts, teaching approaches, and mindsets as well as students' competence levels have been described as perceived barriers in the relevant literature (e.g. [6], [8]). Moreover, similar enabling factors and suggestions for engaging students in research were found, such as teaching recognition by funding, informal learning environments, open-ended inquiries, open-minded academics and perception of students' competencies (e.g. [6], [8]). In addition to that, hindering aspects found in this study were, for example, little practice as integral part in bachelor engineering programmes, the high amount of other duties for academics, many basic and obligatory courses in the bachelor programmes, closed inquiries, dominance of written exams, knowledge transmission in lectures, and few opportunities for students to experience failure. Furthermore, positive aspects found in this study include partnering with students as co-researchers, modern infrastructures, courses in methods of scientific working, integration into the suite of non-technical courses, coordinated modules, scaffolded curriculum design and extracurricular activities, addressing students' autonomy even in given topics, and encouraging creativity. However, it is important to note that these conditions are related to some extent to characteristics of traditional engineering education in Germany (see [3]), such as in this study sample. Finally, the interviews revealed that participating academics already engage students in research, using the opportunities they have in the curriculum. However, their visions move beyond, and they suggest developing research skills in a coordinated way within the curriculum. Also, both academics and students recommend engaging in extra-curricular activities that offer teasers in research for students. Overall, the results of this study are concise with other findings with regard to the various approaches of engaging students in research (see [6]).

4.2 Discussing the methodology of this study

Thinking about the implications of the study results, some aspects have to be taken into account: This investigation follows a qualitative interview study that offered valuable additional insights in obstacles, enabling factors and recommendations for engaging students in research, perceived by qualified research assistants (see [7]). Hence, this group was excluded from this current investigation. This study focuses on a wider range of stakeholders at the university. Since following an explorative approach by conducting semi-structured interviews, the interpretation of study results underlies the known limitations of qualitative research. Furthermore, our selection of six open-minded, more experienced academics and students from one German university of technology as interview partners is limited. It has to be proved whether these results are in-line with results revealed in a questionnaire with more unexperienced stakeholders with regard to engaging students in research.

However, the study sheds some light into the interviewees' conceptions of research and teaching and the conditions of engaging students in research. While systematising conceptions on research as well as teaching in this case was cumbersome, various understandings reported (see [6]) as well as different forms of engaging students in research conceptualized (see [10]), helped to discover interviewees' perceptions and actions. Finally, described categorizations of conditions for engaging students in research (see [6], [8]) provided first insights.

In order to develop more generalizing results towards understanding barriers and enabling factors for students' engagement in research, it is required to formulate hypotheses that take into account the different perceptions of research and teaching. These should then be tested within the framework of a quantitative research design, i.e. a survey with all relevant stakeholders at more than one university from different countries.

5 CONCLUSION AND OUTLOOK

This explorative study discussed complex conditions for implementing students' engagement in research in engineering programmes at a German university of technology. It is argued that when interviewing relevant stakeholders about conditions, their background perceptions are important as well. Some of the revealed barriers, enabling factors, and recommendations have been reported in the existing literature and some of the new findings seem to be connected to some extent to traditional engineering education in Germany. The results suggest that some individuals desire activities for engaging students in research such as coordinated skill development, i.e. at the level of module clusters or over the whole curriculum. Also, they demand extracurricular activities on an individual level. This study requires a follow-up, i.e. deriving hypotheses and quantitative surveying of all stakeholders. As a next step, it is recommended to include widely recognized multi-level key strategies and their appropriate application and further development, involving all stakeholders. Such strategies have a high potential to foster the development of engineering talents for industry 4.0.

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Integration of Courses and Projects
- disrupting a traditional PBL semester structure

L. Busk Kofoed[1]
Aalborg University Copenhagen
Denmark

J. R. Bruun-Pedersen
Aalborg University Copenhagen
Denmark

N. Svarre Kristensen
Aalborg University Copenhagen
Denmark

L.B. Andreasen
Aalborg University Copenhagen
Denmark

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ABSTRACT

Universities are showing a new and stronger focus on developing teaching and learning environments, using digitalized support as well as re-organizing teaching and learning structures. Connected to the research project *Future directions for PBL in a Digital Age*, we are focusing on the organization of courses and projects within one semester. The general semester structure at Aalborg University consists of three parallel courses and one project module. A consequence of that model has been that interaction between study activities has become less coordinated, and integration between courses and projects has diminished. This lack of integration is a key focus of this paper, and the main research questions are; do students and teachers find that courses and projects need to be more integrated? What are students' experiences regarding integration of courses and project work, and how do they see the benefits and concerns? To answer the questions, we have conducted a survey among students at a case semester. The survey opened up for integrating students' experiences in developing new teaching and learning strategies.

[1] Corresponding Author: L. Busk Kofoed, lk@create.aau.dk

1 INTRODUCTION

The problem-based learning (PBL) model at Aalborg University is known for a strong emphasis on learning through students' own projects, supporting a mix of collaboration skills as well as subject specific skills, through an integrated structure of course work and project work [1], [2], [3]. The PBL approach is based on 9 guiding principles which are reflected in teaching, supervision/facilitation and project work [4]. Although the AAU PBL-model is a distinctive feature of AAU, the principles have been challenged in recent years, where lack of resources has meant that it has been difficult to unfold curricula accordingly, and to introduce the basic PBL principles in students' learning processes [5]. A new research project, *Future Directions for PBL in a Digital Age* is carried out from 2017-20 at Aalborg University (AAU) Denmark, with an overall aim to review and challenge the AAU PBL model [6]. One of the research questions is connected to integration of courses and students' projects. Traditionally, a semester is equally divided between courses and project work – both running in parallel during a semester. However, a current tendency is that many courses require extra time, thus taking necessary time away from students' semester projects [7]. We consequently consider it an important challenge to reestablish a better interplay between courses and students' project work. This paper will focus on students' experiences, benefits and concerns, regarding integration of courses and project work. The study will deal with the 4th semester at Medialogy at the AAU Copenhagen campus, and will primary be based on experiences from 5th semester students (the previous 4th semester).

2 COURSES AND PROJECTS

The AAU principles related to problem-based and project-organized work implies a structure for the educational programs at the university where half of the semester is used on courses and half of the semester is used on student-led project work (semester projects). While there are specific differences regarding the structure between different programs, the courses are meant to support the semester projects, in which a high emphasis is placed on students working problem-based and project-organized. The AAU learning strategies and pedagogical ideas of active, social and student-centred learning, has to be integrated in both course-work and project-work, but with a tendency where course activities take too much time away from the semester project work, the balance in the AAU model is influenced. It is important to sustain the PBL project-work, but also to keep improving the possibilities for students to use their courses in new ways. One example is to keep improving students' ability to apply and test theories and methods learned in courses, in their semester projects [4]. This is a unique possibility for students' learning processes, and central to AAU's PBL model. However, we conducted a small pilot survey (June 2018), where 19 students from Medialogy 4th semester were interviewed about several aspects from one course (Audio Processing). To the question, if the students had used elements from the course in their semester projects, 17 of the 19 students answered "no" or "not really". Qualitative responses showed students' reasons for not using course elements in the project, stating that they were not considered relevant (or very far from the project). A few students added "*we could have used it, we just didn't*" [7]. While the limited sample size is not representative for the university programs, it suggests a very concrete problem within its PBL model, where students do not automatically integrate knowledge from the courses into their project work. Possible explanations could be that it is too difficult to integrate courses and projects because of lack of time for implementation, or that the structure of a semester does not inherently support the interplay among courses and projects, but rather the individual isolation of each.

When looking at a semester design like 4th semester at the Bachelor program of Medialogy 2018 (figure 1), we see how courses, activities related to courses, and exams are spread out during the semester. The study intensity for such semester is 30 ECTS, which is converted to approximately 825 hours of work (1 ECTS = 27.5 hour). For the 4th semester at Medialogy, it means that the study intensity for 3 courses of 5 ECTS each, sums to 412,5 hours of expected work. The exact same workload is prescribed for the semester-project, per student. Students are expected to work on their semester project in parallel with the courses [8]. The way students are using their study-time is based on their individual choice. However, there are some study-activities, which are fixed, both content- and calendar-wise, between exams, course assignments, mini projects and semester project work deadlines. There also are some expectations. Course teachers e.g. expect that students do prepare (homework) according to the course plans, and participate in course exercises. Students need to organize their study time according to the semester plan, as illustrated in figure 1, and coordinate the different activities connected to courses and semester group work. This often is a challenge, as the difficulty levels of the activities may be experienced differently between students and teachers. The way students experience a semester is very important for our main questions: 1) How can the courses be integrated in the semester projects, and how can the semester projects integrate the course elements and at the same time improve students' learning process? 2) How do students see possibilities of integrating courses and projects?

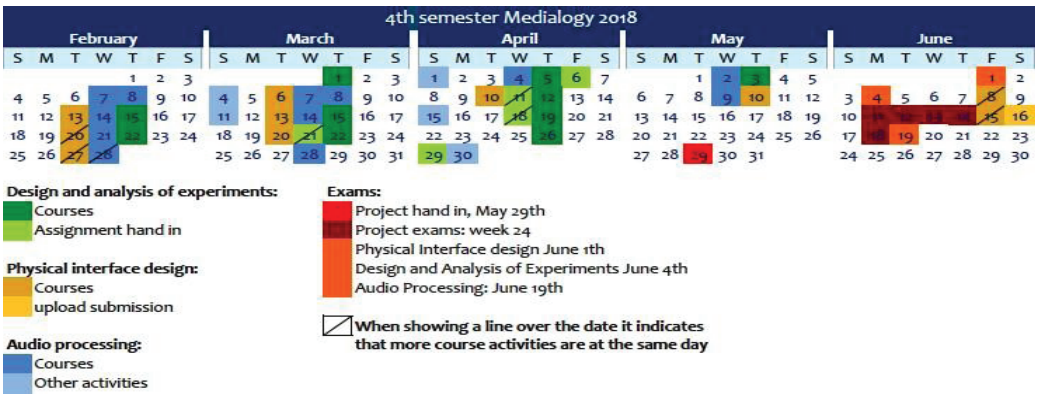

Figure 1: Semester plan activities at 4th semester Media-technology (Medialogy) at Aalborg University [9]

3 METHODS

3.1 Data collection

We have used an explorative case study approach [10], [11], [12] to investigate the context and content of a 4th semester, as background to investigate students' experiences about their Medialogy 4th semester. Included in this context were the study regulation, and students' grades in courses and projects. The parameters of these aspects were reflected in the survey questions, that had space for qualitative explanations to supplement the quantitative answers. The study explored the students' experiences about courses and semester projects, within the semester curriculum and structure. The following parts were addressed:

- Relation between course curricula and projects
- Workload related to courses and projects
- Students reflections on the 4th semester

In order to acquire data about students' experiences of their 4th semester we distributed a questionnaire to all 5th semester students (previous 4th semester) in autumn 2018. The data were analyzed according to the importance of the following questions:

1. Did project work support understanding of courses, and how easy were the courses to transfer to projects? Those questions were followed by the respondents' qualitative explanations of the answers.
2. Did course teachers make it easy to understand how the courses could be integrated in the projects? This question were followed by qualitative comments and explanations of the answers by the respondents.
3. Workload related to the 3 courses, the projects and exams.

Finally, students were asked to comment specifically on the questions of why there were generally given higher grades for project exams than for course exams, and they were encouraged to reflect generally on their 4th semester. We distributed a questionnaire divided in 3 parts: relationship between course curricula and project; students' workload in courses and project; and closing reflections. The parts included 10 quantitative items asking for ratings, and 4 qualitative items, asking for elaborating comments on specific rating types, or for reflections on certain topics. The qualitative additions were rich and added important insights.

4. RESULTS

In the following, the results from the questionnaire are presented. The quantitative items asked students to rate their answers on a 7-point scale (e.g. 6 being very high and 0 being none or very low). 38 students (out of 61 on the semester) completed the entire questionnaire, whereas 6 students completed all but the final part 3 (closing reflections). As part 3 is all qualitative, we had n=44 respondents to all quantitative items. For an overview of all 10 quantitative items, see **table 1** in the appendix.

Part 1 are analysed within the frame of the main question on students' experiences about integration of courses and project work. The name of the three courses are: Audio Processing (AP), Design and Analysis of Experiments (DAE) and Physical Interface Design (PID).

4.1. PART 1: Relationship between course curricula and project

Q1: ***How important were the individual courses for your project?***

- AP course: rated 6 by 24%, 5 by 13% and 2 to 0 by 34%.
- DAE course: rated 6 of 37%, 5 by 26% and 2 to 0 by 8%.
- PID course: rated 6 by 39%, 5 by 16% and 2 to 0 by 30%.

Q2: ***How important was your project to support your understanding of the individual courses' content?***

- AP course: rated 6 by 13%, 5 by 5% and 2 to 0 by 35%.
- DAE course: rated 6 by 37%, 5 by 37% and 2 to 0 by 6%.
- PID course: rated 6 by 18%, 5 by 13% and 2 to 0 by 37%.

Q3: ***How easy was the course content (lectures, homework, practical exercises) to transfer/use in your project?***

- AP course: rated 6 by 5%, 5 by 13% and 2 to 0 by 32%.
- DAE course: rated 6 by 39%, 5 by 29% and 2 to 0 by 6%.
- PID course: rated 6 by 16%, 5 by 26% and 2 to 0 by 29%.

Across the Q1, Q2 and Q3, the DAE course differentiates itself among the courses, being consistently rated highly by most students, as important for the project, supported by the project, and easily transferrable to the project. The PID course is less consistent on the importance of the course for the project, being rated both high and low by many students, but, interestingly scoring consistently low ratings by many students, in terms of its support for course understanding, and transfer of the course to the project. The AP course followed the trend of PID, albeit much lower ratings.

Q4: ***Qualitative student reflections for low Q1, Q2, Q3 ratings:***

All students rating 3 or lower, were asked to comment on their specific rating. The comments cover several aspects. Some of the main problems seem to confirm previous tendencies; that courses were not relevant for the projects: *"We did not apply the theory learned in the course at all because it was not relevant".* Another issue was that the difficulty level in courses was perceived to be too high, making course topics too difficult to fully comprehend, compared to the perceived benefits to the project. There also seems to be a negative loop, where course material is disregarded per default, if not understood to be supportive of the project: *"The courses were hard to transfer as it covers so much and can be hard to follow", "It was too difficult, and we did not have much use for it in the semester project, as we did not put much focus on it".* Finally, some students mentioned that the timing of the course did not fit with the project process: *"The DAE course had some lectures very late in the semester which was very essential to the progress of making the project…we wish we had some of the later lectures, earlier, which would help us form the report in a different way".* Interesting is that some students seems to combine courses with a lot of self-studies: *"We did not actually use any of the course material (except maybe a general understanding) and generally haven't in a single of the semesters. We go out of our way to find the suitable tests and research them on our own, and our problems, solutions, implementations etc. are never close to anything presented in class".*

Q5: ***To which degree did the course teachers make it easy for you to understand how their courses could be integrated into the project*?**

- AP course: rated 6 by 5%, 5 by 8% and 2 to 0 by 43%.
- DAE course: rated 6 by 51%, 5 by 24% and 2 to 0 by 5%.
- PID course: rated 6 by 11%, 5 by 16% and 2 to 0 by 5%.

Here, DAE is very highly rated by students (with over half awarding 6), PID shows neither very high or low ratings, while AP receives many 0-2 ratings as the only course.

Q6: ***Qualitative student reflections for high Q5 ratings:***

All students rating 4 or higher were asked to comment on why they had this impression, for insights to how teachers succeeded to integrate courses into projects. Comment themes included: using lots of examples in courses; practical exercises; a clear structure in the courses; and the direct applicability in projects. *"Course teachers can use projects as examples to explain how to understand and implement course knowledge in projects", "We were given examples that incorporated both courses in a project", "The whole theory of statistics was nicely presented and the math, although complicated, was thoroughly worked with in both practical exercises and with many wonderful videos that supplemented my learning. This is the best course I had so far on the entire education", "The teachers made it super easy with their ways of explaining the courses and helping us to relay them into the course project", "DAE specifically was constantly emphasized to be relevant for the semester project, with lots of examples, practical exercises and a clear structure".*

Q7: *To which degree did your supervisor encourage you to connect course content from the individual courses, to the project?*

- AP course: rated 6 by 24%, 5 by 19% and 2 to 0 by 19%.
- DAE course: rated 6 by 22%, 5 by 11% and 2 to 0 by 24%.
- PID course: rated 6 by 16%, 5 by 19% and 2 to 0 by 37%.

For all courses, some students felt encouraged to connect course content to the semester projects. However, a group of students did not experience this across the courses, which isn't reflecting the intended supervision experience of the AAU model.

4.2. PART 2: Workload between courses and project

Q8: *How would you rate the workload for homework and self-studies for each individual course?*

- AP course: rated 6 by 3%, 5 by 19% and 2 to 0 by 24%.
- DAE course: rated 6 by 5%, 5 by 22% and 2 to 0 by 13%.
- PID course: rated 6 by 8%, 5 by 5% and 2 to 0 by 52%

Q9: *How would you rate the workload for course exams incl. preparation?*

- AP course: rated 6 by 46%, 5 by 32% and 2 to 0 by 3%
- DAE course: rated 6 by 46%, 5 by 20% and 2 to 0 by 8%.
- PID course: rated 6 by 30%, 5 by 30% and 2 to 0 by 14%

Between Q8 and Q9, a clear discrepancy shows between students' highest effort, with only few students working hard on the course curriculum during the semester, and a much higher number putting high effort post-project, to comprehend the courses.

Q10: *How would you rate the workload for project related group work?*

- Rated 6 by 46%, 5 by 24%, and 2 to 0 by 3%.

More than half the 4th semester students report a maximum or high effort during groupwork-based project work, with nearly none reporting low effort.

Q11: ***How would you rate the workload connected to individual self-study, individually, in group room, home or other places?***

- Rated 6 by 16%, 5 by 19%, and from 2 to 0 by 19%.

For individual work on project related things, fewer students give high ratings, and more give low ratings, compared to in-situ shared group-work.

Q12: ***"Workload connected to project exam, including preparation"?***

- Rated 6 by 32%, 5 by 30%, and 2 to 0 by 14%.

Many students report high effort in the (often group-collaborative) project exam preparations. The scores reflect the course exams, but different from courses, they also reflect the effort found in group-work activities.

4.3. PART 3: Closing reflections from the students

Q13: ***Student reflections on the relationship and difference in grades between projects and courses***

While most students rated the workload of the course- and the project exams very similarly, students were asked into their opinion on the relationship and differences between these, based on a background dataset, showing that students' projects received much higher grades than their course exams. The reflections students did for this question circled on three aspects:

- The difference between courses and projects, and their individual exams.
- The perception of grading, between courses and projects.
- The different ways of learning via courses and projects.

Many students mentioned that teachers' expectations towards students' learning ability, had great importance: "*The courses take up too much time and carry too high expectations, for the time allotted, while most effort seems aimed towards the project*".

A similarly striking statement came in the form of *"We were able to get a very good grade for our project by using very little course material. But very low grades for the courses. There are bigger expectations for the course exams"*, suggesting that the experienced level required for a high project grade is lower than the courses. In addition, another tendency showed that some students believe that using course material in the projects, mean nothing for the project grading: *"Project work seems more motivating for the students and it seems easier to get good grades".* Some also consider projects as more important from a career perspective, and are therefore considered more attractive to excel, compared to courses: *"It seems that people want to focus on the projects as it is something one could add to their portfolio and making a good project only makes it better. This takes some of the focus away from the courses to an extent where they become guiding aspects for the project rather than important knowledge for Medialogy students".* As seen in the previous ratings, the collaborative, interdependent and supporting aspect of project work is considered a big motivation factor: *"the motivation of group work is big factor, where students can rely and ask each other. The actual courses are solely dependent on the individual".* The aspects above are logically reflected in the following statement on coursework:

“Courses require significantly more of the individual, not only in the workload but in the individual dedication to the courses”.

Q14: *Students’ recommendations on how courses can support projects - or how projects can support courses*

The students’ recommendations are very practically oriented and even quite feasible. Some suggest project-based courses, courses based on mini-projects, or for courses to include the projects more in course assignments: *“More project-based courses, so you are making smaller projects that use the course material, making it more motivating. Learning by really doing”. “Courses should include the projects more in assignments (both mandatory and obligatory), that way student might see the threads connecting the courses and project more clearly. Of course this might be difficult to implement, as people have very different projects but I really think it could have helped our projects throughout the education”. “Project work is great, maybe force the projects to have more core concepts from the courses”. “The semester project theme suggestions are nice to show some potential ideas or to give direction. The teachers and supervisors should be on the same page if and to what extent the course content should be included in the semester project”. “More emphasis on course inclusion - eventually a supervisor reminding us of the fact that they all more or less need to be included”.* The recommendations are dealing with aspects of integrating courses and projects, where project work is seen to be able to bring passion and motivation into *both* courses and project-work. Some recommendations also mention the role of the supervisor/facilitator, as a supporting agent of integration for course and project. And the importance for teachers and supervisors to align 'on the same page'.

5. DISCUSSION AND CONCLUSIONS

When looking at the results, they confirm previous tendencies; that courses are perceived to be less relevant to projects. Remembering how the AAU PBL model frames courses as the foundation of the project content and academic workload, it is alarming that so many students rate the courses' relevance for the project this low.

In the qualitative responses, we see that students have many reasons for not prioritizing the integration of courses and projects. Workload ratings for courses suggest that courses are not deemed necessary for the projects, as otherwise, they would not need to study as hard for the exams. Arguments include not believing integration or transfer to be necessary, and not perceiving the urgency from the teaching staff (including supervisors). Some students even state that they do not believe that the project needs any course content. To learn 'useful skills' directs Medialogy students' effort and motivation to learn. From our results, students perceive projects as useful learning, for developing their individual portfolios. This partly cements the projects' priority amongst many students, and also arguably illustrates why the courses do not receive similar priority. The transfer of knowledge happens when found useful by students. In this case, transfer means integration between courses and project, ideally with transfer of knowledge between both. However, students generally, ironically, do not see that relationship or potential. While this could be considered a serious issue from a Medialogy-program centric point of view, the case could also be less so, and more an issue of succeeding with the facilitation and management of the course-project integration. Such effort is important for upholding and developing the AAU Model, and to support quality of what students clearly enjoy, and are motivated by the most.

Upholding the AAU model on a semester is no trivial task. It is partly an issue from a semester coordination and management perspective, to define and set clear curricula goals from the semester's overall learning goals, and make them fit holistically with each other. In our results, we get several recommendations from students to improve such integration. They request examples, exercises, structure and direct application in projects. While these are logical guidelines to integrate courses into projects, it also requires the project scope to be manageable from a course planning perspective. If students are free to take their project in a wide range of directions, no course will ever be able to show relevant examples, hit relevant exercises, or provide knowledge that directly applies to projects. In this case, it seems that a possible barrier for the possibility of integration, has been not limiting the specific project framing sufficiently in scope. Students' recommendations also suggest, that if the project direction is managed sufficiently, forming a connection for integration should not be exceedingly complicated; from examples of project application, to the activation of students in-class through practical exercises for more cultivation and familiarization with course material. All should benefit students' transfer of knowledge and integration between courses and projects. Students also mention the importance of courses' timing through the project phases, and having a clear structure of the course. For integration, *timing* the project and course refers to a 'transfer window' so to speak, where students are able to both comprehend material and see its application (or integration) potential. If arriving too late in a course, students will have missed the chance, or been forced to move on from the possibility of implementing it into the project. Meanwhile, extending this 'transfer window' may be achieved through, exactly, a clear and transparent *course structure*, that ideally maps itself to the faculty's overall directions and expectations for the project's progression curve. Students should obviously not be expected to fully comprehend such mapping prematurely. It could be introduced at semester start, and be referenced regularly in all courses, to grow with students along the semester. Students could use the overview to foresee possible 'transfer windows' for integration of course material in the project.

Another central theme in the results, is the high workload effort in all group-based activities. When students meet and collaborate, e.g. in projects, qualitative responses suggest a shared experience of mutual stake and accountability. This could indicate that it's not so much about the project, but about the collaboration. The lower ratings on performing project work individually, would support this to a certain degree. In this sense, projects are largely different from the highly individual-oriented courses, where the individual student's workload has to be undertaken outside collaboration. And while exam workloads are similar between courses and project, students' ratings show a very different effort during the process leading to the respective exams. In our results, students report that courses tend to require more from the individual dedication to the courses, and that courses require a higher level to pass, compared to the projects. Within these statements lies a potential consideration for rebalancing the (perceived) coursework requirements opposite students' impressions of project work requirements, but the premise is highly relative and unclear. Project work could easily be equally demanding, but dismissed as so, being driven by motivational factors such as autonomy and group collaboration factors previously mentioned. This supports the need for well-implemented course-project integration, bringing the course content and workflow closer to the project work.

Meanwhile, our study has shown that there are students who find the courses relevant in relation to their project work, and who also find that teachers have been keen to find examples and cases which students could relate to. Each course is different and students have rated them differently. Where some students find them too hard to understand, it may be due to a lack of the required knowledge from previous semesters, or because students focus on their most difficult course in a comment, forgetting about the other courses. The workload related to the daily course activities was graded to be less than the workload when preparing for both course- and project exams that was graded to be very high. This could be because the semester structure/activities did challenge both students as well as teachers' ability to manage time and activities connected to both courses and projects. It is also important to mention that while our results look at the specific 4th Medialogy semester, it is very likely that students' attitudes do not only stem from the 4th semester, but also from previous semesters. This points towards upholding the AAU model consistently through all semesters. Developing a culture where students are confident in the relevant role of both courses and project is imperative. Sustaining it is just as imperative. Consistency is necessary across all semesters for a model such as AAU's to work. If not kept throughout, students will adapt to the premise they see in front of them, according to their own interests and gains, as it shows from our results. This study has shown that there are several possibilities to integrate courses and projects in a teaching and learning strategy. The students had good reflections and recommendations. Other possibilities include a semester model using more digitized support in a blended learning strategy, perhaps via student-teacher co-creation workshop, for designing a new semester as a democratic process, with both students and teachers as experts.

6. Acknowledgements

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Appendix 1, Table 1 - Quantitative results overview

v	Question	Course	6	5	4	3	2	1	0
Q1	How Important were the courses for your project?	Audio Processing (AP)	24%	13%	26%	3%	13%	18%	3%
		Design and Analysis of Ex-periments (DAE)	37%	26%	21%	8%	3%	5%	0%
		Physical Interface Design	39%	16%	13%	3%	3%	11%	16%
Q 2	How important was your project to support your understanding of your course content?	Audio Processing (AP)	13%	5%	13%	13%	21%	26%	8%
		Design and Analysis of Ex-periments (DAE)	37%	37%	13%	8%	3%	0%	3%
		Physical Interface Design (PID)	18%	13%	18%	13%	8%	8%	21%
Q3	How easy was the cou-rse content (lectures, home-work, practical exercises to transfer to your project?	Audio Processing (AP)	5%	13%	47%	3%	11%	16%	5%
		Design and Analysis of Ex-periments (DAE)	39%	29%	24%	3%	3%	0%	3%
		Physical Interface Design (PID)	16%	26%	29%	0%	11%	5%	13%
Q4	To which de-ree did the course teachers make it easy for you to understand to integrate courses?	Audio Processing (AP)	5%	8%	19%	24%	27%	11%	5%
		Design and Analysis of Ex-periments (DAE)	51%	24%	8%	11%	5%	0%	0%
		Physical Interface Design (PID)	11%	16%	24%	30%	8%	5%	5%
Q5	To which degree did your supervisor encourage you to connect course content to your emester project?	Audio Processing (AP)	24%	19%	24%	14%	16%	3%	0%
		Design and Analysis of Ex-periments (DAE)	22%	11%	30%	14%	5%	14%	5%
		Physical Interface Design (PID)	16%	19%	11%	16%	5%	11%	22%
Q6	Workload: Homework and selfstudies related to courses?	Audio Processing (AP)	3%	19%	35%	19%	16%	5%	3%
		Design and An-lysis of Expe-riments (DAE)	5%	22%	32%	27%	5%	8%	0%
		Physical Interface Design (PID)	8%	5%	11%	24%	11%	27%	14%
Q7	Workload: Exam incl.preparation	Audio Processing (AP)	46%	32%	14%	5%	0%	0%	3%
		Design and An-lysis of Experi-ments (DAE)	46%	20%	24%	3%	8%	0%	0%
		Physical Interface Design (PID)	30%	30%	11%	16%	14%	0%	0%
Q8	Workload: Project group work	Meetings, communication, collaborative activities	46%	24%	24%	3%	3%	0%	0%
Q9	Workload: Self-study for project	Studying individually in group rooms, home or any other place	16%	19%	35%	11%	16%	3%	0%
Q10	Workload: project exam	Including preparation	32%	30%	16%	8%	11%	3%	0%

Stretched Too Much?

A Case Study of Engineering Exam-Related Predicted Performance, Electrodermal Activity, and Heart Rate

D. Christensen
Utah State University – Engineering Education Department
Logan, Utah

M. T. H. Khan
Utah State University – Engineering Education Department
Logan, Utah

I. Villanueva[1]
Utah State University – Engineering Education Department
Logan, Utah

J. Husman
University of Oregon – Education Studies Department
Eugene, Oregon

Conference Key Areas: New notions of interdisciplinarity in engineering education

Keywords: Electrodermal activity, performance, engineering, exam, heart rate

ABSTRACT

Test writing is one of the essential activities that university faculty must do. Evidence-based instructional practice indicates that the exam content and difficulty should match the content taught in the course. Many faculty, however, hold the belief that tests should "stretch" students to tease out the best students or to extend content beyond what is covered in a course. In this case study, we explored if exam items, which are in the scope of the course but are "a stretch," affected engineering students' ability to self-monitor and reflect on performance. We compared and contrasted two examination experiences from the same engineering statics course. In scenario one, students recently learned a concept, and their practice exam reflected that content. In scenario two, students had yet to learn the concepts contained in the practice exams, but the concepts were related to the course. We explored this from a pre- and post-dicted expected performance, actual performance, and physiological response (electrodermal activity and heart rate) perspective for 26 engineering students.

This research examines the relationship between expected performance, actual performance, time per question or exam, and arousal response. Findings suggest the pre- and post-dicted expected performances may influence physiological responses (e.g., electrodermal activity and heart rate), which may not necessarily support students' actual performances on the exam.

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[1]Corresponding Author
I. Villanueva
idalis.villanueva@usu.edu

Introduction

The Centre for Teaching Excellence at the University of Waterloo [1] states that “A good exam gives all students an equal opportunity to fully demonstrate their learning.” The complexity lies in determining what a good exam looks like. What content does it contain? How difficult is too difficult? The question about the difficulty of an exam becomes more prominent in fields like science, technology, engineering, or math (STEM); for example, in engineering, the typical weed-out culture in the field leads to high expectations, many times evidenced in the form of very challenging exams [2].

Vygotsky defined the zone of proximal development as the zone where students cannot necessarily do something entirely on their own but can achieve mastery with encouragement [3]. Transferring this to exams, exams can be an experience that is knowledge building or disabling depending on how much the students are expected to “stretch.” In cases such as engineering, we suspect the latter may be present. One main motivation for this study was to determine the effect that exam experiences have on the performance of engineering students in near-real-time. Through physiological biometric tools, we hope to understand better how these engineering students respond to and react to different exam approaches and situations. The results from this study can better inform instructor formation of assessments and help educators understand what may “stretch” engineering students too much.

THEORETICAL FRAMEWORK

Pre- and Post-dicted Performance

A limited number of scholars have explored the relationships that student performance predictions (both ‘pre-dictions’ before the exam and ‘post-diction’ after the exam) had with the actual performance on exams. For example, in a study by Hacker et al. [4], researchers explored student pre- and post-dictions in an introductory educational psychology course at a mid-southern university (N=99 undergraduates). Students who answered more than 70% of test questions correctly had closer pre- and post-dictions of their actual exam scores than those answering fewer exam questions correctly. Students who answered less than 50% of test questions correctly were overly confident in their pre- and post-dictions [4]. It is important to note that the exam given to the students was within the scope of content that was familiar to them because it had been introduced in class previously [4]. To our knowledge, there is a lack of studies exploring student pre- and post-dictions on exams whose content is within the scope of the course but are outside the content that has been covered in class (referred to as a “stretch”). This study will explore pre- and post-dictions for the student in a “stretched” situation. Also, we will explore how students react to the “stretch” scenario near-real-time during the examination experience through physiology based techniques (e.g., electrodermal activity, heart rate).

Electrodermal Activity and Performance

Due to the development of wearable sensors, continuous skin conductance levels can be recorded in near-real-time scenarios [5], which is attractive to educational researchers. A commonly used signal that measures physiological arousal from the electrical conductivity of the skin is the electrodermal activity (EDA) [6]. EDA is a measure of the activity within the sympathetic (fight/flight system) autonomic nervous system [6]. EDA data can be divided into phasic (stimulus-specific and immediate) and tonic (baseline) forms [6]. Phasic EDA evidences physiological arousal, indicating a cognitive activation or emotional strain [6].

EDA has been reported to be a function of task difficulty, with lower levels of arousal measured when the problem is more difficult [7]. It is assumed that this limited rise in arousal may have to do with inhibitory control [7], which is the ability one has to resist distractions and give full attention to the relevant stimuli due to increased cognitive load [8].

Changes in EDA can provide insight into understanding student performance [9]. High skin conductance indicates an increase in arousal, which is significantly positively correlated with peak performance [10]. Both the studies previously stated dealt with sports and video games, but significant correlations have also been found between academic performance and EDA responses [5]. There is a lack of studies of academic situations when students are not familiar with exam content. This study aims to explore further this phenomenon through a closer examination of the relationships between EDA, expected performance (as reported by the student), and actual performance in both a context where students are familiar with the exam content and a context where the students have not yet learned the exam content.

Heart Rate and Performance

Heart rate has been investigated as an indicator of student stress during various academic activities [11]. It has been found that anxiety is a strong influencing factor for heart rate increases with exams [12]. Heart rate can give insight into the magnitude of stress experienced by students [11] while participating in an exam experience. It has been found that student heart rates can be about 35% higher during an exam than during lecture and a 26% increase in heart rate was observed while students were receiving the results of an exam [11]. During a French oral exam (N=23 first-year college students), a significant positive correlation was found between average heart rate and performance [13], but during a driving test (N=13), a significant negative correlation was found between average heart rate and performance [14]. This suggests that attentional and cognitive shifts may affect or even reduce changes in an individual's heart rate [15]. Since there is a gap for written exam performance and heart rate, this study also sought to determine the relationship between heart rate and performance during a written exam with differing testing scenarios.

METHODS

All procedures were approved by the Utah State University and University of Oregon Institutional Review Board (IRB) offices for studies on human subjects.

Research Design

This study involves a customized experimental setup that includes a laptop computer interfaced with two web-cameras, a customized timestamping program created in MATLAB, and a customized exam protocol, which recorded student responses as well as the time it took the students to respond to the questions. A representative experimental timeline can be found in *Fig. 1*.

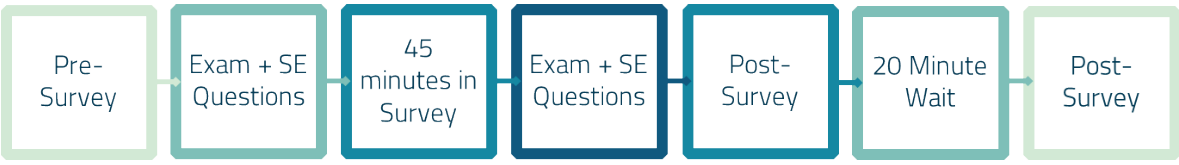

Fig. 1. Experimental timeline for the research study. Survey questions refer to a set of self-efficacy (SE) questions relating to student confidence on individual questions. These questions are not covered in this study.

Our research study focuses on the comparison of one set of students that took an exam with content that had been covered in the course (control group) against one set of students that took the same exam, but the students had not yet covered the content in class (experimental group).

Hypotheses

In this experiment, we hypothesized the following:

H1: Predicted performance by students across the exam will decrease with the magnitude of change being greater for the experimental group compared to the control group.

H2: Time spent on the exam for the experimental group will be significantly less than the control group.

H3: EDA arousal intensity will show lower arousal responses for the experimental group compared to the control group.

H4: Heart rate will be higher for the experimental group and will increase across the exam in comparison with the control group, which will have lower heart rates and will decrease over the exam

The rationale for these hypotheses stems from the findings stated in the theoretical framework. It is expected that students who are in the “stretch” or experimental scenario will face lower arousal because of the increased difficulty since the problems are not familiar, leading to inhibitory control [16]. The experimental group is expected to have a higher heart rate due to higher stress and anxiety resulting from a lack of familiarity with content [11-12]. More significant decreases in predicted performance will be evident in the experimental group since the actual performance is expected to be lower because of the lack of familiarity with the content. Less time will be spent on exam questions for the experimental group because they are not familiar with the content of the exam, though it is within the scope of the class.

Exam Context and Participants

For this study, an engineering statics course was chosen since it is historically the first engineering course that students across multiple engineering majors are required to take in colleges of engineering in the U.S. [16]. This study was conducted on a U.S. western institution of higher education with a higher than average non-traditional, first- generation, and rural student enrollment [17].

The statics course has three midterm exams and one final exam. This analysis focused on the content of the third midterm exam in Fall 2018 and Spring 2019, which was around week 12 of a 16-week semester and whose length and difficulty paralleled the actual exam. The practice exam contained 16 multiple-choice questions, which required some data analysis before selecting a response.

Students were recruited to take a practice exam one week before their actual exam for this research study from an engineering statics course in preparation for their actual exam. As an incentive, students were offered extra credit (decided by the instructor) and a $5 gift card (provided by the research team). Attending this study also fulfilled the class assignment requirement for completing the practice examination. This work- in-progress study shows a case of 13 participants from Fall 2018 who took Exam 3 after learning the content in class (control group) and 13 participants from Spring 2018 who took Exam 3 before learning the content in class (experimental group). Even though participant numbers are small, the amount of data collected and processed was very high, as explained in the sections below.

Experimental Setup

Students are situated at a station featured in *Fig. 2.* As shown in *Fig. 1*, the students take a series of surveys throughout their multiple-choice exam. Additional time is allotted on the exam to account for the time expended during survey taking. In the pre- and post-survey, students self-assess their performance as their predicted percentage of correct answers in the exam.

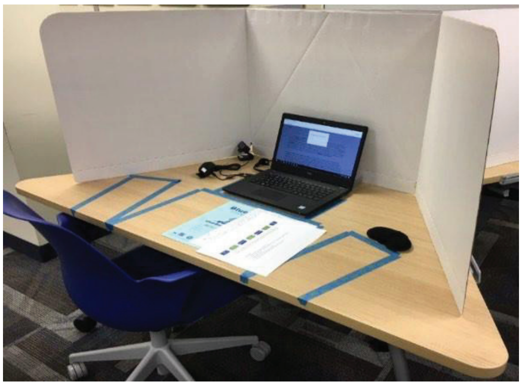

Fig. 2. Individual participant experimental setup for the research study.

Correct responses to each exam question were collected from the course instructor (who designed the practice and actual exams in the course), and performance data were collected from each student via our custom- created program. Students' perceived life stress was self-reported using the validated Perceived Stress Scale from Cohen, Kamarck, and Mermelstein [18].

Electrodermal Activity and Heart Rate Collection

During the entire duration of the exam period, EDA signals were collected from each participant at a rate of 4 Hz for ~2-hour exam (~28,800 data points per student) via an Empatica E4 wrist sensor (Empatica, Boston, MA). After collection, the EDA data must be cleaned, which was done according to a customized protocol [19-20] that filters out sources of noise in the data due to hand or body movement. To compare across the semesters, the EDA data (in the form of arousal intensity or the number of peaks) was normalized by time spent on each question of the exam. Heart rate was collected by the same sensor at 1Hz, which is slower compared to EDA data collection.

Ecological Validity

The ecological validity in this experiment was maintained by closely resembling the students' actual exam conditions. The students were provided with the same equation sheet, which was developed by the instructor, given in the actual exam. The workbooks were similar to what is offered in an actual exam. The test content was an electronic subset of practice test questions developed by the instructor, which paralleled the content and structure of the actual exam. The same amount of time was given for exam time (extra time was allotted for surveys). The actual exam that students take is also administered on a computer.

Statistical Analysis

To compare differences within a semester, a paired one-tail t-test analysis was conducted for time, EDA, and heart rate. Single factor ANOVA was used to compare the two semesters. To identify correlations between each variable, linear regression was used across the two semesters.

RESULTS

The time spent on the exam was compared between the fall (control group) and spring semester (experimental group). We found a significant decrease in time spent on the exam between the two-time points ($p<0.001$). For EDA, the number of peaks were normalized by time and then compared. There was a statistically significant difference between the experimental and control group ($p<0.001$). For heart rate, there was not a significant difference found ($p=0.278$). Interestingly, when comparing expected performance across the two groups, we found that between pre- and post- predictions, there was a ~14% (control group) and a ~29% (experimental group) self-reported reduction in their expected performances to the exam when comparing the pre-dicted and post-dicted conditions ($p<0.01$ and $p<0.001$, respectively). Finally, actual performances on the exams were compared between the control and experimental group. The actual performance for the experimental group was found to be nearly 12% lower than the control group ($t=2.72$; $p<0.05$).

To further explore the EDA arousal intensity statistical differences, a comparison of the number of EDA peaks on correct questions versus incorrect questions was performed for each semester. For the control condition, there was a statistically significant difference between the EDA peaks ($p<0.001$), but not a significant difference for the experimental condition ($p=0.1139$). The EDA arousal intensity was further explored by comparing the number of EDA peaks on incorrectly answered questions between the control and experimental conditions. For both incorrectly and correctly answered questions, the control condition had a statistically significantly higher number of EDA peaks ($p<0.001$ and $p<0.05$, respectively).

Correlation analysis by linear regression was conducted between the control and experimental groups in terms of predicted performance and: (a) normalized EDA arousal intensity (number of phasic EDA peaks/time); and (b) heart rate. A weak but significant positive correlation was found between normalized EDA arousal intensity and predicted performance for the control condition ($p<0.05$). No significant correlations were found between pre- or post-dicted performance and EDA arousal intensity for the experimental condition ($p=0.274$ and $p=0.1524$, respectively) or between post-dicted performance and EDA arousal intensity for the control condition ($p=0.2160$).

When heart rate was compared to pre- and post-dicted performance, both control and experimental conditions showed statistically significant results. Under the control condition, both pre-dicted and post-dicted correlations were strongly negative ($p<0.0001$ and $p<0.001$, respectively). For the experimental condition, the predicted performance showed a strong negative correlation ($p<0.0001$) while the post-dicted performance was weakly but positively correlated ($p<0.05$).

Upon closer examination of the variables, we found no correlation between normalized EDA arousal intensity and heart rate under the control ($p=0.2025$) or experimental ($p=0.9240$) conditions. There were also no significant correlations when actual performance was compared with both predicted and post-dicted performance for the control ($p=0.2941$ and $p=0.4197$, respectively) or experimental ($p=0.3415$ and $p=0.1680$, respectively) conditions.

DISCUSSION

We found that there were overall decreases in both pre- and post-dicted performance and actual performance in both experimental and control groups with a larger magnitude of change in the experimental group suggesting that exposure and familiarity with the exam content do matter. This was also confirmed with decreased time spent on the exam by the experimental group due to unfamiliarity with the content. Literature suggests that if the cognitive load exceeds our processing capacity, individuals will struggle to complete the activity successfully [21]. It was interesting to find correlations with pre- and post-dicted expected performances for EDA arousal intensity and heart rate. The most interesting of these correlations was the finding that reduced EDA arousal intensity in the experimental group paralleled diminished performance. This suggests potential anticipatory influences on physiological and psychological constructs of emotions and stress [22]. If students come into the exam with high levels of stress and thinking their performance will be low, likely their physiological condition and actual performance will be affected. It is also possible that this may support the feedback mechanisms of the control-value theory [23] where individuals who may not have felt in full control of their exam experience may have some residual physiological and psychological responses lingering after the exam.

Collectively, the data suggest the importance of anticipatory and reflective processes during exam-taking, particularly as they relate to a students' well-being and behavior during these types of experiences. Overall, exam content that seemed to be a 'stretch' for these students did ignite differing physiological responses, which may have been reflective of their sympathetic nervous system responses (e.g., fight or flight) [6].

CONCLUSIONS & IMPLICATIONS

The data suggest that when students are placed in situations where their knowledge is 'stretched' beyond domains that are attainable to them, especially in high-stakes situations like exams, various physiological and psychological responses surface. This, in turn, influences the magnitude of change over time suggesting that their reactive physiological responses are not supporting their actual performance or expected performance, as evidenced by the 12% lower actual performance score for the experimental group and 29% reduction in the experimental group's expected performance.

Our findings point to the importance of understanding beforehand the implications of "stretching" students during an exam. Rather than responding to the "stretch" by trying harder, students put less effort into the exam. Over-stretching them may result in decreased performance and maladaptive psychological/physiological processes. If not handled appropriately, these decreases can lead to dire consequences (e.g., failure, drop-out). At the same time, identifying the proper zone by which to stretch students may potentially have a contrary effect such as positive performance outcomes and warrants more in-depth exploration.

This calls for instructors being mindful of how far students are being stretched, with a particular emphasis in assisting students to be ready for the exam experience. Students need an opportunity to assess what they know and what they do not know before an exam in a truly authentic way, such as an authentic practice exam during a laboratory, recitation, or study session. Instructors need to make sure to assess conceptual understanding so they truly know where the students are in the learning process, not just that they are doing well on homework.

One intended future aim of this work will be exploring advanced modeling (such as those based on machine learning) to develop a student prediction model based on various physiological response data (e.g., EDA, Heart Rate) on a higher population of participants.

LIMITATIONS

This study is limited in its sample size, which limits statistical power. Also, this study was conducted in a laboratory environment that, while it was ecologically valid, is still not representative of the full, high-stakes environment that students would experience in a real exam experience. Also, EDA is influenced by other factors other than movement such as temperature and humidity [6]; additional work is needed to identify if these factors may have influenced some of the findings in this data. We did not explore additional outcomes (e.g., self-efficacy, perceived life stress) that could have informed us more about how students coped with the two exam scenarios. Another limitation is that since students were not introduced to the exam concepts while in the classroom context, they may have been demotivated when continuing the exam. To fully understand the phenomenon we explored in this study, we would have to address different levels of content familiarity to understand this in more detail.

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Fit for Purpose? Engineering Educators', Teacher Training & Engineering Scholarship

R. Clark
WMG, University of Warwick
Coventry. UK

R. Penlington
University of Northumbria
Newcastly. UK

J Andrews
WMG, University of Warwick
Coventry, UK

G. Knowles
WMG, University of Warwick
Coventry. UK

Conference Key Areas: Managing Change in Engineering Education, Talent Management

Keywords: Engineering Education: Teacher Training: Confidence in Teaching: Skills & Competencies

FOREWORD: ***The Engineering EDGE Project:*** *The Study to which this paper refers to work that was undertaken by a collaboration of Engineering Educators from the UK & Ireland Engineering Education Research Network. Colleagues from 10 Engineering Departments contributed to the research tools and data collection. In alphabetical order, these colleagues are: Dr Esat Alpay (University of Surrey): Dr Jane Andrews (Aston University and then University of Warwick): Dr Jude Breton (University of York): Professor Robin Clark (University of Warwick): Professor John Davies (University of Liverpool): Manish Malik (University of Portsmouth): Dr Anne Nortcliffe (Christchurch Canterbury University): Ahn Tran (Coventry University): Dr Roger Penlington, (Northumbria University, Newcastle): Dr Peter Wilmott (Loughborough University). Additionally two colleagues have contributed towards parts of the analysis: Graeme Knowles, (University of Warwick) & Dr Suki Phull (Aston University).*

ABSTRACT

Drawing upon a small part of the findings of a large mixed-methodological research study, this paper starts by asking the controversial research question "Are Engineering Educators fit for Purpose?" In answering this question the study itself began with a critical analysis of the literature, something that is reflected in this paper. The articulation and definition of 12 key Engineering Skills, Competencies and Knowledge was undertaken at the beginning of the project based upon the undergraduate engineering curriculum taught at the 10 partner institutions.

Starting with the somewhat controversial research question "Are Engineering Educators' fit for Purpose?" this paper has some important implications for how Engineering academics are supported and trained to teach. It critically discusses the study findings and concludes by suggesting that it is high time that the Postgraduate Certificate in Education and HEA Fellowship Programme were both adapted so as to account for the distinctive issues associated with teaching Engineering & Applied Science.

1. INTRODUCTION

Deservedly viewed as a subject of considerable importance for the continued sustainability of our society, engineering has an invaluable role to play in the global drive towards a poverty free, equitable world in which each individual has access to the latest technological advances that engineering, science and medicine are able to offer. To assure a continual flow of well-trained young people able to work within today's fast-moving global engineering industry, university level Engineering Education is crucial for the development and dissemination of cutting edge engineering ideas, innovations and inventions. Yet, with increasing pressure on universities to provide a cost-effective, relevant and engaging education in which increasing numbers of students are offered high quality, individual educational experiences, the massification of Higher Education over the past two to three decades has resulted in Engineering Educators' progressively finding themselves subject to a multiplicity of simultaneous demands and expectations. The results of such unprecedented increased work levels in terms of colleagues' confidence to teach to a high standard remains largely undiscussed in the literature. It is this gap in knowledge that this paper addresses.

Set at a time when university level Engineering Education in across Europe and the globe is expected to satisfy the demands of a range of different stakeholders including current and future students, industry and employers, Professional Bodies, governments and universities, this paper represents an important turning-point in how Engineering Educators' experiences are viewed and recorded. Looking specifically at how individual colleagues facilitate the development of their individual professional and educational expertise, the purpose of the study was initially to explore and analyse the stresses associated with being an Engineering Educator. One of the most important variables examined was that of ‘**being trained to teach’**. It is this variable which is cross-tabulated with ‘**confidence in teaching key engineering skills’** and examined in this paper.

2. LITERATURE REVIEW

The literature covered in this paper is naturally limited when compared to the whole study. However, the two issues which are examined are both of high importance in setting the context for the data presented and issues discussed.

2.1 What is Engineering Education?

Representing the teaching of a mixture of engineering and scientific skills, competencies and concepts, contextualised across and within a divergent range of socio-economic, environmental and academic settings Engineering Education is somewhat difficult to define. Yet, when viewed holistically across a wide-range of educational and discipline specific sources of knowledge the literature begins to provide a sense of what the ‘large and unwieldy discipline’ that is Engineering Education actually is. For the purposes of the study upon which this paper is based the following definition was developed: “*Engineering Education involves a dualistic learning relationship in which engineering educators provide students with the means to acquire and hone a range of technical, practical and transferable competencies and skills with which to solve complex social, scientific and environmental problems’*[1].

A synthesis of core engineering, scientific and mathematical theories and concepts, university level Engineering Education needs to go beyond merely training new engineers. Indeed it needs to provide the ideal environment in which individual students can develop their creativity and critical thinking skills to adapt to a multi-disciplinary working environment in which they are able to use a range of complex higher order thinking skills and abilities to play a vital and continually changing role at the heart of our society[2,3,4,5]

2.2 Barriers to High Quality Engineering Education

The Engineering Education Research literature identifies a number of **teaching-related** barriers to the provision of high quality learning and teaching within the discipline. Such barriers include: Poor levels of knowledge amongst engineering colleagues with regards to the breadth and depth of available innovative and evidence-based teaching methods: Time pressures within the academic environment meaning there simply isn’t sufficient time for colleagues to spend on professional development in education: A lack of teaching skills and abilities in some colleagues: Shortages of innovative teaching resources, facilities and support for colleagues: Resistance to change by some individual lecturers: Constraints reflective of public and policy impacting student numbers, course design and funding: Inconsistencies and a lack of transparency within individual institutions in terms of tenure and promotion: The type and focus of individual institutions, particularly with regards to a tendency to favour research over teaching: Issues surrounding teaching evaluation, government measures such as the NSS, PTES and TEF: Excessive workloads, and a lack of recognition and reward for excellent teaching[6,7,8].

In addition to the above, a significant portion of the Engineering Education literature focuses on **student perceptions** of the barriers to high quality learning in engineering. This literature which suggests that the majority of students entering university to study engineering do so with little prior experience or knowledge of what the subject is about or what studying engineering will entail[9]. Other studies suggest that students' perceive that there are a number of **lecturer-focused** barriers to high quality learning in Engineering Education including: Poor explanations of key engineering concepts and theories in lectures: A lack of clarity in assessment: A failure to provide high quality feedback: Low quality learning materials: Failure to recognise good quality student work[10,11,12]

Whilst students' perspectives are generally limited to their immediate circumstances and will undoubtedly reflect individual experiences, prejudices and difficulties, there can be little argument that many Engineering Educators fail to engage with evidence-based teaching practice; remaining isolated from mainstream pedagogic theory and in some cases avoiding training programmes offered within institutions. Indeed, it is not unreasonable to note that rather than try and introduce innovation in the classroom, a considerable number of Engineering Educators prefer instead to continue with tried and tested 'traditional' teaching methods many of which fail to address the distinctive needs of today's learners[13]. It is this reluctance, combined with a curiosity amongst the Project Team to closely examine the academic validity of current Engineering Education that led to the somewhat controversial research question of "*Are Engineering Educators fit for Purpose?".*

3. METHODOLOGY

Utilising a Design Based Research approach[14] the Engineering EDGE Project brought together colleagues from 10 different Engineering Schools & Departments from different UK Universities. The Project had four distinctive stages:

1. Project Design: A Critical Literature Review: Development & piloting of research tools:
2. Quantitative Survey: 174 colleagues from across the Engineering Education Sector were sampled:
3. Qualitative Interviews and Analysis: 42 colleagues were interviewed from 15 HEIs:
4. Meta-Analysis and write-up.

The findings discussed in this paper relate to the second stage of the project and focus on a cross tabulation of two variables, the dependent variable of *colleagues confidence in teaching key skills and competencies* and the independent variable of *the level of teacher training colleagues had undertaken*. Other independent variables cross-tabulated against the analysis colleagues' confidence included: *Age: Gender: Level of Student Taught*.

3.1 Sample: Quantitative Study

A total of 174 colleagues were sampled equating to 34.8% of the sampling field of 500. The majority of those sampled were from an Engineering background and aged between 40 and 59 years of age. Figure 2 reveals the participants' demographic details showing that the majority (97%) were of an Engineering or Applied Science (Maths / Physics / Chemistry) background.

Figure 1: Sample Demographics (Quantitative Survey – Percentage of Sample).

Area	%	Age	%	Gender	%
West Midlands	33	Under 25	0	Male	70
Northern England	15	25-39	29	Female	30
East Midlands	13	40-49	29		
South West England	11	50-59	31	Total %	100
South East England	10	60-69	8	**Discipline**	**%**
Ireland, Scotland, Wales	9	70+	3	Engineering & Applied Science	97
Outside UK	9			Business, Humanities & Social Science	3
Total (Location)	100	Total	100	Total	100

3.2 Survey Question Focus

Working together looking at the engineering curriculum within each of the 10 institutions included in the study 12 key 'Engineering Skills, Competencies and Knowledge' were identified as being pivotal to success in Engineering, these were divided into two distinctive groups 'Engineering-Specific' and 'Transferable-Engineering'. These are shown overleaf in Figure 2.

Figure 2 provides an overview of the 12 key skills, competencies and knowledge tested (abbreviated to 'skills' for the purpose of the paper). A full description of each of these skills, based on the literature, is given in Figures 3 and 4.

Figure 2: Key Engineering Skills & Competencies Pivotal to Success in Engineering

Engineering Specific Skills	Transferable Engineering Skills
Engineering Problem Identification	Creative Design
Building Things	Ability to be Adaptable
Ability to Make things Work	Critical Problem Solving
Optimisation Abilities	Spatial Visualisation
Discipline Specific Engineering Knowledge	Systems Thinking
Competence in Applying Technical Engineering & Scientific Knowledge	Ability to Contextualise Engineering within Society.

Whilst all of the above skills are relevant to Engineering, those identified as 'Transferable Engineering Skills' can be equally applicable to students from a range of backgrounds, albeit in different contexts and settings.

3.3 Analysis Techniques

The survey required colleagues to rate their own level of confidence in teaching the 12 key Engineering Specific Skills and Transferable Engineering Competencies identified in Figure 2 (and fully described in Figures 3 and 4). 'Very Confident' was coded as '5' and 'Somewhat Confident' as '4' (whilst totally lacking in confidence was coded as 1). During the analysis the data rated at 4 and 5 were merged and identified as indicating a level of Confidence.

For the part of the study discussed in this paper, 'Confidence in Teaching' was identified as the Independent Variable and a cross-tabulation undertaken in which it was measured against the Dependent Variable of being "Trained to Teach". The negative hypothesis *"Being trained to teach* ***does not*** *impact Engineering Educators' confidence in teaching"* was tested using Chi Square and calculating *'p'.* Because of wording restrictions in writing this paper, the decision was made that the readership will be better served by the provision of a full definition of each skill (grounded in the literature) than the inclusion of additional tables depicting Chi square and 'P' values (although these are available from the researchers if required). It should be noted that 'Optimisation Abilities' proved extremely difficult to academically define as there is a lack of research focusing on this particular Engineering Specific Skill / Competency. Hence, the research team itself defined 'Optimisation Abilities in Engineering' based on the industrial and academic engineering focused work experiences, insights and knowledge of colleagues on the team who between them have hundreds of years of engineering experience in industry and academia. All of the other skills are fully referenced and academically defined.

Figure 3 in the following section reveals that for five of the key skills and competencies, the possession of a Teaching Qualification is **not** a significant factor influencing colleagues' confidence in teaching. Whilst Figure 4 shows the seven skills and competencies where Being Trained to Teach is a significant factor impacting confidence (although not necessarily in a positive manner)

4. SURVEY RESULTS AND DISCUSSION: Does being 'trained to teach' matter in terms of colleagues' confidence in teaching?

The study revealed that being trained to teach or possessing professional recognition in teaching **did not** significantly impact colleagues' confidence in teaching three of the 'Engineering-Specific' and two of the 'Transferable Engineering' skills (see Figure 3 overleaf).

The three 'Engineering Specific' skills where being trained to teach does not significantly impact confidence in teaching are: Engineering Problem Identification: The Ability to Make Things Work, and: Optimisation Abilities. It is interesting to note that these skills are not covered by generic postgraduate teaching programmes or professional recognition. Indeed, as noted earlier, the specialised nature of Optimisation Abilities within Engineering is rarely discussed even in the Engineering Education Literature. It is hardly surprising that it does not figure in generic teacher training. Moreover, it appears that engineering colleagues simply assume that all engineers know what this skill is (although how to teach it is a different matter altogether). Likewise, the two 'Transferable Engineering Skills' of 'The Ability to be Adaptable' and 'Systems Thinking' are rarely discussed in generic teacher training in Higher Education.

Figure 3: Confidence in Teaching Key Engineering Skills & Teacher Training (Where being trained to teach **IS NOT** significant factor determining confidence: C = Confidence [% of sample]).

Engineering Specific or Transferable Engineering skill.	DEFINITION	C %
Engineering Problem Identification: ENGINEERING SPECIFIC SKILL	The ability to use core engineering theories and knowledge to firstly identify and articulate what the issue is before going onto assess whether solutions are already exist. Engineers view problem finding as an opportunity and a challenges, with each new problem acting as a stimulus for innovation and invention[15,16]	**90**
Ability to be Adaptable TRANSFERABLE ENGINEERING SKILL	*The ability to work across disciplines and to empathise with others' experiences and perspectives. For Engineering students this means learning how to apply scientific and engineering principles to identify, analyse and explain how things work combined with a personal ability to be pliable in how engineering tasks, problems and theories are approached*[17,18]	**82**

Systems Thinking TRANSFERABLE ENGINEERING SKILL	Systems thinking requires students to view complex problems and situations rigorously and holistically. Using systems thinking, professional engineers are able to recognise interdependencies, connectivity, patterns and linkages across and between problems, processes and practice [19.20]	**70**
Ability to Make things Work ENGINEERING SPECIFIC SKILL	*Having applied appropriate technical knowledge to a given engineering problem, engineering students learn how to utilise key practical engineering skills to assure that engineering artefacts, tools and models are fit for purpose and in working order*[21]	**70**
Optimisation Abilities ENGINEERING SPECIFIC SKILL	A unique engineering skill in which engineering knowledge, skills and technology are applied in such a way so as to create high levels of synergy assuring engineering artefacts, tools and models operate at optimal levels	**56**

Whilst the skills listed and defined in Figure 3 are not influenced by whether colleagues are trained to teach, confidence in the remaining 7 skills listed and defined in Figure 4 are. Amongst these are the Engineering Specific Skills of: Competence in applying technical knowledge: The ability to correctly interpret and apply discipline specific engineering knowledge: and: Building things. Each of these three Engineering Specific skills, whilst generally not referred to in teacher training, require high levels of confidence and competence to teach as well as specialised levels of technical knowledge. That over half of the sample were not confident in teaching how to 'build things' is a matter of some concern given the hands-on nature of engineering. Likewise, the link between teaching training and colleagues' confidence in teaching the four 'Transferable Engineering Skills' identified in Figure 4 is not necessarily a positive one.

Figure 4: Confidence in Teaching Key Engineering Skills & Teacher Training (Where being trained to teach **IS** a significant factor determining confidence [C = Confidence % of sample]).

Engineering Focused Or Transferable Engineering S	DEFINITION	C %
Critical Problem Solving TRANSFERABLE ENGINEERING SKILL	The ability to **analyse** problems and situations in a critical, logical & innovative manner. For engineering students this means being able to apply workable and logical solutions to a wide-range of technical, social and environmental problems so of which are yet to emerge[22].	95
Ability to Contextualise Engineering within Society TRANSFERABLE ENGINEERING SKILL	**Contextualise** engineering problems, issues and challenges within wider society. Engineering students need to learn how to make sure that all engineering artefacts, tools and models are fit for purpose and accessible to the society for which they have been developed. Students also need to be able to communicate key engineering and scientific theories and concepts across all levels of society[23].	95
Competence in Applying Technical Knowledge ENGINEERING SPECIFIC SKILL	The ability to **apply** technical engineering and scientific knowledge to problems occurring within the constructed or natural environmental in order to develop, test and implement practical and workable solutions[24]	91
Correctly interpret and apply Discipline Specific Engineering Knowledge ENGINEERING SPECIFIC SKILL	Provide evidence of an ability to **understand**, interpret and apply discipline-specific engineering, scientific and mathematical knowledge to technical, environmental and societal challenges. Student Engineers should be able to draw upon appropriate levels of discipline specific knowledge independently and apply it to given situations or challenges[25,26]	84
Creative Design TRANSFERABLE ENGINEERING SKILL	The ability to think 'out of the box' to imagine, design and **create**. For engineering students this involves a cognitive process culminating in the generation of an idea which is then applied to a design setting or engineering problem[27]	62

Building Things ENGINEERING SPECIFIC SKILL	The ability to **construct** scientifically appropriate engineering artefacts, tools and models for use in everyday situations by those with no specialist knowledge[28]	48
Spatial Visualisation *TRANSFERABLE ENGINEERING SKILL*	Whilst the ability to be able to view a given situation, model or artefact in 3 or 4 dimensions is essential across disciplines, in Engineering Spatial Visualisation requires being able to recognise the identity of an object when viewed from different angles. This means being able to **imagine** the movement or internal displacement amongst parts of a given configuration or object. In applying spatial visualisation, student engineers are taught how to be able to conceptualise spatial relations and linkages at the root of a particular problem, challenge or issue[29]	44

That only 44% of the sample were confident in their ability to teach 'Spatial Visualisation' and only 62% were confident in teaching 'Creative Design' says much about the focus and content of 'Teacher Training' and 'Professional Development' in Higher Education supporting arguments that there is a need to introduce specialised Teacher Training for those working in Engineering & Applied Science. Moreover, that none of the skills had a 100% confidence rating amongst the sample is something which requires serious thought and further investigation.

The results from the survey were used to guide and inform semi-structured interviews with 40 colleagues which sought to examine in some depth the various factors influencing colleagues' lived experiences of teaching engineering. The qualitative findings together with a summary of the findings of a meta-analysis of the whole project are reported elsewhere[30]

5. CONCLUSION: IMPLICATIONS FOR PRACTICE

This paper represents a small part of a much larger study which set out to investigate whether *Engineering Educators are fit for purpose.* In looking at the data presented here the question becomes not one of whether Engineering Educators are fit to practice or not but one of ***whether Teacher Training for and of Engineering Educators working in Higher Education is fit for purpose?***

The data suggests in the areas where confidence is not impacted by Teacher Training the specialised nature of Engineering Education means that the skills in this category would generally not be covered by generic teacher training. Likewise, where confidence is impacted by Teacher Training, the more technical or engineering specific skills are not covered in any current Postgraduate Certificate in Education or Professional Recognition Programmes.

The reasons for this are complicated, whilst both PG Certificates and Fellowship of the Higher Education Academy are purposefully focused widely so as to incorporate colleagues from across all disciplines, there is a strong case to argue that both types of training tend to be constructed so as to address the teaching needs of non-engineers and applied scientists. Indeed, it is not unreasonable to postulate that most

Educationalists responsible for developing and running such programmes originate from a non-scientific or engineering background.

There clearly is a need for change. The requirement that all of those teaching in Higher Education undergo a period of professional development or teacher training is not unreasonable; indeed, it should be lauded for its potential to enhance learning quality. However, the distinctive nature of Engineering & Applied Science Education means that many colleagues are not being given the tools, skills or resources to teach what are often perceived by students to be 'hard subjects'.

In conclusion, Engineering & Applied Science Education differs greatly from Business, Social Science & Humanities; likewise, it also differs from Medicine and the Natural Sciences. Year after year it seems that the NSS places levels of student satisfaction in Engineering below that of other disciplines in the UK. Whilst this is widely known, it is rarely discussed and the potential reasons for the deficit simply ignored. The data presented in this paper suggests there is a clear problem with *how we train Engineering Educators to teach.* It is high time that those responsible for teaching tomorrow's Engineering Professionals (and others working in the Applied Sciences and associated disciplines) were given support and recognition for the uniqueness and importance of the task in hand. The time is ripe for a redevelopment of Teacher Training. Key stakeholders from Engineering Education, the Professional (Engineering) Bodies and Industry need to get together to challenge the status quo and demand the introduction of bespoke, Engineering Education Teacher Training that is fit for the 21st Century!

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Exploring Congruency between Engineering students' Professional Role Preference, Competences and Career Choice

S. Craps[1]
PhD Researcher
Faculty of Engineering Technology KU Leuven
Leuven Engineering & Science Education Centre (LESEC) KU Leuven
Leuven, Belgium

M. Pinxten
Research Associate
Faculty of Engineering Technology KU Leuven
Leuven Engineering & Science Education Centre (LESEC) KU Leuven
Leuven, Belgium

H. Knipprath
Research Expert
Research Institute for Work and Society (HIVA), KU Leuven
Leuven, Belgium

G. Langie
Professor, Vice-dean
Faculty of Engineering Technology KU Leuven
Leuven Engineering & Science Education Centre (LESEC) KU Leuven
Leuven, Belgium

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ABSTRACT

Self and professional awareness are important factors when choosing a profession that is congruent with one's interest and competences. This study investigated the quality of professional role choice of 55 Belgian final-year engineering students. We examined congruency between vocational interest, self-perceived strengths and weaknesses and career aspirations. Through mixed methods, three professional role outcomes were measured: role preference (job interview), role competence (questionnaire) and job role (job vacancy selection). We used the Professional Roles Model for Future Engineers (Craps et al. 2018) as theoretical framework and evaluated (1) the alignment between the role preference and competency profile (aligned, fluid, unaligned) and (2) the consistency with the chosen job vacancy (consistent, inconsistent).

The results indicated that the role preference could be aligned with the self-perceived competency profile for 43% of the students (N=23). However, the difference with the

Corresponding Author: S. Craps
sofie.craps@kuleuven.be

Unaligned was small (N=20). Almost a fifth (N=11) did not have an outspoken competency profile and could be aligned to all roles. Remarkably, most of the Unaligned preferred to work in an innovative role. The majority of the students (87%) preferred a job vacancy consistently with the role preference or competency profile. Interestingly, only 8 students (15%) obtained a one-to-one congruency between the role preference, competences and job role. Unaligned students seemed to select a job vacancy in accordance with their competency profile, rather than with their role preference. Further research is required to investigate the contribution of professional awareness, the alignment with the actual career behaviour and the correlation with background variables.

1 INTRODUCTION

Research has demonstrated that a better understanding of one's professional identity not only has positive consequences for student learning and study choices [1-3], but also increases employability and job satisfaction [4-7].

Professional identity development involves an interaction between the expectations related to a specific professional role and the needs and aptitudes of the student preparing for that role [8]. However, this argument presumes that students have enough information about (a) their own competences, preferences and personality and (b) the professional roles and role requirements.

This study contributes to the contemporary debate on the pivotal role of engineering identity in that it explores to what extent a better understanding of the professional roles contributes to the quality of role choice. The quality of role choice refers to the evaluation by the student of a fit between his/her aptitudes and occupational wishes on the one hand and the learning tasks on the other hand [9]. In this study, the quality of role choice will be operationalised by role congruence. More specifically, we will examine (1) to what extent students' professional role preferences align with their self-perceived professional competency level and (2) whether they make potential career choices consistent with their preferred role.

This study is part of a larger research project that investigates to what extent professional role awareness support career development learning of engineering students.

2 BACKGROUND

2.1 Role congruence and role confidence

According to Holland's Theory of Vocational Choice, people will search for work environments where they can optimally use their competences and express their values and attitudes [10]. For example, an investigative type who is likely to be precise, analytical, curious, and intellectual, will search for an investigative environment that enables and facilitates this type of behaviour. More congruency between personality and career leads to greater job satisfaction and success [5]. This implies that engineering students must be aware of both their personality (e.g., interests, strengths and weaknesses) and the job type (e.g., professional role, wage, job autonomy) they choose to apply for.

Thornton and Nardi (1975) describe four stages in the process of professional role identification, which ranges from idealised perceptions of the professional role to making the role more congruent with one's own values and goals [11]. The final stage – the personal stage in which they internalise a professional role – is often not reached by the time students graduate. One essential reason is that they lack experiences in the professional role, but they may also lack 'sense making' opportunities in their education in which students learn to connect information about professional roles with their skills and knowledge and with their needs and ambitions [4,11]. However, earlier research has reported that when students are able to align their competences with those essential in a professional role, they will experience feelings of role congruence and increase their perception of role fit which will make them more confident in a professional role. For example, Cech et al. (2011) examined two dimensions of professional role confidence: expertise confidence referring to the confidence in the competences required in the job, and career-fit confidence referring to the confidence that a career path is consonant with the interests and values [2].

The course in which the current research activity is conducted, aims to make students more aware of and more confident in their professional competences and interests. Based on a reflection exercise of interests and competences, students were instructed to search for a job vacancy. The course and research activity will be further explained in the Method Section.

2.2 Professional Roles Model for Future Engineers

The professional roles described by Hofland et al. (2015) and further developed by Craps et al. (2018) in the Professional Roles Model for Future Engineers (PREFER-model) were used in this study to examine vocational interest and self-perceived level of professional competences. The model represents three professional roles independent of discipline: Operational excellence (focus on process optimization & increasing efficiency); Product leadership (focus on radical innovation & research and development); Customer intimacy (focus on tailored solutions for specific clients). The roles specifically focus on early career engineers and are flexible in use since several roles can be combined in one job. The model has been thoroughly validated with both industry stakeholders and engineering students [12,13].

The PREFER-model describes competency profiles per role reflecting the professional competences engineering graduates need to possess at a Master's level in order to be successful in one of the professional roles [13,14]. For example, persuasiveness and perseverance are essential in a product leadership role, whereas networking and capacity for empathy are crucial in customer intimacy. Engineers working in the role of operational excellence need, amongst others, a positive critical attitude and must excel in work management. In essence, as different jobs have different requirements, the PREFER-model aimed to identify which competences are essential in each professional role. It should be noted that the competency profiles do not include (basic) competences required for all engineers but only comprise competences of which industry seeks an excellent level.

2.3 Research questions

This study zooms in on a unique aspect of career development learning: that of alignment with professional roles, and how alignment might be associated with the quality of role choice. The latter concept is operationalised by the construct of role congruence. Following Hirschi, Niles and Akos (2011), role congruence is defined as the similarity between a student's vocational interest, professional competences and career aspirations [15].

One dimension of our analysis considers alignment of a student's role preference (vocational interest) with his/her self-perceived professional competency level. The second dimension of our analysis is forward-looking, considering consistency with the preferred career choice (career aspirations). We developed categorical labels from Aligned to Unaligned and from Consistent to Inconsistent, as detailed in the Method Section.

This paper reports on the first part of a case study investigating whether a better understanding of the professional roles contribute to a higher degree of role congruence. Following research questions were formulated:

> **RQ 1** *How aligned are engineering students' professional role preferences with their self-perceived professional competency levels?*
>
> **RQ 2** *How do Aligned students differ from Unaligned with respect to their preferred career choice?*

3 METHOD

3.1 Sample

The sample comprised 55 final-year students (16% female) of the master's programmes in Electronics-ICT and Electromechanical Engineering Technology at KU Leuven. The proportion of female students in these programmes ranges between 6,50% and 8,33%, and is as such lower than in our sample. The research was performed in the first semester of the academic year 2018-2019 (November 2018). All participants were informed and have consented to be part of this study.

3.2 The Engineer as a Professional Communicator

The research was conducted in the master's course Management and Communication. One part of the course, called '*The Engineer as a Professional Communicator'*, focuses on the understanding of the differences between the technical communication skills used by engineers and the way of thinking and communicating in the business world. A practical exercise of learning how to translate these insights in a professional win-win communication, was a fictional job application process. Students were instructed to translate a critical self-analysis into a unique selling proposition. They analysed their personality and professional skills through various competence and personality tests (e.g., Myers - Briggs), searched through different recruitment channels, critically analysed job offers and responded to one vacancy appropriately. They were allowed to make minor changes in the job requirements to make the job vacancy more tailored to their profile. Finally, the students engaged in a role play simulating a job interview.

From each individual student, the lecturer received a portfolio including the critical analysis of their personality and qualities, the chosen job vacancy, a resume and a cover letter. In the role play job interview, the lecturer acted as an HR representative of the company that was offering the job they responded to.

3.3 Role congruence

To measure role congruence, professional role outcomes per student were collected through the job interview (vocational interest or professional role preference), a questionnaire (professional competences in terms of self-perceived role competency profile) and the job vacancy (career aspirations or preferred career choice). Fig. 1 illustrates the theoretical framework that is developed based on the three role comparisons. The research questions focus on the congruency between the three role outcomes.

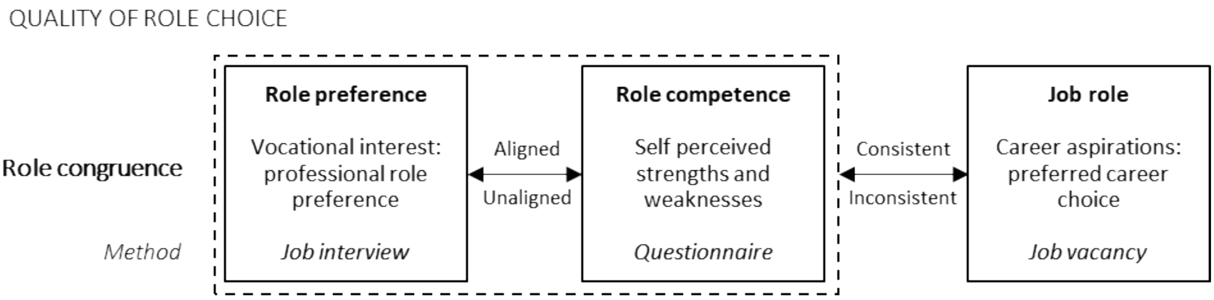

Fig. 1 Theoretical framework of the current study

- ***Measurement Role preference***

During the job interview, a question was asked related to professional role preference. Students could pick one of the three possible answers implicitly referring to the three professional roles. This means that the interviewer did not refer to the roles, nor the competences. The students were invited to defend their choice in order to clarify their preference. The role preference question was derived from a set of questions from a validated test aimed at aligning students to the professional roles of the PREFER-model [16]. A question could be for example: "*Thinking of some projects you have been involved in, what part was typically your favourite part of the project? Brainstorming and designing; execution and implementation; communication with stakeholders and presentation of preliminary results or final output*." We labelled this outcome as *role preference.*

- ***Measurement Role competence***

After the job interview, participants were asked to complete a competence questionnaire, containing the 19 competences of the PREFER-model (each with a brief definition). Students were requested to rate their self-perceived skills levels for each of the competences on a five point Likert scale. Role scores were calculated by aggregating the scores of the competences belonging to the same professional role. In case of a missing value on one of the competences, no role score was calculated (3,03%). In this way, we obtained 3 scores per participant - one for each professional role - between 7 and 40. The minimum and maximum score depended on the number of competences included in the competency profile of the professional role (*Table 1*).

Table 1. Maximum and minimum score per competency profile

Competency profile	**N competences**	**Min. score**	**Max. score**
Product leadership	7	7	35
Operational excellence	8	8	40
Customer intimacy	8	8	40

If a particular role deviated by one standard deviation from the other two, this role was attributed as the dominant role. An example of this role attribution, labelled *role competence*, is illustrated in Table 2 (SD≥3.0, see *Table 3*).

Table 2. An example of role competence outcome

Student	**Score $_{PL}$**	**Score $_{OE}$**	**Score $_{CI}$**	**Role competence***
Student1	21	22	26	CI
Student2	18	24	25	OE + CI

**PL = product leadership, OE = operational excellence, CI = customer intimacy*

- ***Measurement Job role***

The preferred career choice, labelled *job role,* was operationalised by the job vacancy the students opted for. The students were free to select any job advertisement from any recruitment channel.

The 55 chosen vacancies (one per participant) were independently positioned in the PREFER-model by three researchers. They assigned the vacancies to one or more professional roles, based on the job description and job requirements. Through interrater reliability, emphasizing the similarity between the 'judges' [17], the outcomes were compared and each job vacancy was finally assigned to one or more professional roles indicated by at least two researchers. The interrater reliability was calculated with Cohen's kappa with k between 0 (the agreement between reviews rests entirely on chance) and 1 (complete agreement). k>0.60 indicates substantial agreement.

- ***Level of alignment***

The level of alignment was determined by the role preference and the role competence. Based on a categorization adopted by Rüde et al. (2018) in their research of alignment between job plans and postgraduation outcomes, three groups were identified: Aligned, Fluid and Unaligned students [18]. Students who rated their strengths in terms of professional competences in accordance with their preferred professional role, were identified as *Aligned*. For example, if a student had a preference for role X and the role competence was assigned to role X and Y, the student was classified as Aligned. A one-on-one alignment between the role preference and role competence was identified as *Exclusively aligned.* In case there was partial alignment, a student was classified as *Inclusively aligned*.

If they did not have an outspoken preference or competency profile and position themselves in the middle of the PREFER-model (three roles combined), they are categorised *Fluid*. If the role preference and role competence were not congruent, they are classified *Unaligned*.

- ***Level of consistency***

The level of consistency is determined by the preferred career choice. If students opted for a vacancy that is similar to the role preference *or* role competence, we categorize the students as *Consistent.* If not, they are classified as *Inconsistent.*

4 RESULTS

In this study we investigated congruency between the professional role preference (vocational interest), professional competences and the preferred career choice (career aspirations). We first present descriptive results of the three role measurements. Second, we explore to what extent these results are congruent.

4.1 Role preference

During the job interview, students were explicitly asked which role they preferred. The results indicate that role preferences are distributed rather equally over the three roles. (*Table 4*). Only three students replied they would prefer to combine two options (product leadership and customer intimacy). It should be noted that students were asked to indicate what they preferred the most and they might have felt obliged to select only one answer.

4.2 Role competence

Students perceived their competences related to operational excellence to be the strongest (M=22.81, SD=2.895) and the competences related to product leadership the least strong (M=19.00, SD=2.733) (*Table 3*). This was also reflected in the roles that could be assigned to the students based on the sum scores per competency profile (*Table 4*). The operational excellence role was most pronounced (61%, N=33), either uniquely or combined with the customer intimacy role. A fifth of the students (N=11) did not have an outspoken competency profile and were attributed to a combination of three roles. One respondent was excluded due to non-response to the role competence questionnaire.

Table 3. Mean scores professional competences per professional role

	N*	Minimum	Maximum	Mean	Std. Deviation
Product leadership	54	14	25	19.00	2,733
Operational excellence	54	16	28	22.81	2,895
Customer intimacy	52	16	27	21.54	2,947

** In case of a missing value, no role score was calculated.*

4.3 Job role

All job vacancies could be positioned in the PREFER-model with overall moderate agreement (k=0.57) and substantial agreement per role (k_{PL}=0.69, k_{OE} =0.61 and k_{CI}=0.73). Almost 70% of the vacancies was classified identically by the three researchers. In the remaining cases, disagreements were mostly related to multiple assignments to a role, rather than completely different assignments (N=19).

The majority of the students (63,64%, N=35) choose a job vacancy related to operational excellence (single role or combined with another role), followed by customer intimacy (50%, N=28) and product leadership (29,09%, N=16) (*Table 4*). Vacancies that reflected both the opportunity for technological optimization (operational excellence) and tailored solutions (customer intimacy) seemed also to be appealing to quite some students (N=12).

Table 4. Distribution of role outcomes (N)

	PL	OE	CI	PL + OE	PL + CI	OE + CI	PL + OE + CI	Total
Role preference	15	20	17		3			55
Role competence	1	18	8		1	15	11	54
Job role	4	16	11	7	5	12		55

PL = product leadership, OE = operational excellence, CI = customer intimacy

4.4 Level of alignment

Table 5 illustrates the level of alignment between role preference and role competence. 43% (N=23) of the students could be categorized as Aligned. However, the difference with the Unaligned is small (N=20). Interestingly, the majority of the Unaligned (60%, N=12) preferred a job in the product leadership role while none of the Aligned preferred this role. A fifth of the students (N=11) did not have an outspoken competency profile and were categorized as Fluid.

More than half of the Aligned students (57%, N=13) were exclusively aligned showing a one-on-one outcome for role preference and role competence (9 for operational excellence, 3 for customer intimacy).

Table 5. Level of alignment between role preference and role competence

		Role preference									
		PL		**OE**		**CI**		**PL + CI**		Total	
Role competence	**Aligned**	0	*0%*	12	*52%*	10	*43%*	1	*4%*	23	*43%*
	Fluid	3	*27%*	4	*36%*	3	*27%*	1	*9%*	11	*20%*
	Unaligned	12	*60%*	4	*20%*	3	*15%*	1	*5%*	20	*37%*
	Total	15	*28%*	20	*37%*	16	*30%*	3	*6%*	54	

PL = product leadership, OE = operational excellence, CI = customer intimacy

4.5 Overlap between level of alignment and level of consistency

Table 6 displays the overlap between the level of alignment between role preference and role competence (Aligned/Fluid/Unaligned) and the level of consistency of the preferred career choice (Consistent/inconsistent).

Table 6. Comparison between level of alignment and level of consistency

	Consistent		**Inconsistent**		**Total**	
Aligned	19	*83%*	4	*17%*	23	*100%*
Fluid	11	*100%*	0	*0%*	11	*100%*
Unaligned	17	*85%*	3	*15%*	20	*100%*
Total	47	*87%*	7	*13%*	54	

Whereas the difference between Aligned and Unaligned categories was rather small, the majority of the students choose a job vacancy consistent with the role preference or role competence (87%, N=47).

A more detailed analysis of the Aligned students indicated that 8 of the 13 Exclusively Aligned could also be categorized as Exclusively Consistent, 2 as Inclusively Consistent, 3 as Inconsistent. By consequence, only 15% of the outcomes were congruent along the line (Exclusively Aligned, Exclusively Consistent) on the total sample.

The large consistency in the Unaligned category is due to the congruency between role competence and job role. It seems that all 17 students were able to select a vacancy according to their strengths and weaknesses but did not articulate their vocational interest consequently. The smallest group of the sample (N=3) were categorized Unaligned and Inconsistent which means they had different outcomes for role preference, role competence and job role.

5 DISCUSSION

It is assumed that when students are more aware of their professional identity, they will be more motivated and persistent in their study and display higher levels of employability and job satisfaction [5,7,9]. Self and professional awareness are important factors when choosing a profession that is congruent with the students' interests and competences. This study investigated the quality of professional role choice of final-year engineering students. Through the construct of role congruence we examined whether students could align their vocational interest with their self-perceived strengths and weaknesses, consistently with their career aspirations. Through mixed methods, three professional role outcomes were measured: role preference, role competence and job role.

The proportion of Unaligned students (37%) suggests that more than a third of the final-year engineering students did not express a vocational interest in line with their self-perceived strengths and weaknesses. Especially students who preferred to work in an innovative role (product leadership) struggled to align their interest with their competency profile. On the one hand, this finding emphasizes the importance of supporting career development learning earlier than in a students' last year of university. On the other hand, it should be noted that the programme in engineering technology at KU Leuven is mostly focused on operational excellence. As a consequence, it might not be surprising that students feel most competent in competences related with this role. This was also confirmed by the outcomes of role competence. However, we did not observe similar findings for customer intimacy. Earlier research indicated that students felt least prepared for the role of customer intimacy [13], but only 3 out of 16 students who preferred this role were categorized Unaligned.

Although the proportion of Consistent students (87%) is high, only 8 students (15%) of the total sample displayed full congruency between role preference, role competence and job role. Students appeared to seek more congruency between the job vacancy and their self-perceived strengths and weaknesses than between the job vacancy and their vocational interest. Whether a better understanding of the professional roles contributes to role congruency will be investigated in a follow-up study where the PREFER-model will be explicitly introduced.

The findings should be interpreted carefully against the specific context. In the Management and Communication course, students were urged to critically analyse their professional competence levels and to reflect on this analysis in a portfolio including peer-reviewed feedback. They were instructed to select the vacancy based on those outcomes and were even allowed to rewrite few requirements in order to increase job fit, which might explain the high Consistency score. Although this kind of career interventions has positive effects on career-decision making skills and career knowledge, choosing a job vacancy as an assignment might differ from the actual career choices [9]. A follow-up study on actual career behaviour of young graduates would be recommended for future research.

In line with earlier findings [4,9], the course method with critical reflection and career dialogue seems to be effective. However, a larger sample and a research design with an experimental and control group could enrich the data to draw further conclusions on significant differences between Aligned and Unaligned respondents and background variables such as educational background, grades or gender.

Professional role preference was included in the study by asking only one question during the job interview. More research using validated measurement instruments should be conducted concerning role preference and role competence in large representative samples. It could contribute to the implementation of the Professional Roles Model for Future Engineers in engineering education as a valuable instrument in increasing engineering identity development and career guidance.

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Industry Validation of a Professional Roles Model to Promote Engineering Identity of Young Graduates

S. Craps[1]
PhD Researcher
Faculty of Engineering Technology KU Leuven
Leuven Engineering & Science Education Centre (LESEC) KU Leuven
Leuven, Belgium

M. Pinxten
Research Associate
Faculty of Engineering Technology KU Leuven
Leuven Engineering & Science Education Centre (LESEC) KU Leuven
Leuven, Belgium

G. Langie
Professor, Vice-dean
Faculty of Engineering Technology KU Leuven
Leuven Engineering & Science Education Centre (LESEC) KU Leuven
Leuven, Belgium

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ABSTRACT

In order to offer engineering students a framework to get a grasp on the diverse engineering field, a Professional Roles Model for Future Engineers has been developed by Craps et al. (2018). In this model, three distinct engineering roles are defined: Operational Excellence (focus on optimization); Product Leadership (focus on innovation); Customer Intimacy (focus on tailored client solutions). In this study, we will investigate how industry professionals perceive the model in their company. Additionally, we will determine which professional competences discriminate between the three roles. A survey was distributed at several job fairs for engineering students in Flanders, Belgium. In total, 188 industry professionals returned the survey. In the first section, respondents rated to which degree they (1) recognized the three professional roles in their company and (2) were able to place job vacancies for young engineering graduates in the model. In a second section, respondents were asked to rate the importance of 15 professional competences (e.g., creativity, empathy...) for each of the three professional roles. Overall, industry professionals responded positively to the model: 66% (strongly) recognized the three professional roles in their company and 59% could easily classify positions for young engineers in this framework. In terms of professional competences, especially the customer intimacy role contrasted strongly with the other two roles: client focus, empathy and building

[1] Corresponding Author: S. Craps
sofie.craps@kuleuven.be

relations were rated significantly more important in a client-focused role. Conversely, creativity and innovation were of greater importance in a product leadership role.

1 INTRODUCTION

1.1 Engineering student employability

It is commonly accepted that successful engineers must hold a well-balanced set of technical and professional skills [1]. Engineering institutions have various ways to train their students in both areas. In their systematic literature review, Winberg et al. [2] discerned different positions to conceive employability along two continua: engineering science on the one hand and professional skills on the other. For example, one category of positions focuses on establishing a strong disciplinary foundation and professional skills are embedded in this engineering science foundation. In another position, stand-alone professional skills development course are implemented, independently of the mainstream engineering courses. According to the authors, the latter courses tend to be sometimes misaligned with the disciplinary content.

However, Magnell et al. [3] indicated that the term employability is an ambiguous concept. In a narrow sense, it is often conceptualized as the ability to get a job after graduation or as a set of skills (as outlined above). In line with Knight and Yorke [4], the authors endorse a broader meaning of the term employability by making claims in four areas: understanding, skillful practices, efficacy beliefs and metacognition. This conceptualization is more comprehensive as it combines knowledge and skills with students' self-perceptions of their own skills levels and their ability to apply knowledge and skills in a particular context. Especially the latter element, meta-cognition, is important in that it refers to learners' capability to look at themselves and reflect upon self-perceived skills levels, strengths, and weakness. Prior research by Nilsson [5] and Cech et al. [6] indicates that when students are able to articulate their strengths and weaknesses and gain confidence in a particular engineering role, this increases their employability and persistence in engineering.

In this respect, triggering engineering students to reflect on their professional future is an important challenge for engineering institutions [7]. Prior research showed that explicitly articulating student social identity and career goals has beneficial consequences for student learning [8]. In this respect, Bennett and Male [9] indicated that engineering students need more opportunities to explore both the roles of engineers and their possible future selves.

1.2 Professional role model

In order to offer engineering students a framework to (1) get a grip on the diverse engineering field and (2) offer them a starting point for developing their own engineering identity, a Professional Roles Model for Future Engineers has been developed by Hofland et al. [10]. In this model, three distinct engineering roles are defined, each with a very specific focus: Operational Excellence (process optimization & increasing efficiency); Product Leadership (radical innovation & research and development); Customer Intimacy (tailored solutions for individual clients). In their study, Craps et al. [11] were able to define the three professional roles using 23 professional competences. Through an extensive Delphi design, the authors organised 13 qualitative expert panels in industry. The output resulted in a competence mapping of 23 professional competences on the Professional Roles Model. For example, innovation, out-of-the-box thinking and creativity were deemed more important in a Product Leadership role whereas client focus, capacity for empathy and clear communication were considered indispensable in a Customer Intimacy role. A comprehensive overview is subject of a paper in progress and available on request.

1.3 Industry influences on the engineering curriculum

In developing tools that could be helpful in increasing engineering students employability, external influences (e.g., employers or business professionals) could be of particular interest. Barnett [12] found that there is a degree of variation in the extent to which external influences affect curricula in higher education. Examining perceptions of a large sample of faculty staff (N=363), Magnell et al. [3] found that most faculty members were generally interested in including work-related issues (e.g., guest lectures, project work) in their teaching. Interestingly, two observations regarding their extensive sample are noteworthy. First, about 50% of the respondents did not have prior experience in industry. Second, a quarter of the respondents indicated that they did not have contacts outside of academia in the past year. This observation is surprising, given that there is an increasing call from industry stakeholders to increase work-related learning in engineering education. It is generally assumed that better linkages to working life have beneficial consequences for the employability of students.

Therefore, in developing a framework for professional roles intended to enhance engineering students' employability, the input and support of industry is indispensable. Hence, the prime objective of this paper is to report on the industry perceptions of the Professional Roles Model developed by Hofland et al. [10] and Craps et al. [11]. In their study, Hofland et al. [10] gauged the perceptions of industry through 5 qualitative in-depth interviews with HR managers. Almost all interviewees recognised the model in the recruitment process of graduated engineers.

In this study, we aim to extend the findings of Hofland and colleagues by examining the external validity of the professional roles model in a diverse sample of business professionals, both with and without an engineering background.

1.4 Research questions

Follow research questions (RQ) will be addressed in this paper:

RQ 1 *"To what degree do business professional recognize the professional roles model as a way to classify positions for young engineers?"*

› Are there statistical differences in the perceptions (a) between respondents with an engineering, HR or marketing background and (b) between employees of small, medium-sized or large companies?

RQ 2 *"To what degree can business professionals apply the model to positions for engineering graduates in their company?"*

› Are there statistical differences in the perceptions (a) between respondents with an engineering, HR or marketing background and (b) between employees of small, medium-sized or large companies?

RQ 3 *“How are positions for young engineering graduates typically filled in (one specific role, combination of two or three roles)?”*

› Are there statistical differences in role implementation between employees of small, medium-sized or large companies?

RQ4 “*What is the relative importance of 15 professional competences for each of the three professional roles?”*

2 METHOD

2.1 Sample

An extensive survey was distributed on paper and pencil during the job fairs in the spring of 2018 at 6 different university campuses. Together with the survey, each company representative received a small leaflet with a brief explanation of the Professional Roles Model. At the end of each of the job fairs, all surveys were collected from the booths. In total, 188 completed surveys were retrieved.

In the first part of the survey, background information was collected from all respondents. Regarding the company size, following proportions were observed: large company (>250 employees - 57%), medium-sized companies (50-250 employees – 28%), small companies (10-50 employees – 12%) and micro companies/start-ups (<10 employees – 2%). In terms of professional background, 51% of the respondents held an engineering degree whereas 47% came from the HR department. Overall, the companies are active in a wide variety of sectors (construction, IT, petrochemical industry, manufacturing, automotive…). Due to the large degree of heterogeneity, the sector was not included as a covariate in our statistical analyses.

2.2 Survey

Perceptions Professional Roles Model

In the first part of the survey, we measured company representatives’ perceptions of the Professional Roles Model through three descriptive questions. First, representatives were asked to which degree they recognized the model as a framework for classifying the wide range of engineering functions. This item was rated on a 5-point Likert type scale ranging from 1 (‘*Not at all recognizable to me*’) to 5 (‘*Completely recognizable to me*’). Second, respondents were asked to which degree they were able to position young engineers in their company in this framework. This item was also rated on a 5-point Likert type scale ranging from 1 (‘*Very easily*’) to 5 (‘*Very hard*’). Finally, we gauged the respondents perceptions on how engineering positions were filled in their respective company (i.e., in a single role, in a combination of two roles, or a combination of all three roles).

Associated competences

In the second part of the survey, company representatives were requested to evaluate the importance of 15 professional competences for each of the three professional roles (for a full overview and definition of the 15 competences, see Appendix 1). These 15 competences were chosen on the basis of two expert panels with engineers in the field (the expert panels were the first two panels of the more extensive research reported by Craps et al. [11]). A panel consisted of 6 to 8 engineers supplemented with colleagues from HR. Through a systematic approach, participants were instructed to select the essential competences for each of the three roles. The resulting 15 competences were included in the current survey. For each professional roles, respondents were asked to rate the importance of each competence on a 5-point Likert type scale ranging from 1 (‘*Not important at all*’) to 5 (‘*Very important*’). For the complete competence mapping, we refer to Craps et al. [11].

3 METHOD

3.1 Analysis of Variances (ANOVA)

In order to evaluate statistical differences regarding perceptions of the professional roles model between different company sizes, ANOVA analysis were performed. Analogously, statistical differences regarding the importance of particular competences between the three professional roles were evaluated using this technique.

4 RESULTS

4.1 Industry perceptions of the Professional Role Model

At a descriptive level, there seems to be general agreement on the Professional Roles Model: 65% of the respondents (easily) recognizes the model for classifying engineering graduates in their respective company (Fig. 1).

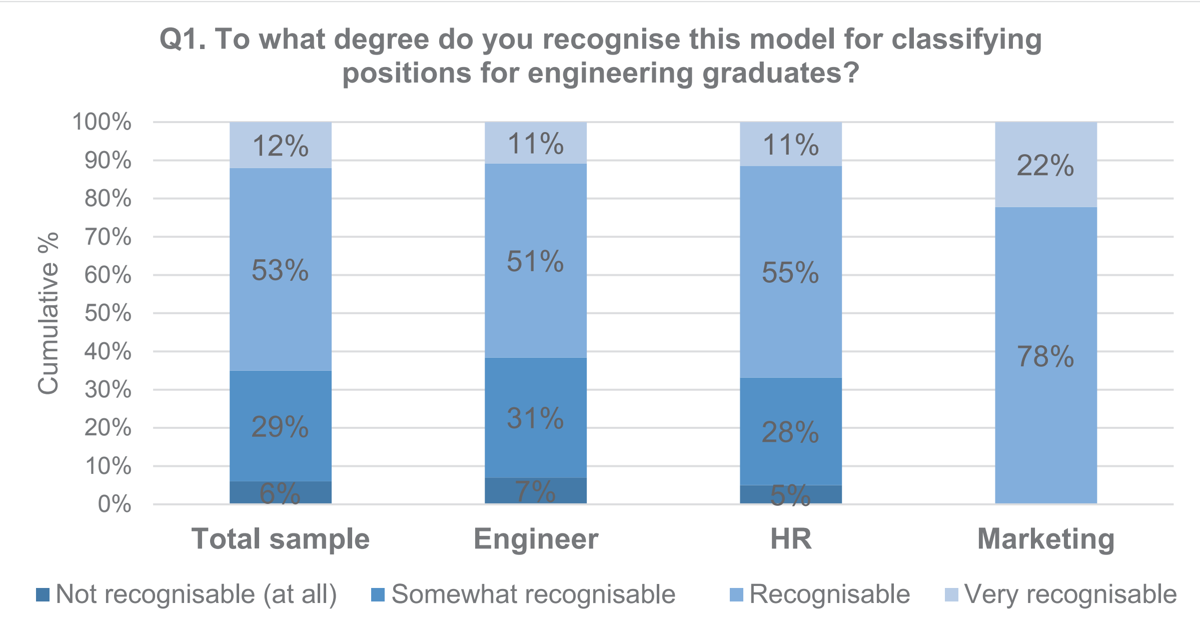

Fig. 1 Industry perceptions of the professional roles model (total sample, engineering, HR & marketing background)

Interestingly, there are only minor differences in the perceptions of engineers, HR professionals, and marketing professionals. A more detailed analysis of the respondents who replied negatively to this item indicates that these were predominantly active in the ICT business. There was no significant effect of company size on degree of recognisability of the model, F (3,179) = 1.43, p=.24. Hence, the model seems to be supported equally well in small, medium-sized and large companies.

In a follow-up question, respondents were asked to which degree they could place the company's job positions for young engineering graduates in this model. 60% of the respondents indicated that they were (very) easy able to link positions for young engineering graduates to this model (Fig. 2). Little to no differences are observed in the response pattern in function of the role inside the company. Additionally, there was no significant effect of company size on company-specific implementation of the model, F (3,180) = 1.24, p=.30. Hence, irrespective of the company size, most respondents indicated that it was rather easy to classify positions for young engineers into the model.

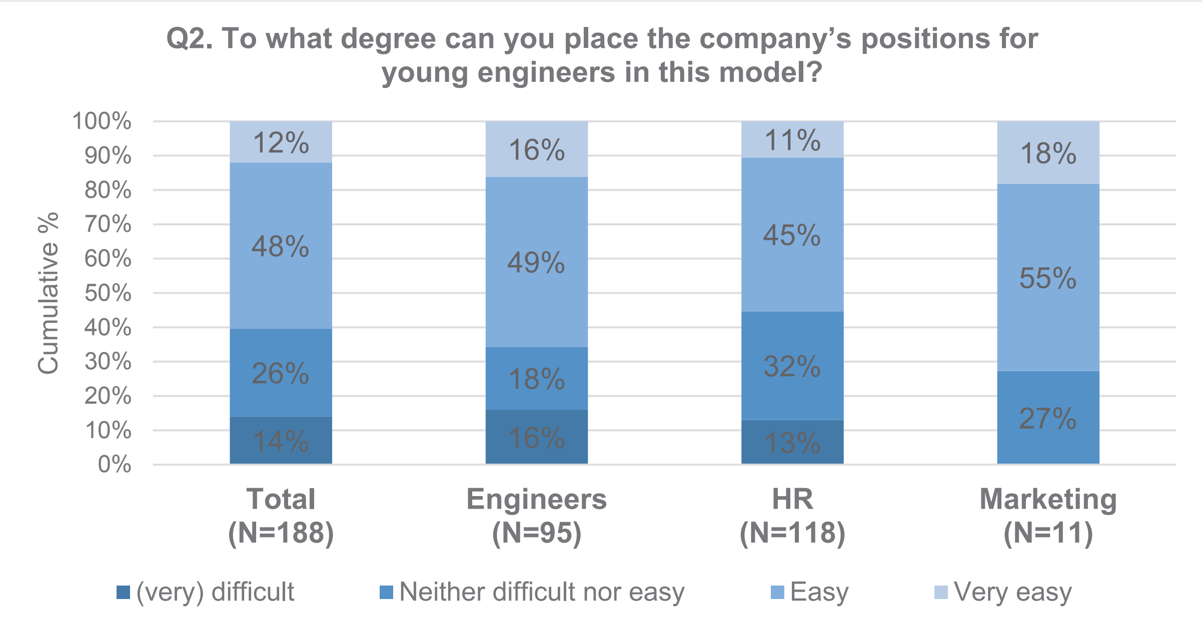

Fig. 2. Industry perceptions on the applicability of the model in their company (total sample, engineering, HR & marketing background)

When participants were asked how the different roles were applied inside their company, around 55% of the respondents indicated that most engineering positions required a combination of two roles (Fig. 3). Also for this question, no statistical differences were observed for different company sizes.

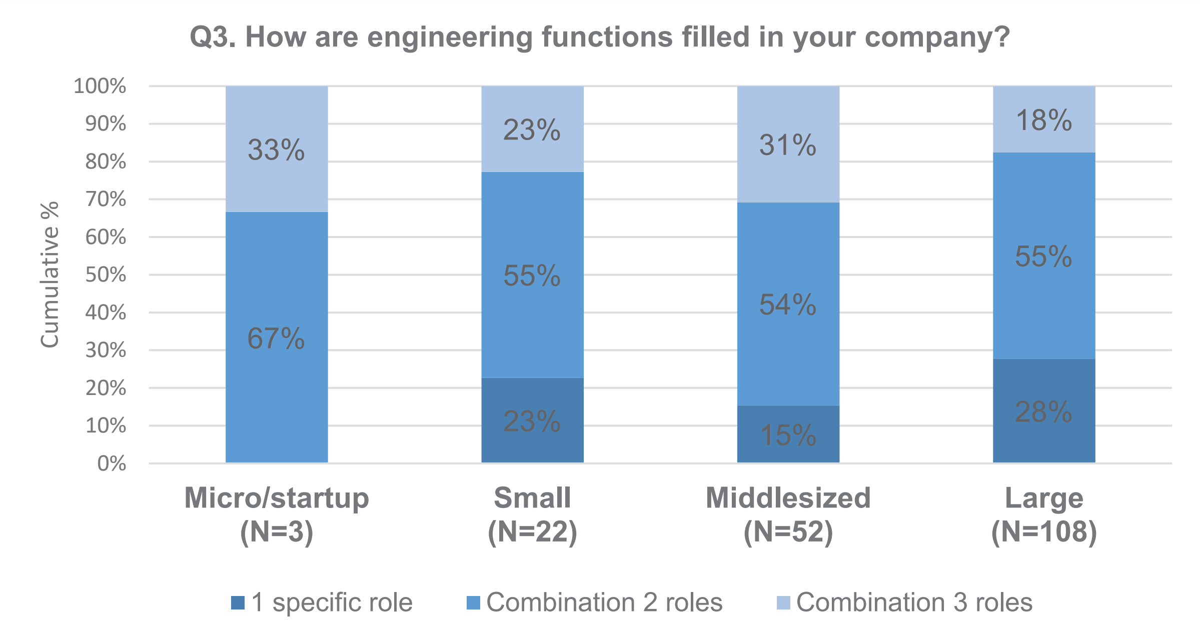

Fig 3. Composition of engineering positions in industry, based on the three professional roles (per company size)

4.2 Associated competences

In the second section of the survey, the respondents were requested to rate the relative importance of 15 professional competences for each of the three professional roles on a 1-5 Likert type scale (for a descriptive overview, see Fig. 4). A general observation is that the average importance of all professional competences is rather high. For example, the average importance of solution orientation and goal orientation is high in all three professional roles with average scores ranging between 4.15 and 4.48 and 4.19 and 4.49 respectively. This finding indicates that these qualities are expected from engineering graduates, irrespective of the professional role.

As shown in Table 1, for all professional competences we found statistical differences between the three professional roles. The largest differences are observed for client orientation ($F(2,477)=108.38$, $p<.001$), building relations ($F(2,471)=79.12$, $p<.001$), and capacity for empathy ($F(2,472)=68.64$, $p<.001$). All three competences were deemed considerably more important for engineers working in a Customer Intimacy role. For the Product Leadership role, creativity, innovation skills, and conceptual thinking were rated significantly more important compared to the other two roles (Fig. 4). Finally, planning and organizing, insight in the organisation, realism and result orientation were somewhat more pronounced in an Operational Excellence role.

In conclusion, these findings indicate that industry professionals attach different relative values to the three professional roles in terms of professional competences. These results illustrate that is possible to define and discriminate the three professional roles identified by Hofland et al. [10] based on a number of clearly defined competences and Likert type scales.

Table. 1. Results ANOVA test statistical differences of importance competences for the three professional roles.

Competence	df	F-value	Sig
Planning and organization	2,480	18.45	<.001
Insight in the organization	2,470	9.32	<.001
Positive critical attitude	2,474	9.81	<.001
Decision-making	2,469	8.65	<.001
Client orientation	2,477	108.38	<.001
Creativity	2,478	32.85	<.001
Innovation	2,471	59.24	<.001
Capacity for empathy	2,472	68.64	<.001
Building relations	2,471	79.12	<.001
Realism	2,468	9.68	<.001
Conceptual thinking	2,473	37.14	<.001
Result orientation	2,472	11.516	<.001
Persuasion	2,472	26.99	<.001
Solution orientation	2,470	7.14	.001
Goal orientation	2,473	5.81	.003

5 DISCUSSION

The prime objective of the Professional Role Model developed by Hofland et al. [10] is to offer engineering students a grip on the complex engineering reality. Thorough industry validation of the model is indispensable in this respect. In sum, we can conclude that the Professional Roles Model is generally supported by a variety of industry stakeholders. About 2/3rd of the respondents recognized the model to classify functions for young engineering graduates and about 60% agreed they could apply the model in their respective company. Altogether, we did not observe statistical differences between (1) the respondents' professional background (engineering, HR or marketing) or (2) the company size. These findings illustrate that the model seems to be widely applicable across different industrial sectors. However, it should be noted that current description of the model might not be sufficiently tailored to the ICT sector, resulting in an impaired interpretability by IT professionals. The majority (55%) of the industry professionals indicated that most engineering positions in their company required a combination of two roles. No statistical differences were observed in this respect between small, medium-sized and large companies.

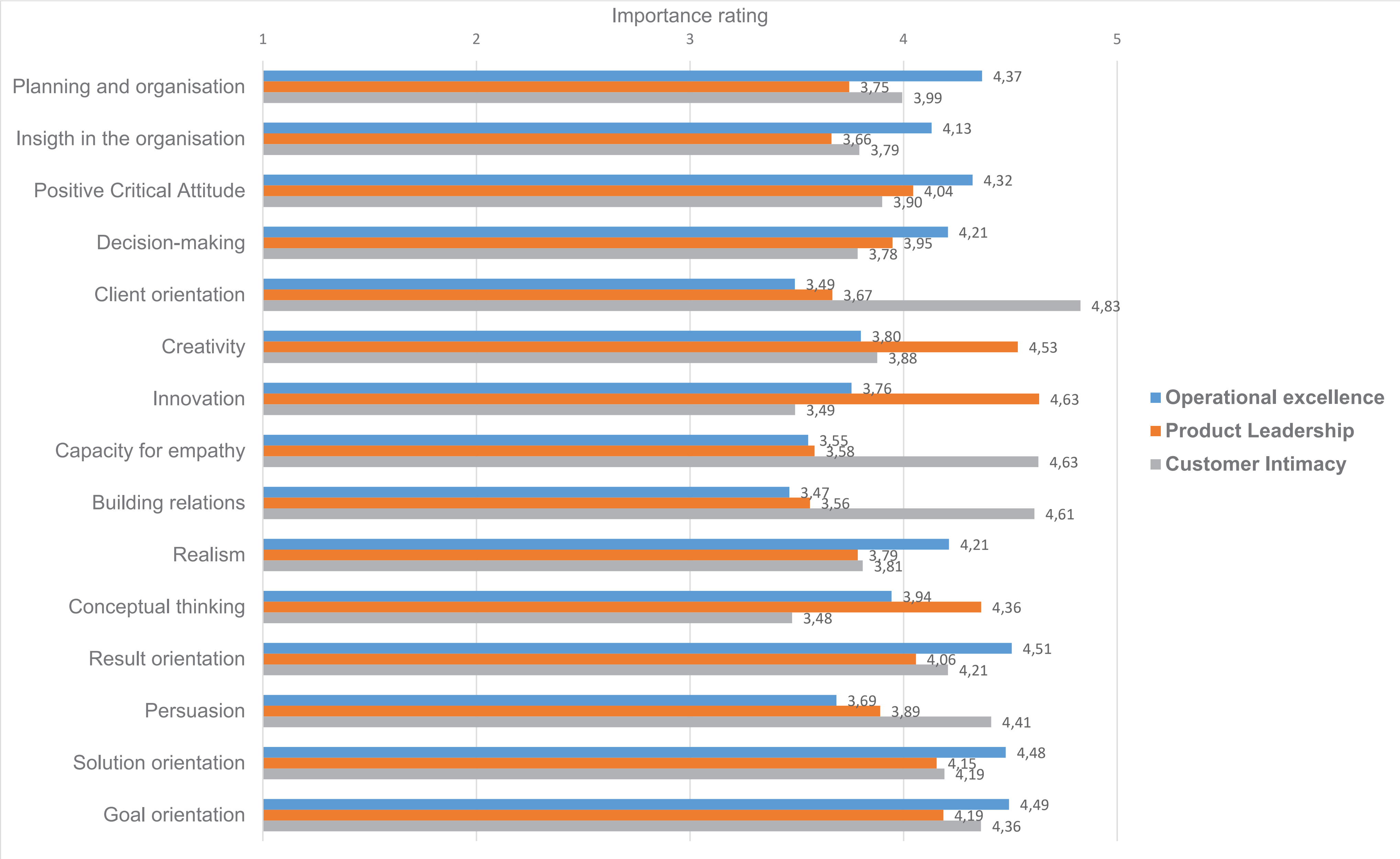

Fig. 4. Perceived importance of 15 professional competences for each of the professional roles.

Furthermore, our findings indicate that business/industry professionals hold different expectations towards the three professional roles in terms of the required professional competences. For example, capacity for empathy and client focus are deemed more important for a customer intimacy role whereas creativity and conceptual thinking are more pronounced in a product leadership role. These findings indicate that industry has different expectations towards engineers working in a different role (also see [13]).

Although the present study yielded a number of interesting findings, a number of limitation should be addressed. First, to measure the (relative) importance of a number of professional competences for each role, we relied heavily on quantitative methods. Recent research by Craps et al. [11] showed that mixed method research (a combination of quantitative and qualitative methods) has promising potential for identifying competences profiles. Using Likert-type scales, the respondents might be driven by a propensity to provide the maximum score for each of the competences. This propensity could stem from a desire for versatile engineers who excel in a wide variety of skills domains. By analogy of the hungry caterpillar, industry professionals might lose themselves in a quest for their white knight. Qualitative focus group discussion might be an interesting avenue to refine our understanding which competences are quintessential for each of the three professional roles. Second, we explored industry perceptions on the professional roles model but unfortunately this method does not enable a deeper understanding of difficulties in the interpretability of the model. A superficial analysis hints at a slightly impaired interpretability in the IT field but due to the closed survey format, this could not be explored in greater detail. In this sense, this study provides valuable insights on how the model specification could be improved to be applicable to a wider student population.

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APPENDIX

Appendix 1. Competences and definitions

No.	Competence	Definition
1	Planning and organizing	*… determines goals and priorities effectively. (S)he clearly indicates the time, activities and resources needed to achieve goals.*
2	Client orientation	*… attunes his/her own actions to the feelings, needs and wishes of internal and external clients, even when these are not directly expressed.*
3	Creativity	*... approaches problems from different angles, contributes new and original ideas and solutions, and breaks through established thinking patterns.*
4	Insight in the organization	*… thinks cross-functionally and acquires insight into and determines the policy parameters.*
5	Innovation	*... has and encourages new, original ideas, working methods, processes and applications. He/she focusses on future innovation in strategy, products, services and markets with an inquiring and inquisitive mind.*
6	Capacity for empathy	*... listens to and thinks along with others. (S)he acknowledges the feelings and needs of others, puts him/herself in others' shoes and consciously deals with different backgrounds and interests.*
7	Positive critical attitude	*... reflects on the methods, techniques, processes and strategies used by the company. (S)he questions them in a positive manner.*
8	Building relations	*... builds relationships and networks with people within and outside of the organisation, at different levels and from different cultures that are important for the goals of the organisation or organisational unit.*
9	Realism	*... demonstrates a good sense of the feasibility of his/her ideas and instinctively and intuitively chooses the right course of action.*
10	Decision-making	*... can take appropriate decisions within the scope of his/her given responsibilities, accounting for risks, limited information, existing issues and situational requirements.*
11	Conceptual thinking	*… can think conceptually and turn concepts into workable solutions.*
12	Result orientation	*... is focused on translating - concretising - goals and achieving results in accordance with timeframes, standards and agreements.*
13	Persuasion	*... obtains buy-in for ideas and proposals by making the right arguments - at the right time and in an appropriate manner and so (s)he has an influence on others.*
14	Solution orientation	*… thinks in terms of solutions. (S)he does neither ignore problems nor unnecessarily consider a given situation a problem.*
15	Goal oriented	*... has the commitment, will and ambition to generate results for the organisation and to achieve organisational objectives or targets.*

Predictors of study success for students of civil engineering at the beginning of their studies

Elmar Dammann
Hochschule Furtwangen
Furtwangen, Germany

Julia Waldeyer
Universität Duisburg-Essen
Essen, Germany

Jens Fleischer
Universität Duisburg-Essen
Essen, Germany

Joachim Wirth
Ruhr-Universität Bochum
Bochum, Germany

Detlef Leutner
Universität Duisburg-Essen
Essen, Germany

Martin Lang
Universität Duisburg-Essen
Essen, Germany

Conference Key Areas: Diversity in Engineering Education? Fundaments of Engineering Education: Mathematics and Physics

Keywords: Study success, civil engineering, technical knowledge, mathematical knowledge

ABSTRACT

Engineering courses make high demands on students in subject and motivational skills. Problems with subject-specific requirements often lead to students terminating their engineering studies prematurely [1]. The presented research project investigates the question of which characteristics at the beginning of the studies predestine academic success. This relates to a perspective on characteristics that prevent unsuccessful students from achieving academic success.

There are study success models that contain in particular the grade of university entrance qualification (Abi) and personality traits as predictors (e.g. [2]). We assume that additional subject-specific predictors and regulatory strategies of individual resources determine academic success [3]. For this purpose, we have developed test

and questionnaire instruments and presented them to about 180 first-year students of civil engineering. The test instruments refer to the subject engineering mechanics (EM) and technical knowledge (FW), subject-specific modelling ability (MF) [4] and mathematical knowledge (MW) [5]. Success in studies is defined as written exam performance and subject-specific knowledge after the first semester.

In path models, we can demonstrate significant correlations between Abi, intelligence, subject-specific skills and mathematical knowledge on the one hand and the study success variables on the other (N=177; χ^2=3,387; CFI=1; RMSEA=0). From a subject-specific perspective, particularly mathematical knowledge at the beginning of a course is therefore very important for the success of study. In the paper we will present the above models and analyses of the mathematical knowledge test at task level.

1 INTRODUCTION

In its attractiveness as a bridge to a profession, higher education has recently overtaken alternative paths such as vocational training. Surveys by the Federal Statistical Office show that since 2011 between 55 and 58% of graduates start university studies [6]. There are many ways to study at university. Through the objective of education policy to increase the permeability of the education system people with different educational background enter the universities. Those are challenged to deal with heterogeneous groups of study beginners.

However, first and foremost, the students themselves, with their respective educational biographies, have to pass the requirements of the university system. This is still oriented towards a high degree of independence and offers only limited support compared to school teaching and learning opportunities. The question arises whether, in particular, students with a lack of basic technical knowledge and ability succeed in complying with the requirements of higher education, especially at the beginning of their studies.

In this study, students of civil engineering were accompanied in the initial phase of their studies. This article describes the importance of mathematical knowledge at the start of the semester for the performance of the exam after the first semester, and whether students succeed in working through technical deficits within the first semester.

2 INITIAL SITUATION

The failure of studies appears mostly in the fact that exams are not passed or a study is even canceled. Especially in engineering courses, the number of students who finish their studies prematurely is high. According to Heublein et al. [1] the reasons for dropping out are often divers and understood as an interaction of several reasons. These refer to the personal situation of the students, the study conditions, the professional orientation or the requirements in the study [1]. Heublein et al. [1] show that in particular the requirements of the study were mentioned most often or even as the decisive reason for the disenrollment.

Study requirements in a technical perspective are often used in empirical examinations, for example in the form of a written exam, as a dependent variable "study success" [5]. Several variables at study entry were identified as predictors. These are, for example, the grade of university entrance qualification, personality traits (big five) or learning behaviour [eg. 2, 6, 7, 8]. As technical predictors of study success, the mathematical and subject-specific knowledge of the beginning of studies is shown in examinations [eg. 5]. The inclusion of technical knowledge and skills in study success models was only undertaken in recent studies, for example in the project “KoM@ING” [eg. 3, 9], in which mathematical as well as subject-specific competencies were assessed at the start of the study. In the investigations of this project first tendencies to correlations between mathematical previous knowledge and professional competences after the first semester occurred. It is clear from these findings that especially those students who have a certain performance potential, who already have specific knowledge and skills at the beginning of their studies, and who are likely to use this knowledge and skills profitably in their studies, will be successful.

The importance of especially mathematical knowledge and abilities at the beginning of studies is also made clear in surveys that were carried out among lecturers of the study entry phase in STEM programs (STEM: Science, Technology, Engineering and Mathematics). In the publications of the cosh group [10] and in the project “MaLeMINT” [11] concrete mathematical contents and examples are given.

If study requirements are interpreted as subject-specific study requirements, there is a tendency for those first-year-students to drop out, who do not have the specific technical knowledge and skills, also who are unable to work through these deficits within the first study phase. For the development of institutionally anchored and targeted support measures, it is crucial to know which technical knowledge and skills are available or not. Therefore, this article presents the test results from an empirical survey of the study success on the item level. In doing so, we investigate the following research questions (RQ):

RQ 1: Are there any correlations between the achieved item solution rates and the mathematical test contents in the test results?

RQ 2: Do students of civil engineering at the beginning of the study have comparable performance levels with regard to mathematical knowledge?

3 DATA BASE

In the study, which is part of the DFG researchgroup ALSTER (Academic learning and study success in the entry phase of science and technology study programs) [13] 208 students of civil engineering were accompanied by regular surveys in the first two semesters of their studies. For these students, information is available at the beginning of studies and at the end of the first semester. Information at the beginning of studies are, for example, the grade of university entrance qualification (Abi), the basic cognitive ability (KFT [12]), the mathematical (RF_T1) and subject-specific knowledge (FW_T1) or the subject-specific modeling ability (MF_T1) as well as the last achieved grade in mathematics (math) at school. This variable "math" has two levels. In the German Gymnasium, mathematics can be learned at a basic level and a performance level. This level difference is not taken into account in the variable. At the end of the first semester, the students were tested again for their professional achievements, for example with the Test for Mathematical Knowledge (RF_T2). The academic success variable is the average grade of the examinations in Engineering Mechanics (EM) and Advanced Mathematics (HM), which was achieved at the end of the first semester.

Statistical correlations of the recorded data were checked by means of a hierarchical regression. As a dependent variable (DV) serves the achieved average exam score in EM and HM (*Table 1*). In Model 1, the variable 'Abi' is used as an independent variable that can explain 24,37 % of the variance of DV. In model 2, the variable KFT is added, thus increasing the variance elucidation from DV to 28.42%. Model 3 also includes the variable math, which does not generate a significant charge to DV. The variance elucidation increases again, but the variable math does not provide any added value. In model 4, the variable math is no longer taken into account; the variable KFT also no longer shows a significant correlation and is removed from the model. The variables FW_T1, MF_T1 and RF_T1 are added. With this model, a variance of 46.26% can be clarified. In addition, the variables MF_T1 and RF_T1 show significant relationships to DV. Model 4 is therefore best suited to the data. Important variables for the explanation of DV are therefore RF_T1, MF_T1 and Abi. A detailed description of the modeling of this regression model will be presented at [4].

Table 1. Hierarchical regression, DV: average exam score in EM- and HM after semester 1

	Model 1	Model 2	Model 3	Model 4
constant	0,033	0,025	0,017	0,057
Abi	0,492***	0,497***	0,581***	0,318***
KFT		0,155*	0,165*	
math			0,108	
FW_T1				-0,027
MF_T1				0,196*
RF_T1				0,448***
corr. R^2	24,37 %	28,42 %	30,87 %	46,26 %
df	175	170	158	161
p	1,775e-12	1,673e-13	2,813e-13	2,2e-16

p < 0,1’; 0,05*; 0,01**; 0,001***

As a result, model 4 provides the comparatively largest explanation of variance with respect to the dependent variable and is thus to be preferred in this model comparison. If variables of the basic cognitive ability, the grade of university entrance qualification, the grade in mathematics and subject variables are included in the model, then the variables of the basic cognitive ability and the mathematics grade do not become significant and thus fall outside the model. Also, the subject-specific knowledge at the beginning of the study shows in model 4 no significant influence on the performance in the exams EM and HM. On the other hand, influences are reflected in the subject-specific modeling ability, the mathematical knowledge and the grade of university entrance qualification (Abi).

These three variables account for approximately 46.3% of the average exam grade in EM and HM after the first semester. This can also be explained in terms of content, because the content of the technical requirements of the EM and HM exams is focused on mathematical and subject-specific (in the case of EM contents of mechanics) content. However, the great importance of the technical knowledge and abilities at the beginning of studies shows that the success of the exam is especially successful for those students who already have the necessary knowledge and skills at the beginning of their studies. They seem to succeed in the exam significantly better.

The following chapter introduces the test used to measure mathematical knowledge (RF_T1) and then examines the mathematical knowledge of the students from an item based perspective.

4 CALCULATION ABILITY AT STUDY BEGINNING

The test instrument for the acquisition of mathematical knowledge was published [5] and consists of 27 items in the content areas "calculation", "terms and equations", "vectors and matrices", "differentiate", "integrate" and "trigonometry". The tasks were presented to the students in a half-open answer format, the test instrument as a whole in a paper & pencil form. No further aids were available for the students. In the study of mathematical knowledge there are data from 196 of the 208 students of the cohort. These achieved a mean solution rate of M = .54 with a standard deviation of SD = .24. From an IRT-analysis of the test data results a very good EAP reliability of the test of .87. *Table 2* below shows the mathematical content areas of the instrument already mentioned, the respective number of items and the corresponding solution rates.

Table 2. Content areas of the test instrument for measuring mathematical knowledge

Content area	Number of items	solution rate
calculation	3	.83
vectors and matrices	7	.62
trigonometry	2	.57
differentiate	3	.45
terms and equitations	9	.43
integrate	3	.44

The contents represented in the test instrument are based on the already mentioned surveys of teachers regarding mathematics at the beginning of the study regarding the expected mathematical knowledge and abilities at this time [10, 11].

5 PERFORMANCE CLUSTERS

Students will be considered as successful after the first semester if they have shown high performance in the exams of the EM and HM and have received corresponding exam grades. These notes are used to build performance clusters (PC) in this chapter, and then to compare these clusters with various other features, such as mathematical knowledge.

5.1 CONSTITUTE THE CLUSTER

The group of students was divided into four performance clusters in this sub-study. The final examination grades in EM and HM were subdivided into four ranges, as shown in *Table 3*. *Table 3* also includes the group name and the absolute or percentage group size.

Table 3. Performance cluster after the average exam grade EM and HM after semester 1

Cluster	grade	Group size (percentage)
A	> = 1; < 2	14 (7,14)
B	> = 2; < 3	35 (17,86)
C	> = 3; < 4	62 (31,63)
D	> = 4	85 (43,37)
total		196 (100,0)

Grades > 4 were also taken into account. This may be confusing from the examination point of view, because examinations that are graded with grades > 4 are usually considered as "failed". Since, however, an average grade of the written exam was used for this examination, cases arise in which, for example, one written exam was passed and one failed. The variable "average exam grade" therefore does not represent a grade under examination, but rather a professional level of achievement that the students achieved at the end of the first semester.

It becomes clear that a large part (about 43%) of the examined sample can be found in the performance cluster D. Thus, a part of these students did not pass at least one of the two exams (all grades are from initial tests, results of possible final examinations are not taken into account).

5.2 ACHIEVED SOLUTION RATES OF THE PERFORMANCE CLUSTERS

In the next step, the examination of the performance clusters focuses on the achievements in the test for mathematical knowledge at the beginning of the studies (RF_T1). *Table 4* shows the solution rates of the specific clusters and the respective standard deviations.

Table 4. Solution rates of the performance cluster in test RF_T1

Cluster	Solution rate	Standard deviation
A	.78	.23
B	.67	.22
C	.54	.27
D	.45	.26

It is clear that the performance in the test for mathematical knowledge (RF_T1) differ and decrease with higher letter designation of the clusters, and thus with a higher average exam score. Here, the significant correlation that has been shown in the regression model in *Table 1* between RF_T1 and the average exam score becomes clear.

However, this relationship between the mathematical knowledge at the start of the course and the exam performance is not only shown in specific but in all mathematical content areas of the test instrument. This becomes clear in the following diagram (*Fig. 1*). The content areas are color-coded as follows: calculation, trigonometry, vectors and matrices, integrating, terms and equations and differentiation. Thus, research question 1 can be answered: the solution rates of the test tasks are not directly related to the mathematical content areas.

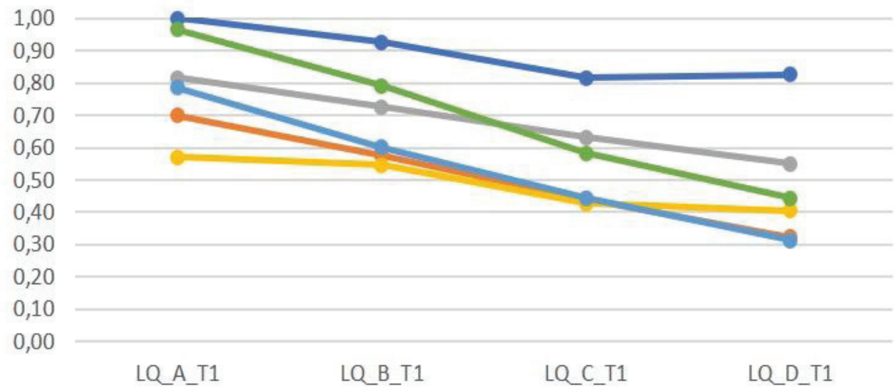

Fig. 1. Solution rates in RF_T1 of the performance clusters (read: LQ_A_T1: Solution rate in performance cluster A at the start of the study (measurement time T1))

With reference to research question 2, it is evident that the deficits in mathematical knowledge at the beginning of studies and at the end of the first semester are not the same for all students. Nevertheless, about 43%, and thus the majority of students in the cohort (see *Table 3* - PC_D), have very large mathematical deficits.

Table 5 shows the achieved solution rates of the performance clusters for T2.

Table 5. Solution rates of the performance cluster in test RF_T2

Cluster	Solution rate	Standard deviation
A	.81	.19
B	.70	.22
C	.52	.25
D	.39	.27

All content areas of the test instrument RF are represented in the group of items with large solution rates differences. For example, within the group of 11 items with large differences in solution rates - both T1 and T2, one item refers to the "calculation" content area, five items to the "terms and equations" area, two items to the "vectors and matrices" area, one Item for the differentiate area, one Item for the integrate area, and two items for the trigonometry area.

The comparison of the two measurement points with the focus on the solution rates shows after the first semester that the students of the performance clusters A and B tend to show higher, the students of the performance clusters C and D tend to show lower test performances.

6 SUMMARY

In this empirical research project, it could be shown that subject-specific variables at the beginning of studies (eg. mathematical knowledge and the subject-specific modeling ability) explain the achievements in examinations for EM and HM after the first semester (variable study success). These variables explain additional variance to the variable grade of university entrance qualification (see also [5]).

The strong connection between the mathematical knowledge at the start of the study and the exam performance at the end of the first semester becomes more evident when the sample is divided into performance clusters. Depending on these performance clusters, item-specific, sometimes very large performance differences can be seen. Thus, there is no influence of the mathematical content areas on the solution rates difference. Rather, all content areas are represented in the items with low as well as in the items with high solution rates differences. Thus, the difficulty of mathematical knowledge tasks in this study does not seem to depend on the content but rather on task-related complexity facets not specified in this study.

The primary aim of this paper was to describe the differences between undergraduate students in mathematical engineering at the beginning and end of the first semester on the content level. The use of the test items for the mathematical knowledge of T2 allows a consideration of the performance development of the subjects. There are performance differences between the performance clusters both at the beginning of the study and at the end of the first semester. T2 shows very similar differences in solution rates between the performance clusters. In particular, between the performance clusters A and D is rather an increase in the solution rates differences. That means that the subjects of the performance cluster D are not able to noticeably reduce the performance differences within the first semester, they tend to get bigger. At the same time, the differences at the item level of T1 are almost unchanged.

This is a remarkable finding, since the test contents for mathematical knowledge in the opinion of teachers of the EM and HM have great significance for the knowledge and understanding development in both subjects in the first semester (see [10, 11]). According to the results of this study, it can be assumed that a large number of students in the first semester of their studies fail to work through their basic subject-specific deficits. Also from the perspective of the performance clusters oriented grades of the written exam, these subject-specific deficits represent a risk for passing the exams in EM and HM after the first semester.

This raises the question to why, in particular, the students of the PC_D do not succeed in working up their deficits in the area of mathematical knowledge within the first semester. In particular, it should be asked whether the teaching and learning opportunities available at the universities are suitable for supporting students in the development of basic knowledge and skills.

From our perspective, it is appropriate to examine which specific support for students of civil engineering is needed. The findings of this study show that the independent development of basic mathematics skills is unlikely to be expected of students in the first semester. Here it is to be considered whether further institutional teaching and learning offers are meaningful and affordable. In particular, with regard to the participants' motivation to participate in support programs, measures to increase the student's liabilities are to be examined.

This study provides a well-founded, but limited view of the students' situation in the introductory phase in civil engineering and the links to academic success. Thus, the marks of the first test were used as characteristics of the study success. However, many students succeed in the second attempt, which will be taken into account in the further analysis in this study.

With regard to the individual items, there is no correlation to the mathematical content in the test. It has to be clarified, if missing previous knowledge are the only characteristics of the task difficulty or if there are further difficulties determining characteristics with these test tasks. For example, process analyzes with the cohort of comparable subjects can be carried out. In addition, the items will be examined for already proven difficulty-determining traits.

With regard to the development of mathematical knowledge within the first semester, it has to be clarified why this is largely absent, especially among students in PC_D. Which strategies use students in the first semester in order to cope with the demands of everyday life (exercises, etc.) and what significant role plays the basic mathematical knowledge demanded in the test?

Finally, for the development and orientation of specialist support measures in the introductory phase, it must be clarified which support requirements first-year-students actually have. It can be assumed that students who have mathematical knowledge but have not sufficiently solidified it have different support needs than students whose curriculum at school did not include certain content.

The development of mathematical knowledge within the first semester is a "black box" in this study. For example, there is no information available about which teaching and learning offers or which learning strategies the students have used. However, this information is particularly important for the development of individual support measures.

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Peer Review Procedures in Higher Education applied to Engineering Studies

H. Englert[1]
Research Assistant
Chair of Structural Mechanics, Technical University of Munich
Munich, Germany
E-mail: hannes.englert@tum.de

C. Schmaußer
Research Assistant
Chair of Structural Mechanics, Technical University of Munich
Munich, Germany
E-mail: corinna.schmaußer@tum.de

G. Müller
Full Professor
Chair of Structural Mechanics, Technical University of Munich
Munich, Germany
E-mail: gerhard.mueller@tum.de

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Keywords: Peer Learning, Peer Review in Higher Education, Engineering Studies

ABSTRACT

The peer review procedure is based on a mutual exchange process of giving and receiving feedback from people with similar competences. Set in the context of higher education, it is a specific form of peer learning, where the solution proposal of an exercise and the feedback comes from students attending the same course.

Using the peer review process, individual feedback for all students can be generated, even for large courses, under reasonable effort for the teachers. It enables students to reflect on their own solutions and share their knowledge, which is mutually beneficial.

A challenge when applying the technique to new courses or study fields lies in developing suitable tasks. It should be possible to cope with the assessment of the tasks at a satisfying quality level and in reasonable time, providing beneficial learning effects to both the reviewer and the reviewee.

[1] Corresponding Author
H. Englert
hannes.englert@tum.de

In this contribution, we revisited the technique with the aim to provide new ideas for applications in civil engineering education and to improve existing ones. We applied three different types of tasks and evaluation schemes to a peer review procedure in the context of a fundamental undergraduate course with about 500 attendees. We statistically evaluated the exam results and observed an upward deviation in the grades of the participants in the peer review procedure. Additionally, we determined the acceptance amongst the participants using a questionnaire. Based on our experiences, we make proposals for using peer review procedures in engineering education.

1 INTRODUCTION

The peer review procedure is based on a mutual exchange process of giving and receiving feedback from people with similar competences [1]. Peer review procedures are conventionally used in scientific publications, where experts in the relevant research field of a particular publication evaluate the contents with respect to credibility. Its main purpose is to ensure the quality of a published text. Also on a professional level, peer review is common practice, as for example clinical or technical peer review.

Set in the context of higher education, peer review is a specific form of peer learning [2], where the solution proposal of an exercise and the feedback comes from students attending the same course and therefore having roughly the same level of experience in that topic, instead of feedback given by the teaching staff. The idea behind adapting specific aspects of peer learning in higher education is that learning from each other is not limited to informal learning. The ability of developing skills on our own is something engineers are confronted with regularly in everyday working life. It is also something already taking place in university life, on an informal as well as on a formal level.

Introducing the peer assessment procedures in the fundamental pre-graduate lecture "Technical Mechanics in Civil Engineering" was based on the ideas of Boud et al. [2]. They state that the reciprocal learning process is not necessarily incidental, but rather can be actively promoted. Although this was not the main intention, reducing the workload on the part of the teaching staff also played a role in these considerations.

2 BENEFITS OF USING PEER REVIEW IN HIGHER EDUCATION

According to literature, different models of peer learning can be identified, for example

- proctor models, where peer tutoring seniors teach juniors [3],
- discussion seminars,
- collaborative project and group works,

to name only a few of them. Topping [4] mentioned some examples of peer tutoring adapted to higher education and already stated the beneficial learning effects of this method.

Whereas the above mentioned methods aim to provide an exchange of knowledge between students [4] or encourage discussions, peer review procedures in higher education context urge students to evaluate the work of other peers [1], e.g. in form of a written feedback. It can be distinguished from peer assessment, which aims to grade the work of a peer [5]. Using the peer review process, individual feedback for all students can be generated, even for large courses, under reasonable effort for the teachers. It enables students to reflect on their own solutions and share their knowledge, which is mutually beneficial [2].

A former study by Nicol et al. [1] showed that using peer review procedures in education can reduce the necessity of external feedback. The same study also refers to national surveys in the UK and Australia, highlighting that feedback is one of the key elements identified by students to lack during their studies.

3 ON THE CURRENT USE OF PEER REVIEW IN HIGHER EDUCATION

Peer review is well established in medicine and legal studies, and in recent times has been adapted to various study fields, including engineering education. Reported applications in engineering studies often focus on particular types of tasks like design processes, programming skills, writing skills or laboratory reports as some of the more common ones.

A well-documented example of using peer assessment methods in engineering education deals with a single midterm task in the context of an electrical engineering undergraduate course as described by Boud et al. [7]. This also served as a template to our first try to adopt the procedure in our courses. A more recent study of using peer review procedures in an Informatics course is given by Conde et al. [8]. Andersson et al. [9] contribute an application of a peer review process of laboratory reports for engineering students, focusing on the classification scheme for the reviewing.

Mulder et al. [6] presented a study on students' perception of peer review in higher education, highlighting some of the difficulties that arise. Studies determining the learning mechanism behind peer review procedures, as in Cho et al. [10] and Nicol et al. [1], state that the examination and critical review of peer texts provide a better understanding of the topic. Even though mainly aimed at writing skills or product design as in Nicol et al. [1], in our opinion this effect seems to hold true also for calculation tasks, as they are common in engineering education. Now the question arises, how the same ideas can be adopted to theoretical tasks, such as mathematical solution procedures or calculated results.

One challenge lies in developing suitable tasks, which can be assessed with satisfying quality in reasonable time, providing beneficial learning effects to both the reviewer and the reviewee.

Besides this, our experiences showed that well suited incentive systems are favourable measures in order to motivate the students to take part in the peer review procedure, in case participation is not mandatory anyhow.

4 TECHNICAL LAYOUT OF THE PEER REVIEW PROCESS

One important challenge of the introduction of a peer review procedure in fundamental lectures with a great amount of course attendants is the administration. The additional workload for supervising the peer review procedure has to be kept low. Additionally, a high quality of the assessment and the accompanying feedback has to be ensured, especially if an incentive system is offered.

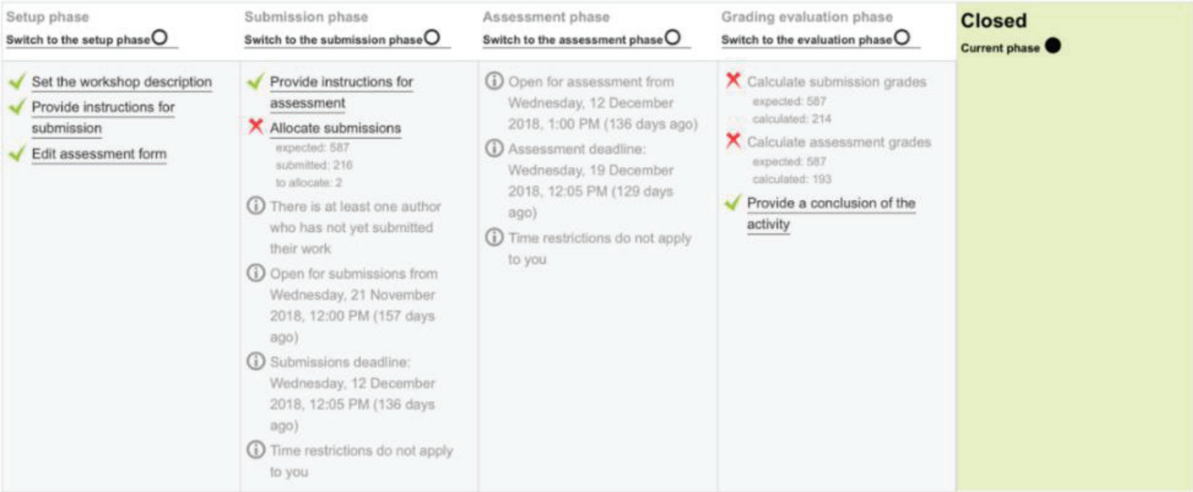


Fig. 1. Layout of the peer review procedure in Moodle

In the given study, the participants were guided through the peer process by using the integrated tools of the open-source learning management system (LMS) Moodle, which was developed in 2001. Here, a complete automatization of the submission and assessment process, a random distribution amongst the participants and returning the individual feedback is possible. The main interface is shown in *Fig. 1*. The quality of the given feedback can be ensured by comparing different feedbacks against each other, verifying that the discrepancy between them is within an acceptable range.

5 CONTENTUAL LAYOUT OF THE PEER REVIEW PROCESS

In this research, we compare different types of tasks and assessment schemes applied to a peer review process in the context of engineering science in fundamental theoretic lectures, in particular on the example of the course “Technical Mechanics in Civil Engineering”. Two types of tasks are examined in depth and the results are evaluated qualitatively by means of comparing the grades of participants and non-participants as well as the assessment of a questionnaire amongst the participants on learning benefits, time effort, conception of the tasks, assessment of the tasks and quality of the received feedback.

We applied the peer review procedure to the following tasks:

- Case 1: Mid-term exam
- Case 2: 14 weekly task sheets, prepared and discussed in tutor groups
- Case 3: Ongoing study project with practical relevance, distributed in three task sheets

In all cases, the students had to process the given tasks, upload their solution in the open source learning management system (LMS) Moodle, scrutinise solutions of fellow students and upload the assessed solution in Moodle. Afterwards, they received feedback from their peers. Depending on the case, the peers could be one or more students attending the same course. In order to create a safer environment for the students, i.e. to minimize anxiety and stress caused by the peer review process, we kept the feedback anonymous, as recommended by Andersson et al. [9].

The participation in the peer review procedures was voluntarily due to legal constraints. To increase the students´ motivation to participate in the offered peer review procedure, in case 2 (weekly task sheets) and case 3 (ongoing study project) we provided an incentive system. This included a grade improvement of 0.3 (1.0 best, 5.0 worst mark) in case of a successful participation. Thereby, a successful participation meant, that the students have passed 75% of the issued task sheets including an additional mid-term. The task sheets and the mid-term were passed, if the processing was good, e.g. a minimum of 50% of the points available had been achieved and the evaluation of the fellow students' task sheets was reasonable.

In the following, the three investigated cases are described in detail:

Case 1: In a first trial, we started by using a peer review procedure to evaluate a mid-term exam. The exam was held during lecture time and mainly served as a preparation for the final exam. Therefore, the tasks closely resembled those of the final exam with respect to complexity, level of difficulty and degree of abstraction. With a rough number of 500 course attendants it would not have been possible for the teaching staff to evaluate thoroughly the students' solutions. However, by using the peer review procedure to assess the mid-term exam, detailed feedback could be created for every student. After solving the exam, students uploaded their own solution in Moodle and randomly were assigned to one fellow student's work for reviewing. For the reviewing process a detailed solution proposal with a suitable point scheme, several comments and additional hints existed. Thus, the students could be motivated to reflect on their solution and a detailed assessment of the mid-term exam was possible. As a result of the peer assessment, the students received the peer´s comments on their processed tasks and a grade. The grade was calculated by the peers in a similar manner as this is done in the final exam. Each task is rated and weighted due to its percentage of the total score of the mid-term exam. The grade didn´t account for the final course grade due to legal constraints, but it provided the participants a fair estimation on their current state of knowledge. By this means, we tried to encourage the students to catch up with lecture contents, before it would be too late. With only 21 participants in the first year and 62 in the second the acceptance was way below our expectations.

Case 2: In the second trial, we adopted the process to weekly task sheets (*Fig. 2*), the students were encouraged to solve during the semester. The task sheets so far had been discussed and supervised in a well approved system of peer tutoring [4] in fixed weekly slots. As in the case of the mid-term exam, the teaching staff could not handle the expenses to evaluate every student´s task sheet and give individual feedback. Now, we decided to adapt the already tested peer review procedure to those weekly task sheets, introducing the described incentive system for increasing the motivation for participation in the peer review procedure. The used tasks were rather abstract and theoretic. Again, the students had to solve the task sheets and upload their proposed solution. For the assessment, the peers obtained a detailed solution of the task sheet. To avoid disproportionate correction effort, the students used a very coarse evaluation scheme. The peers had to decide whether the solution is mostly correct (2 points), partly correct with a mechanically reasonable approach (1 point) or insufficient (0 points) for each single task. To ensure the quality of the assessment - respectively the peer´s feedback - each student had to evaluate the task sheets of three fellow students. Thus, different feedbacks could be compared and verified by the discrepancy between them. This is done in Moodle automatically.

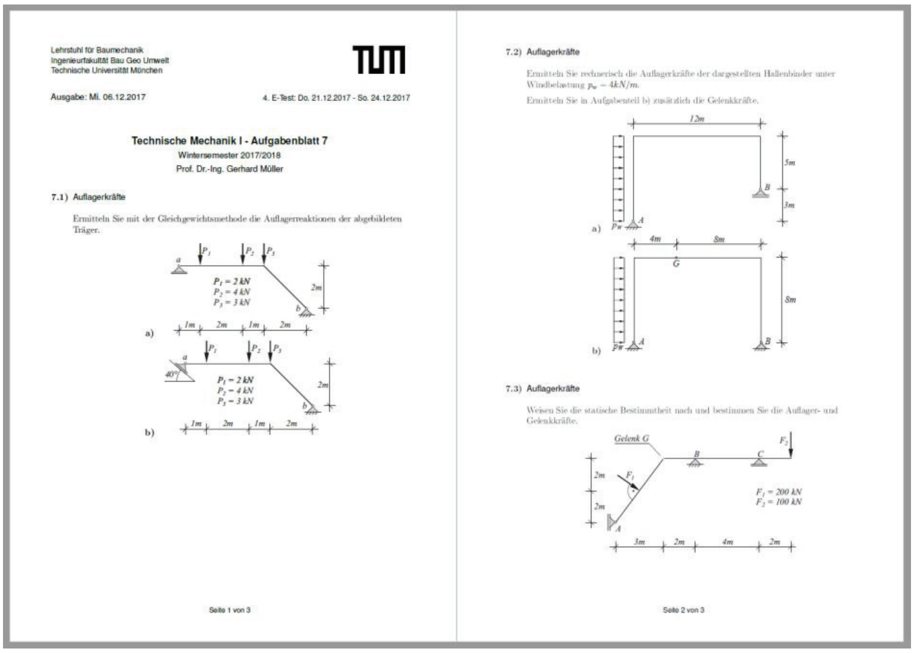
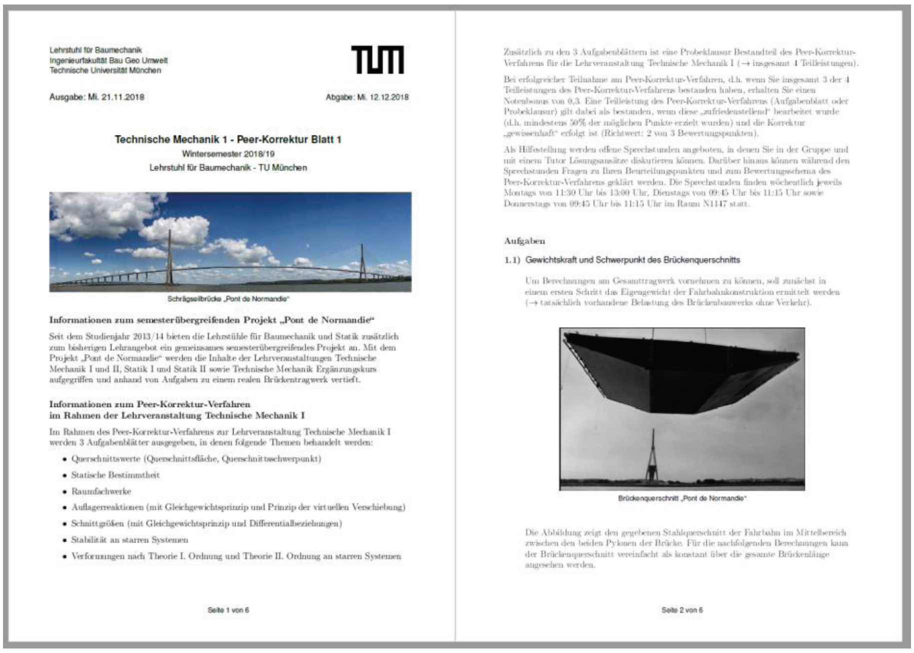


Fig. 2. Exemplarily task sheet as used for the second adaption of the peer review procedure

Case 3: In the third adaption of the peer review procedure, we varied the task once again by offering a lower number of task sheets. This included longer processing and assessment periods. Additionally, the tasks were less abstract and theoretical examples, but rather an ongoing study project (*Fig. 3*) with practical relevance to show the students how the taught methods can be used in a real engineering context, here for example for the designing of bridges. Besides the offer of a grade improvement for a successful participation in the peer review procedure, the practical application was used for a further enhancement of the students' motivation. While creating suitable tasks, it was important to find a balance between complexity of the problem to be solved and a restriction of possible solutions for the reviewer to be capable of producing qualitative feedback within considerable time and without immoderate effort for the assessment. On the other hand, tasks with a variety of possible solution strategies should be created, as the understanding and correction of different approaches might enhance the peer´s learning effect. The peer procedure itself did not differ from case 2, described above. Only the assessment had to be done finer than in case 2. The peers were distributed a point scheme for their correction, together with a detailed solution of the tasks including comments and some varying solution strategies. The submission is rated due to its percentage of the total score of the task sheet and then assigned to a rather fine percentage scheme divided in steps of 10 percent. Additionally, there was the option to give a personal written feedback.


Lehrstuhl für Baumechanik
Ingenieurfakultät Bau Geo Umwelt
Technische Universität München

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Technische Mechanik 1 - Peer-Korrektur Blatt 1
Wintersemester 2018/19
Lehrstuhl für Baumechanik - TU München

Schrägseilbrücke „Pont de Normandie"

Informationen zum semesterübergreifenden Projekt „Pont de Normandie"

Seit dem Studienjahr 2013/14 bieten die Lehrstühle für Baumechanik und Statik zusätzlich zum bisherigen Lehrangebot ein gemeinsames semesterübergreifendes Projekt an. Mit dem Projekt „Pont de Normandie" werden die Inhalte der Lehrveranstaltungen Technische Mechanik I und II, Statik I und Statik II sowie Technische Mechanik Ergänzungskurs aufgegriffen und anhand von Aufgaben zu einem realen Brückentragwerk vertieft.

Informationen zum Peer-Korrektur-Verfahren im Rahmen der Lehrveranstaltung Technische Mechanik I

Im Rahmen des Peer-Korrektur-Verfahrens zur Lehrveranstaltung Technische Mechanik I werden 3 Aufgabenblätter ausgegeben, in denen folgende Themen behandelt werden:

- Querschnittswerte (Querschnittsfläche, Querschnittsschwerpunkt)
- Statische Bestimmtheit
- Raumfachwerke
- Auflagerreaktionen (mit Gleichgewichtsprinzip und Prinzip der virtuellen Verschiebung)
- Schnittgrößen (mit Gleichgewichtsprinzip und Differentialbeziehungen)
- Stabilität an starren Systemen
- Verformungen nach Theorie I. Ordnung und Theorie II. Ordnung an starren Systemen

Seite 1 von 6

Zusätzlich zu den 3 Aufgabenblättern ist eine Probeklausur Bestandteil des Peer-Korrektur-Verfahrens für die Lehrveranstaltung Technische Mechanik I (→ insgesamt 4 Teilleistungen).

Bei erfolgreicher Teilnahme am Peer-Korrektur-Verfahren, d.h. wenn Sie insgesamt 3 der 4 Teilleistungen des Peer-Korrektur-Verfahrens bestanden haben, erhalten Sie einen Notenbonus von 0,3. Eine Teilleistung des Peer-Korrektur-Verfahrens (Aufgabenblatt oder Probeklausur) gilt dabei als bestanden, wenn diese „zufriedenstellend" bearbeitet wurde (d.h. mindestens 50% der möglichen Punkte erzielt wurden) und die Korrektur „gewissenhaft" erfolgt ist (Richtwert: 2 von 3 Bewertungspunkten).

Als Hilfestellung werden offene Sprechstunden angeboten, in denen Sie in der Gruppe und mit einem Tutor Lösungsansätze diskutieren können. Darüber hinaus können während den Sprechstunden Fragen zu Ihren Beurteilungspunkten und zum Bewertungsschema des Peer-Korrektur-Verfahrens geklärt werden. Die Sprechstunden finden wöchentlich jeweils Montags von 11:30 Uhr bis 13:00 Uhr, Dienstags von 09:45 Uhr bis 11:15 Uhr sowie Donnerstags von 09:45 Uhr bis 11:15 Uhr im Raum N1147 statt.

Aufgaben

1.1) Gewichtskraft und Schwerpunkt des Brückenquerschnitts

Um Berechnungen am Gesamttragwerk vornehmen zu können, soll zunächst in einem ersten Schritt das Eigengewicht der Fahrbahnkonstruktion ermittelt werden (→ tatsächlich vorhandene Belastung des Brückenbauwerks ohne Verkehr).

Brückenquerschnitt „Pont de Normandie"

Die Abbildung zeigt den gegebenen Stahlquerschnitt der Fahrbahn im Mittelbereich zwischen den beiden Pylonen der Brücke. Für die nachfolgenden Berechnungen kann der Brückenquerschnitt vereinfacht als konstant über die gesamte Brückenlänge angesehen werden.

Seite 2 von 6

Fig. 3. Extract of the ongoing project used for the third adaption of the peer review procedure

6 EVALUATION AND FINDINGS

The different peer review methods have been evaluated using a survey on students' experiences, as well as assessing their overall performance in the final exam. Significant improvement of the grades of those students participating in the peer process could be observed in the second and third case, whereas we did not statistically evaluate case 1 due to the limited number of participants. In the course "Technical Mechanics 1", where we employed case 3, the mean grade of the exam was 3.43, with a grading scale reaching out from 1.0 to 5.0 and a minimum of 4.0 needed to pass the course. From 500+ course attendees a total number of 446 students took the exam. *Fig. 4* shows the distribution of the grades for those 145 students, who successfully participated in the peer review procedure, in the following indicated as "Group 1", and those 301 students, who did not participate or succeed, indicated as "Group 2", separately.

The mean grade for "Group 1" was 2.49, with a standard deviation of 1.03. For "Group 2" we could identify a large downward deviation, with a mean grade of 3.88 and a standard deviation of 1.04. For "Group 1" 92.42% of the students attending the exam passed it, whereas in "Group 2" only 51.50% passed.

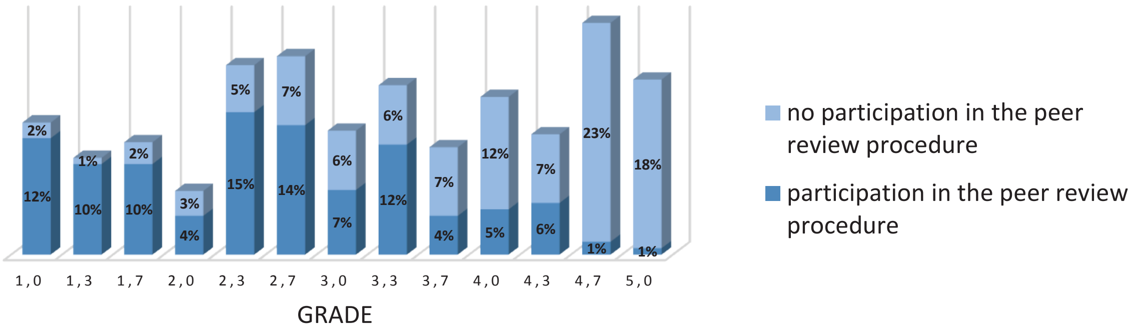

Fig. 4. Distribution of grades – Case 3

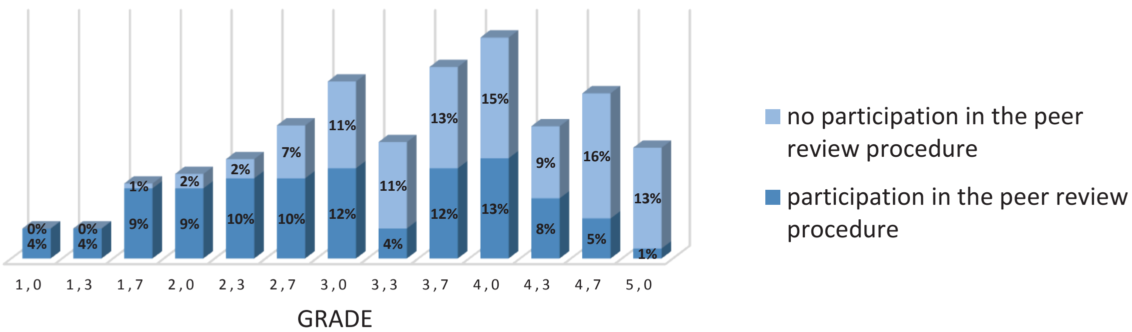

Fig. 5. Distribution of grades – Case 2

The same data is shown for the course “Technical Mechanics 2”, where we applied case 2 (*Fig. 5*), with 241 students of the relevant year, that took the exam. Once again, *Fig. 5* displays the grades separately for those 78 students that did participate in the peer review procedure, indicated as “Group 3”, and those 163 students that did not (“Group 4”). In accordance with the other results, the mean grade showed a downward deviation for “Group 4” as compared against “Group 3”. The complete comparison of the mean grades and standard deviation is given in *Table 1*.

Table 1: Mean grade and standard deviation for different groups of students

	Case 2			**Case 3**		
	all	**“Group 3”**	**“Group 4”**	**all**	**“Group 1”**	**“Group 2”**
mean grade	3.71	2.98	3.86	3.43	2.49	3.88
standard deviation	0.93	1.04	0.81	1.22	1.03	1.04
mean grade (passed)	3.18	2.73	3.34	2.72	2.34	3.06
standard deviation (passed)	0.91	0.93	0.77	1.16	0.91	1.16

The survey was conducted in the course, where the third peer review case was applied. The used five point Likert-Scale had ordered response levels starting with 1 – “strongly disagree” and ending with 5 – “strongly agree”. In the following we present the main findings of the evaluation of the survey along 124 course attendants. After restricting on those surveys of students that participated in the peer review procedure and excluding contradictory answers, a total of 93 surveys was left. Amongst those, 85 students claimed to have received a bonus, thus succesfully participated in the peer review procedure from beginning to the end, whereas 8 students answered negative on this question, mostly arguing that they aborted their participation due to a too high time effort. Of all participants of the survey, only 7 have made previous experiences with peer reviewing. *Table 2* shows the mean levels and the percentage of students that agreed with a statement exemplarily for selected questions.

Table 2: Results of the survey

		Mean level	**Percentage of agreement**
I.5	The time effort for the peer review procedure compared to learning benefits is justified.	3.33	43.01%
II.4	By solving the tasks, I could improve my understanding of the course content.	4.10	79.35%
III.4	By reviewing the work of peers, I could improve my understanding of the course content.	2.72	26.88%
IV.5	The received feedback improved my understanding of the course content.	2.13	7.87%
I.6	I can imagine a voluntary participation in a similar activity.	2.18	11.83%
I.7	I generally support the idea of reviewing and receiving feedback from peers.	3.50	54.84%
I.8	I would like to have more similar activities during my further studies.	3.74	61.29%
II.1	The tasks served as additional motivation to deal with the course content.	3.95	66.30%
III.3	I feel confident to review and grade peers.	4.12	80.43%
IV.1	The received grading, to my opinion, was fair.	3.85	74.19%
IV.2	The received grading, to my opinion, was correct.	3.74	68.48%
IV.3	The received feedback and comments were useful.	2.64	17.98%
IV.4	The received feedback was comprehensible.	2.99	28.89%
V.4	During work, I received sufficient support throughout a tutor or teacher.	3.89	67.05%

Fig. 6 shows the time effort needed for the solution of the task sheets as estimated by the participants. Referring to the median, the estimated time effort lies around 8-10 hours per task sheets with a total number of 4 task sheets. This value corresponds more or less to the time effort related to 1 ECTS-Credits in a module with a total of 8 ECTS-Credits. The figure also shows that the time spent on solving the tasks was slightly higher than the time for reviewing.

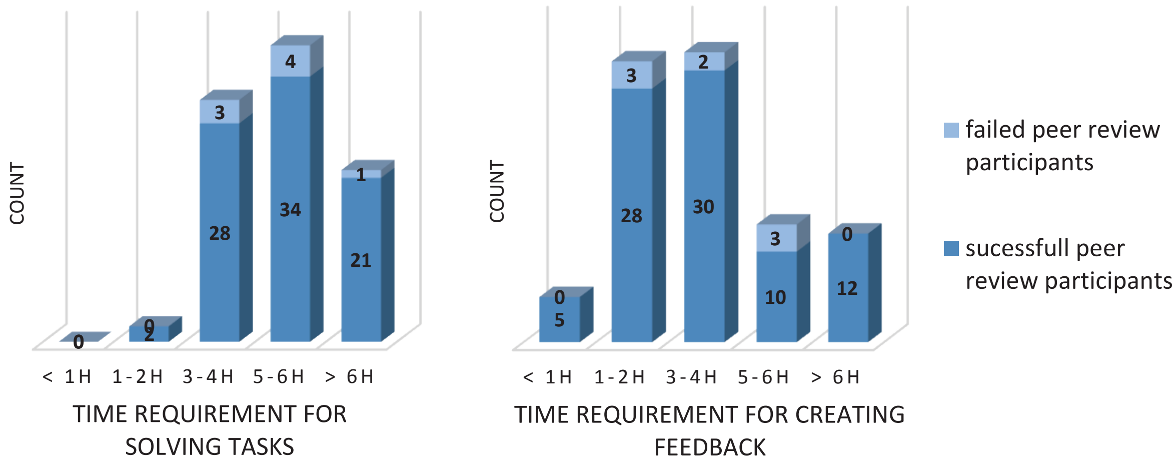

Fig. 6. Time requirements as estimated by the participants

Asking if the total time effort was justified compared against the learning benefits, 43% agreed, whereas only 20% disagreed. No significant deviation could be identified for this value between those students receiving a bonus and those that did not. 79% of the students agreed, that they could improve their understanding of the course contents by solving the task sheets. The survey also showed, that almost one third of the students (27%) perceived a learning benefit from giving feedback. This feeling is in accordance with the results presented in a study of Cho et al. [10] in an undergraduate laboratory physics course. In this study the beneficial effects of reviewing laboratory reports on the quality of written text are determined. Compared to the approval rates to learning benefits from solving and reviewing the tasks, the approval of learning benefits from the received feedback was rather low with a value of just 8%. The reason for that might result from the form of feedback expected to pass the peer review procedure. Some comments of students mentioned that forcing participants to give a more detailed feedback would have been desirable. Concerning the perception of learning benefits in either of the three steps no correlation to the final grade could be identified. Weaker and stronger students felt pretty much similar about the learning benefits of the peer review procedure without any clear deviation in the survey that needs to be mentioned.

Despite the rather low agreement concerning beneficial learning effects of the received feedback, 74% of the participants perceived it to be fair and 68.48% claimed the feedback and assessment to be correct. Nevertheless, only 29% of the participants evaluate the received feedback to be comprehensible and an even lower percentage (18%) agreed that the received feedback and comments were usefull. This clearly highlights the necessity to train the ability to create and interpret feedback.

Concerning the used tasks, two third of the participants considered them as motivation to address the course content. Nevertheless, only 12% could imagine a purely voluntary participation in such an activity. Therefore, incentive systems seem to be inevitable, if a compulsory participation is not possible due to e.g. legal constraints.

Looking at the overall acceptance of the procedure, as already mentioned, 43% claimed the measure to have positive effects on their learning. 54% agreed that the general idea of assessing their peer's work is good and 61% answered that they would like to have similar activities more often during their upcoming studies. It also deserves to be mentioned that 80% of the participants felt good about reviewing and grading their peers.

Beside the quantitative evaluation and the feedback given by the students, one important aspect needs to be mentioned: In both the second and the third peer review adaption, accompanying office hours have been offered to the students, to come together and discuss their solution as well as the received feedback. Whereas we could regonize only a minor interest in these office hours during the second adaption, the third run showed a tremendous interest of the students on the project as the task left more space for interpretation. In this way, students were encouraged to invest plenty of additional time to question and discuss contents and set focus on particular aspects of the tasks.

7 SUMMARY AND OUTLOOK

The high level of acceptance amongst the students shows, that contrary to existing concerns, the method can be adopted to engineering studies even on a theoretic level and also for other skills than writing texts. Encouraging participation going further than the original task is beneficial with respect to the exchange and discussion that might arise.

To keep the workload within acceptable bounds and to ensure the quality of the given feedback in all cases a solution proposal was distributed before the peer process started. The correction template for the evaluation in all cases was rather detailed, allowing little space for interpretation. Referring to the aspect of developing the skills “to judge the accuracy of information we receive” [2] as well as reflecting and discussing differing solutions, these aspects are not exploited completely. Nevertheless, the participants were encouraged to comprehend and reproduce different solution strategies for the same task. In order to assess the variation in the final grades of the group of students that attended and those that did not attend the peer-review process, the correlation between the improvement of the grades and the participation in the peer-procedures still has to be investigated in detail.

In the processes incorporated so far, a possibility to apply the received feedback to improve the work as mentioned in Nicol et al. [1] is still missing. This definitely includes additional potential to the acceptance and enhances the benefits for the feedback receiver. Also, a self-assessment of their own work could provide additional benefits to the students, especially when it comes to reflecting their own solution.

To conclude, the positive feedback and broad acceptance amongst the students encourages to further enhance the use of such methods in higher education purposes, keeping in mind that the tasks have to be chosen carefully to avoid superfluous work.

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Individual peer assessment of contribution to group work (IPAC): Key points and recommendations

MdP Garcia-Souto[1,2]

Y Azma[2]

R Grammenos[2]

T Kador[2]

C Striolo[2]

M Whyndham[2]

M Vogel[2]

M Richardson[2]

A Gibson[2]

J Britton[2]

T Robinson[2]

G Hughes[2]

[2]University College London
London, United Kingdom

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ABSTRACT

Individual Peer Assessment of Contribution to group work (IPAC) has been widely reported in the literature as successfully addressing problems that arise when students are asked to perform group work, such as complaints of 'passengers', and staff and student concerns about fairness of the marks. However, there are multiple variations on how to implement it, which makes it difficult for current and potential users to have an in-depth view and understanding of this assessment method or what works best. A working group was created at University College London (UCL) to look into this methodology (IPAC Consortium). This paper reports the key points of the IPAC methodology, as well as guidelines and recommendations for practice, e.g. make it more useful for students by sharing the feedback. These are informed in the review of

[1] Corresponding Author: Md Pilar Garcia-Souto; p.garciasouto@ucl.ac.uk

relevant literature, discussion with academics and educators, and own experience. We also introduce the software that is currently in use at UCL to implement this practice easily and time efficiently. This is of interest to anyone organizing and running assessed student group work activities, and that is using or might want to use in the future the IPAC methodology.

1 INTRODUCTION

The benefits of incorporating group work activities in Higher Education are well recognized [1], which include giving the opportunity to present students with more relevant projects, as well as providing a good learning experience for students both in terms of knowledge and personal skills. However, problems arise when all members of the team get the same mark, e.g. concerns about the fairness of assessment [2-4], complains of 'passengers' or 'free ridders' and associated poor student experience [5]. A way of addressing these issues is to use the IPAC methodology to assess group work (IPAC stands for Individual Peer Assessment of Contribution to group work), where individual marks are partially based on the contributions and/or work behaviour of the individual as seen by the peers.

The concept of applying IPAC is very simple, and it is presented in *Figure 1*. Students who work 'together' in a group will complete an assignment (a presentation, a report, a prototype, plan of an educational activity, an art work…) which is assessed by the tutor, and given a 'group mark'. The students then assess the level of contribution of each of their peers (including themselves if requested by the tutor) from which an IPAC value is calculated after tutor moderation. The 'group mark' and the 'IPAC value' are then combined such that now every student receives an individual mark. This individual final mark is therefore based on how the group worked together and the participation of that particular student.

This method is welcomed by students [4,6-8] who find the marking approach fairer, encourages them to have better engagement and professional behaviour during the group work [1,5,8,9] and learn towards future teamwork [8]. The marks are also seen fairer by staff [10].

Although the concept of the IPAC assessment methodology is simple, its actual implementation requires consideration and decision making on multiple aspects. These aspects are still unclear despite the broad use of this methodology and literature papers. In fact, the high dimensionality of the practice has resulted in a multitude of variations of IPAC methodology [1,2,5-7,9,10] while in addition, often authors in the literature do not report (or do not consider) some important aspects when running and testing the practice. All of this makes it very difficult to compare between studies and discern which options or features might have made the practice more successful. The focus of this paper is to identify and describe the various key aspects while designing and running IPAC, indicating what works and what can be safely customised, which is highly relevant for the educational community.

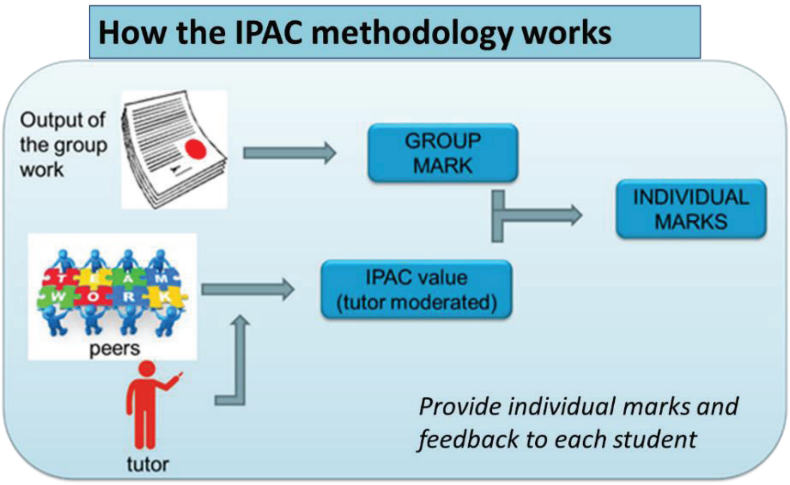

Fig. 1. Representation of the IPAC method of assessment.

2 UNDERSTANDING THE IPAC METHODOGOLY

In April 2016 the IPAC Consortium, led by Dr Pilar Garcia-Souto, was formed at University College London to look into researching the methodology and identify appropriate tools to run it. The group is formed by academic staff, technologists, experts in education, and students. As a group, we held numerous staff discussions, compare how we implement the IPAC methodology and our experience, run focus groups with students, and searched the literature.

As a result, we identified that the main aspects or points while designing and running IPAC in terms of methodology are (i) how the IPAC value is assessed; (ii) how the IPAC value is applied or combined with the group mark; (iii) information and feedback given to the students; and (iv) tutor involvement and moderation. One should also consider the context in which the methodology is applied.

2.1 Key elements

2.1.1 Assessment of the IPAC value

Assessment of the IPAC value refers to the process and criteria used to ascertain peer evaluations from students and compute them into IPAC values. One of the main questions is ‘What do we want to assess by IPAC?’. This can be for instance the actual level of contribution to the group work, their (professional) behaviour, or both. Some examples are *general contribution to delivery of quality work, insightful ideas, solving problems, effort, ability to work in a team, leadership,* etc. Based on what fits better with the objectives of the activity and assessment, the tutor needs to decide which attributes or qualities will be incorporated in the assessment of IPAC, the rating scale, the ’assessment criteria’, and if this is defined by the tutor itself or stablished by the students themselves. It is also of value to request students to justify the peer marks given. *Fig. 2* shows an example of a student questionnaire to peer assess with one attribute and associated rating scale. Values given here by the students is what we call the ‘raw scores or peer marks’.

Once the "raw peer marks" are collected, these need to be combined into a single IPAC value. The tutor needs to decide (i) which form should this value take, with the main possibilities being *a percentage* or *a normalized value around the average of the team; and* (ii) the calculation to use, e.g. if all attributes are worth the same, if corrections should be applied for instance to mitigate bias.

A final question is 'Who is allowed to assess?'. We would encourage all students to peer assess themselves and their peers in first instance. This is good for reflection and to give a full picture to the tutor of how the team functioned. However, for the calculation of the IPAC value, the tutor can decide which raw scores to use. For instance, the tutor can use/ignore the self-peer marks according to preference. Another popular request among the students is to ignore the marks given by those who themselves have a very low IPAC score, as students claim that *'those who did not contribute to the group work are not in the position to assess others fairly'*.

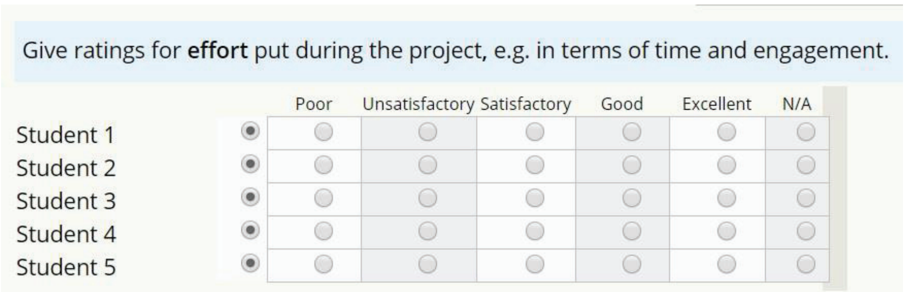

Fig. 2. Example of one attribute and rating scale used to ascertain the IPAC value.

2.1.2 Combining group mark and IPAC value

Once the tutor has the ***group mark*** for each team from his/her assessment of the submitted team work, and the ***IPAC values*** derived from the peer assessment of contribution by the students, these need to be combined to obtain the ***individual mark*** for each student. There are two main approaches to doing this: (i) adding the group mark and the IPAC value given in percentage using some weighting values of own choice (*Eq. 1*); or (ii) multiplying the group mark by the IPAC value given in its normalized form. Small variations can be seen among practitioners, who take one of these two forms and adapt it to their own preferences, e.g. selecting particular values for *a* and *b* in *Eq. 1*, or applying some sort of cap values.

Each method has their own advantages and limitations. The first method (*Eq. 1*) is easier to understand and has a milder student effect on the marks; however, this method only discerns students who contributed less than the rest, and students tend to be more forgiven on poor effort when rating others, or just give high marks to all to bust marks up. The second method (*Eq. 2*) seem to encourage students to be more honest with their peer evaluations, as their own mark is influenced by the mark of the others. Another advantage is that it discerns students who have contributed more or less to the group work, so *'reward'* or *'penalty'* is applied by the method itself. The limitation is perhaps the staff fear that some students could score more than a 100%, though this is extremely rare and can be easily mitigated by capping values [11].

$$Individual\ mark = a \times group\ mark + b \times IPAC \quad (1).$$
$$where\ a\ and\ b\ are\ constants;\ a + b = 1; IPAC\ is\ given\ in\ percentage$$

$$Individual\ mark = group\ mark \times IPAC \quad (2).$$
where *IPAC* is normalized and given around 1, this representing the average contribution

Table 1 (adapted from reference 11) presents some experimental results on how the individual marks look like in the case of applying the IPAC methodology as a percentage (N=710 students) or a normalized factor (N=476 students). Examples are given for 3 different typical teams with group marks of 40%, 60% and 80%, and the IPAC values specified as percentiles from the entire IPAC scores set from the combination of case studies.

Table 1. Spectrum of the effect of combining IPAC values with group marks [adapted from reference 11]

Percentile of IPAC scores among all case studies	Final individual mark					
	IPAC value * group mark			0.3*IPAC + 0.7*group mark		
	Baseline group mark			Baseline group mark		
	40%	60%	80%	40%	60%	80%
5	33.6	50.4	67.2	51.5	65.5	79.5
20	39.2	58.8	78.4	55.7	69.7	83.7
50	40.0	60.0	80.0	57.4	71.4	85.4
80	42.0	63.0	84.0	58.0	72.0	86.0
95	45.6	68.4	91.2	58.0	72.0	86.0

2.1.3 Information and feedback given to students

Besides the normal introduction to the group work activity aim and assignment, tutor can (and should) provide the following initial information and/or preparation to the students: (i) IPAC marking process, (ii) tutor involvement with the assessment process and moderations, (iii) an introductory talk about the purpose of using the IPAC method as well as its benefits, and (iv) training on how to assess their peers' contribution and/or performance, e.g. with a class discussion of expected professional behaviour and work ethics when working in a group, as well as a discussion of the IPAC marking criteria. This is beneficial for the engagement of the students in the process, e.g. providing and receiving feedback, as well as reducing the scepticism that students might have.

After the IPAC process takes place, students can receive various degrees of summative and/or formative feedback. The choices of summative feedback that can be given to the students are (i) their final individual mark only which is the basic approach; (ii) provide the group mark and the overall IPAC value separated so students can see how the tutor valued the group work, and how her/his peers value her/his individual contribution; (iii) provide their average scores per attribute, so they can see in which areas they might have excelled and in which others they were lacking.

The formative feedback can take different forms. Those mostly recognized as such would be generic (to the entire class or group) or personalized (to each student or group) tutor feedback. However, the students' justifications or comments done for each of their peers can also be used as valuable feedback of how the personal contribution was perceived by others, which students claim would be help them to improve performance and behaviour in the future [8].

2.1.4 Tutor involvement and moderation

Although the IPAC method is based on peer assessment, the tutor can and should be involved in the process, particularly in critical cases. This reassures student that the marks are fair, deals with complicated cases of team dysfunction (these tend to be very few, much less than what people fear when using this practice! [11]), and it addresses one of the main student requests.

The tutor involvement and moderation can be in different forms, the main ones being (i) keeping tutor (or assistant) observations that can inform later moderations, (ii) check (and moderation of) summative marks, and (iii) check (and moderation of) student comments.

Moderations of the summative marks might be appropriate in dysfunctional or segregated groups, that can be identified by highly uneven peer rate scores for one (or more) individuals within the team, or students with very low/very high IPAC marks. One approach for instance is to disregard the peer scores given by students who, themselves, were mostly absent from the group work.

Moderation of the comments can be done at different levels, and this highly depends on the class size and staff capacity. A basic check is to look for and eliminate profanities which is usually sufficient. Others (more rarely) with the time and staff resources might check and moderate each individual comment before releasing them. A middle ground would be to check the comments related to very low scores to see if the later are justified, perhaps even comparing with tutor observations if existent.

Tutor involvement also includes the traditional approach of setting up alternative assessment for extreme cases, for instance, when a student has disengaged almost entirely from the group work because of genuine reasons.

2.2 Context

When implementing the IPAC methodology, ideally we would like to achieve the best student experience using the least staff-time and resources, but this is rarely possible. Instead, we seek to find an 'optimal' or compromise between the two, such that student experience improves while working within the resources and staff-time available.

In this regard, one should consider the context in which the IPAC methodology is applied, as the settings that might be optimal for one class and activity might not be the same for another. Also the staff preferences play an important part here, as different staff will have different ways of compromising. In general, some of the variables to consider are the class size and the available staff and support resources, as this highly influences how much involvement the tutor will have in each team. Others variables refer to the activity itself, e.g. the weight of the assignment within the module and the activity timescale, as this will influence if the IPAC process is use once or more times, for example at several points during long projects perhaps for formative purposes. Finally, understanding the ability of the students to perform peer assessment is also important as it will inform the introduction to IPAC and training activities that might be needed, for example a 3rd year student who has done peer assessment before (IPAC or otherwise) will need less training.

3 IMPLEMENTING THE IPAC METHODOLOGY: GUIDELINES AND RECOMMENDATIONS

After a year of conversations with staff and research, it came clear that although we all supported the benefits of incorporating the IPAC assessment into teaching practices, it was going to be impossible to reach a consensus on a strict and rigid 'recipe' on how it should be implemented. Many of the actual details and choices done under the four key points discussed earlier are highly dependent on the context in which the activity takes place, and more significantly, on the preferences of the tutor. However, there are other elements that are identified and acknowledged as requirements for a successful practice.

This section gives the fundamental guidelines of what needs to be done and/or considered when running the IPAC practice, stating also some recommendations that have been found to be successful. Within these guidelines we differentiate between things that all practitioners should incorporate, and those that are open for customization.

3.1 Guidelines

The fundamentals of running the IPAC practice are given in *Table 2*, with *Before, During* and *After* sections. Under the section *Your Choice* some elements are given that practitioners can freely choose without compromising the effectiveness and success of the IPAC method, allowing for customization. *Table 1* also includes some recommended practices, although they are optional.

Table 2. Guidelines and recommendations to run the IPAC assessment method

Before	Your choice
• Define your IPAC assessment process, i.e. the details of the 4 key elements. Some options of value are: ○ Include self-assessment to promote reflection and to get full information ○ Request students for justification of marks ○ Use few qualities/attributes to keep questionnaire short (N<=6) • Inform students that the IPAC assessment method will be used and benefits of doing so. • Inform students on how the IPAC assessment works, and the tutor involvement.	• How to assess the IPAC value, i.e.: ○ Attributes (but N<=6) ○ Rating scale and criteria ○ Tutor or student led attributes &criteria ○ Equal or unequal weighting ○ Calculation used, e.g. bias correction ○ Output form, e.g. normalized around 1 or % (but normalized is recommended) • Moderation process ○ Low rate students ○ Large SD, etc. ○ Based on observations • Equation used to combine the IPAC value and the group mark ○ Based on added percentage vs based on a multiplier factor (the latter is recommended).
During	**After**
• Ensure students are ready or plan a small activity towards this aim: ○ Trained to perform peer assessment ○ Aware of professional behaviour and peer expectations in team work ○ Define/discuss expectations or meaning of each of the assessment scale levels • (Of value) Keep some tutor observations records.	• Review IPAC scores and apply moderations when relevant • Make it valuable not just as a summative assessment but also formative ○ (Of value) Give the anonymized students' feedback back to students. Students need to be informed of this in advance, and use at least the profanity check before releasing the comments. ○ Give tutor feedback, even if generic.

3.2 Recommendations

Assessment of the IPAC value

The assessment of the IPAC value is highly customizable, allowing for purpose use with different activity aims and tutor preferences. However, there are some recommendations that have been found to be of value. The number of attributes used to assess the IPAC value should be kept to a maximum of 6, this is to avoid asking students to complete long questionnaires, and there is not much gain on the information collected. In terms of the rating scale, descriptive or categorical (such as in *Fig 2.*) is preferred to numerical, as students relate better to it. But whichever rating scale is selected, it should remain the same if possible for all attributes used, as it makes it clearer and easier for students. Students should be requested to perform also self-assessment (even if not included in later calculations) and to write a justification for the marks given to each student. These are useful for the tutor to understand the group dynamics, and the later becomes very useful to provide formative feedback to the students at the end.

Tutor involvement and moderation

The tutor is always the ultimate responsible for the marks used for student assessment. In the case of peer-assessed generated marks (even if they are partial marks for an assignment), the tutor needs to take ownership of these marks to be able to use them and present them at the exam boards. Therefore, it is wise for the tutor to check the integrity and validity of the marks (and feedback) and moderate accordingly. Moderation does not need to take long, and it can be in any of the forms discussed in section 2.1.4. The students should be informed at the start of the activity of the main moderation process (regardless of what that is) as it gives them confidence and reassurance with the process.

Combining IPAC value and group mark

Some of the advantages for the two forms of the IPAC value (percentage or normalized) have been given in section 2.1.2. However, the recommended practice is to give the IPAC value as normalized to the group performance. This allows students to easily see if their contribution was perceived to be around, above or below the average of the group without needing to know the values received by other students, and this is useful for the student to reflect on her/his contribution. This therefore leads to the recommendation of using *Eq. 2* as a basis of combining the IPAC value with the group mark.

Information and feedback given to the students

Student training is a very important element towards the success of this methodology. The training should be done before or at the start of the group work activity, and it should include information on: the importance and benefits of engaging with peer assessment in general, how the IPAC methodology works, how to assess themselves and others, importance of giving honest marks, as well as how to provide useful and constructive feedback to peers, and be open to criticism on personal performance and use it to improve. This helps to clarify the methodology to the students, hence preventing ‘fears and worries’ about how their marks are calculated (specially for high ‘achievers’), and engaging all students into contributing to the group work as free-riders are no longer going unnoticed by the staff. It also engages students with the process of giving honest and more insightful feedback to peers, which is in itself a good skill to have.

The most basic form of training would be to give a presentation to the students covering these points. However, if time permits it, there are other more active ways of incorporating some training into the activity. One way is to ask students to define the attributes and criteria that should/is to be used for the assessment of the IPAC value. This has also the benefit of helping them to understand what is expected of them while working in a team, and how to rate themselves and peers according to that criteria.

One of the benefits of the IPAC methodology is that it is very valuable not just as a summative assessment but also as formative. It can be used to give feedback to the students on how their contribution and behaviour was ***perceived*** by others by releasing the peer comments applicable to each individual student. To make this more successful, a good approach is to remind students that their comments will be released to their peers even if in an anonymous way, hence encouraging them (and training them) to write them in a constructive and professional way. In addition, tutors can apply some basic moderation of the student comments such as a simple profanity check just for peace of mind – though it is extremely rare that profanities are included.

There are other pieces of useful feedback for the students that we recommend. One would be to release to each student her/his IPAC value (even better if given per attribute) if in normalized form, so the students can see how they rated in the context of their group. Another is tutor feedback, either customized per individual or group according to their performance, or generic for the entire class.

3.3 Software

The main limitation of the IPAC method is that it can be very staff-time consuming to implement due to the need to handle and administer a large amount of data, hence even the keen practitioners are likely to give up if they do not have an appropriate software. Practitioners are recommended to equip themselves with a software that allows them to run the practice in a time-efficient manner, and their own way i.e. with the desired customization level, such that they can focus on understanding the team dynamics, providing meaningful assessment and improving the student experience, rather than on the administrative work.

The IPAC Consortium reviewed some currently available softwares, but these did not fit the requirements. As such, a new software was developed at UCL (depicted in *Fig.* 3) that addresses the identified staff priority requirements, which includes being easy to run, allow for extensive customization, facilitate quick and personalized feedback to students and be staff-time efficiency. This software is widely used at UCL, and it is being expanded to other institutions. The software is further described and reported in the conference paper *"Making assessment of group work fairer and more insightful for students and time-efficient for staff with the new IPAC software"* [12]. Anyone interested on knowing more or potentially using it can contact the corresponding author.

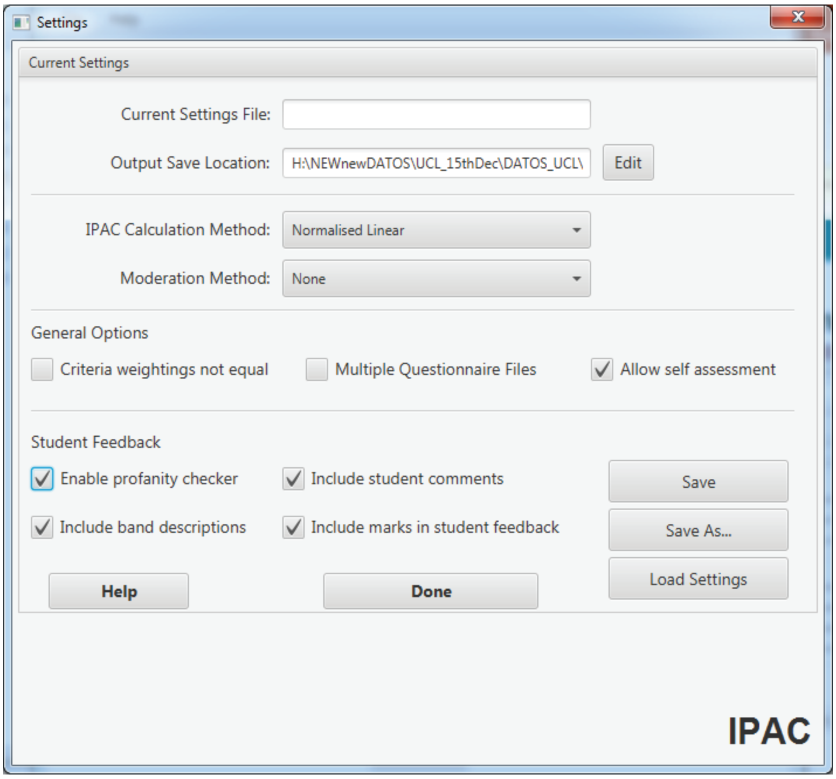

Fig. 3. Settings screen of the UCL IPAC software. Copyright © 2018 UCL [12]

4 SUMMARY AND ACKNOWLEDGMENTS

In conclusion, this paper explains the IPAC methodology as well as the key aspects that need to be considered for its implementation. It also provides the guidelines and recommendations for any new and current practitioner to make this assessment method successful and insightful for students. Finally, we briefly presented a software developed at UCL that can be used to run the practice easily and efficiently.

Our thanks to the UCL Vice-Provost office (Education & Student Affairs), UCL ELDG, UCL CC Collab, UCL Medical Physics and Biomedical Engineering Department, UCL Chemical Engineering Department, and UCL Change Makers for their financial support to the IPAC Consortium; this has been key to gain a good understanding of the IPAC methodology. Our great thanks also to all IPAC Consortium members, staff and students who have contributed in focus groups, interviews, informal conversations and questionnaires. Thanks to UCL Knowledge and Innovation Fund for supporting the further development and dissemination of the developed software and IPAC practice. Thanks to CEE for supporting/encouraging educational research in the Engineering Faculty.

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Sparking Action: How Emotions Fuel or Inhibit Advocacy around Hidden Curriculum in Engineering

L.A. Gelles
Utah State University
Logan, Utah, USA

K.L. Youmans
Utah State University
Logan, Utah, USA

I. Villanueva[1]
Utah State University
Logan, Utah, USA

Conference Key Areas: Diversity in Engineering; Gender, Inclusion, and Ethics

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ABSTRACT

Emotions are not typically addressed or valued in engineering. However, emotions may play a pivotal role as individuals within the field navigate the complexities of the hidden curriculum (HC) or the unofficial guidelines and rules that characterize a learning or working environments. These emotions may be especially relevant for underrepresent students and faculty who may feel isolated, alienated or overwhelmed by negative and unacknowledged HC. As part of the larger mixed methods study, 174 undergraduates, graduate students, faculty and administration in engineering programs across the U.S. were asked to reflect on the role of emotions in advocating for themselves or others to reveal HC in engineering programs. Participant responses were analyzed using a combination of thematic, process, pattern, and co-occurrence coding.

Findings revealed that HC advocacy requires: (1) awareness of the issue; (2) ignition (i.e., emotion); and (3) a sustaining force (e.g., confidence). The most prevalent emotions to fuel advocacy were anger, frustration, and passion; hope was present only after an ignition occurred. On the other hand, inhibited advocacy was a result of one of three factors: (1) disbelief; (2) lack of value; and (3) perpetuating the status quo. Apathy and contentment were associated with participants who thought that action was unnecessary (i.e., disbelief, lack of value) while fear, exhaustion, and hopelessness corresponded to participants who felt prevented from taking action (i.e., perpetuating status quo). Findings from this work highlight how emotions are critical in advocating for issues of inequity in engineering.

[1] Corresponding Author:
I. Villanueva
idalis.villanueva@usu.edu

INTRODUCTION

The motivation for this study is to explore in more detail the role that emotions plays in an individual's willingness to advocate for hidden curriculum (HC) in engineering. Understanding hidden curriculum allow for the success of engineering students, particularly for minoritized groups. The intent of this exploratory study is to heighten awareness about how existing engineering education environments, explored through participants' responses around emotions and self-advocacy, influence the roles and expectations of students and faculty in this field. The information will help institutions of higher education to consider alternate ways to promote diversity and inclusion in engineering.

1.1 Hidden curriculum in engineering

Hidden curriculum (HC) is one of four primary forms of curriculum that focuses on the messages or lessons learned that individuals experience in a learning or working environment [1]. HC represents a medium (a key source of messages) by which attitudes, values, beliefs, and behaviors are transmitted.

HC may compliment other forms of curriculum (e.g., formal, null, informal; [1]) in a schooling system to engender positive messages about a profession or education. On the other hand, when a conflict arises between different types of curriculum, there is a strong likelihood that HC is present in that situation. For example, admission into engineering honor societies requires high GPA suggesting that academic performance is indicative of engineering success. In this case, the admissions criteria (medium) conveys a subtle yet negative message that grades are prioritized for success in engineering. (transmission of message); together, they form a HC. HC becomes dangerous when the transmitted messages to learners are negative (e.g., stereotypes, implicit bias; [2]). These negative messages become pervasive over time, resulting in an established and 'invisible' norm where injustices based on meritocracy, hegemony, apathy, exclusion are unseen and unquestioned by the majority [1].

HC has been used to explore unexamined issues in fields like education [3], medicine [4], sociology [5] and more recently, engineering [1,6,7]. In particular, for engineering, Villanueva and colleagues [6,7,10] have begun to uncover the mechanisms that inhibit or limit individuals from advocating for issues of diversity in engineering as this field is known for its male-dominated [8], militant [8] and oftentimes chilly climates for underrepresented populations [9]. In the authors' studies, they have found that four steps or stages have to occur in order for individuals to advocate in engineering: awareness (a sub-component of consciousness by which an individual internalizes an experience; [10]), emotions (the form by which individuals evaluate an environment; [10]), self-efficacy (an individual's confidence in their ability to have control over one's own environment; [10]), and self-advocacy (an individual's willingness to become an agent of their own actions; [10]). The focus of this work will be on the emotions step.

1.2 The role of emotions in processing hidden curriculum in engineering

Emotions are fundamentally important to how we learn, perceive, decide, respond, and problem-solve [11]. Pekrun and colleagues [11] postulate that emotions, at least in academic settings, consist of coordinated psychological subsystems that intertwine affective, cognitive, motivational, and expressive and peripheral physiological processes expressed in two forms: valence (positive/negative) and activation (activating/deactivating). For instance, positive activating emotions, such as enjoyment, may increase reflective processes like metacognition [11], while positive deactivating emotions such as pride may result in low levels of cognitive processing [11]. Likewise, negative activating emotions such as anger and anxiety may spark engagement [11] whereas negative deactivating emotions such as hopelessness may dampen motivation [11]. Other emotions (e.g., frustration) have been reported by underrepresented populations in engineering [12]. This work focuses primarily on the emotion present and its valence but not its activation.

2 METHODS AND RESEARCH DESIGN

2.1 Positionality

The authors in this exploratory study represent underrepresented racial and gender minorities in engineering whose own experiences in hidden curriculum have shaped the lens used to interpret the data. We recognize that we all have biases and assumptions and as such, we engaged in lengthy discussions and intercoder agreements of the data to minimize any potential misrepresentations on our part.

2.2 Research Design and Questions

This research design is part of a larger complex, mixed-method experimental intervention design [13] where qualitative and quantitative data collection (used to validate a survey instrument we developed [10]) was analyzed first separately and whose findings will be converged at a later time. For this particular study, we are representing the data collected from earlier validation stages of this instrument. To describe briefly, the iteration of the instrument used for this work was as follows: demographics, expectations in engineering education, video exemplar, character identification and resources, hidden curriculum awareness, self-efficacy, emotions, and self-advocacy [10]; all items included a definition of the terms as needed. Additional information about the specific content of these items are provided elsewhere [7]. For this work, we focused on the participants' qualitative responses to the following three questions, which further explored issues of access, equity of resources, and emotions pertaining to advocacy of HC in engineering:

a) How do you think your emotions relates to your ability to advocate to unveil the hidden curriculum in engineering at your university?

b) How do you think your awareness of campus resources can equip you to advocate to unveil the hidden curriculum in engineering at your university?

c) How do you think your confidence (self-efficacy) relates to your ability to advocate for unveiling aspects of hidden curriculum in engineering at your university?

These questions were used to inform the overall research question of this study:

(1) How do engineering students and faculty self-report the influence that their emotions have in their ability to advocate for HC in engineering?

2.3 Participants

Participants represented 174 individuals who responded to this iteration of the instrument. The participants were 48% undergraduate students, 29% graduate students, and 23% faculty. We opted to not break down demographic groups by age, race, gender, ethnicity, or other variables as our primary goal was to understand conceptually and mechanistically how emotions, in general, can fuel or inhibit advocacy around HC in engineering. Other work connected to this data has been broken down by participant demographics and are described elsewhere [7,14]. As part of a larger mixed-methods study, we explore participants' written qualitative responses regarding the role of emotions related to self-advocacy in engineering.

2.3 Methods for Qualitative Data Analysis

We employed a multi-stage qualitative coding strategy for the 174 participants' responses to the three qualitative questions using conceptual mapping and thematic analysis. The first stage consisted of in vivo and versus coding, where participants' own words and potential conflicts and dichotomies were used to explore the data. This was followed by preliminary conceptual mapping and code landscaping to organize the data into categories. These categories informed the creation of a codebook. We conducted an intercoder agreement session to validate codebook codes and refine the conceptual map. We reached 97% consensus of the codes using random selection of 25% of the data after several iterations. The ICA session informed selection of the second cycle of coding: emotions and process coding which allowed us to explore how participants take action and what emotions they experience. Next, we conducted pattern coding followed by co-occurrence modelling of all categories and codes to compare the frequency of themes and topics conveyed by the participants. From this, the concept map was refined, discussed at length by the research team, and finalized.

As an additional check, we used participants' quantitative data from the larger mixed-methods survey to provide context when participants qualitatively expressed feeling 'positive' or 'negative' emotions. Participants indicated what emotions they felt and whether they considered this positive or negative. All coding phases were conducted using MAXQDA 2018, a mixed-method analysis software.

From the coding, stages of stepping back or stepping up were identified. The order of these stages were determined by the degree of action which an individuals described throughout the three qualitative answers. Emotions indicated in these answers were associated with the level of action described.

3 RESULTS

3.1 Primary Themes: Stages to fuel or inhibit HC advocacy in engineering

From our codes, we found that individuals in general, can take one of two actions when discovering HC in engineering: (a) stepping up or (b) stepping back. **Stepping up** represented the different forms that an individual was willing to take action to reveal and address HC in engineering. Stepping up could be summarized in three primary stages: (i) awareness, (ii) ignition, and (iii) conservation. First, an individual's level of ***awareness*** of hidden curriculum and the resources available to address this issue represented a state of knowledge about HC or knowledge about resources to promote success in engineering. Second, ***ignition*** was equated to a 'spark' or impetus to take action once HC is recognized or experienced. This impetus was associated with an emotional reaction where an internal conflict to take action or not arose. While this impetus could be promoted internally within an individual (e.g., through witnessing or feeling), it did not necessarily mean that an action would be taken. Third, ***conservation*** of an action refers to the considerations needed to oppose the status quo, such as perceived and actual negative consequences within the context of engineering education. For example, an individuals' confidence was seen as a bolstering and maintaining force to reveal HC and enact an action in response to it. Together, the findings suggest that being aware is insufficient for an individual to take action. This awareness must be coupled with a corresponding igniting emotion that is tempered through strategies and the confidence needed to support such an action, in the face of opposing forces and challenges.

Stepping back represents an individual's withdrawal or unwillingness to take action, in light of their current and specific university and departmental contexts. Stepping back can be represented in several stages: (i) disbelief, (ii) lack of value, and (iii) perpetuating the status quo. ***Disbelief*** involves either a denial that HC exists in engineering or that it poses a negative influence on underrepresented populations. It also may indicate that an individual has not personally experienced the effects of negative HC and equate their experience to what other populations experience in engineering. ***Lack of value*** represents an individual that is aware of HC or issues of inequity in engineering but are not placing value or express a desire to take any actions to address it. ***Perpetuating the status quo*** includes individuals who would like to take action or help correct inequities but some force prevents them from taking action; it is a self-sustaining force that passively resists change and is a result of organizational structures found in academia and in engineering. These organizational structures are hierarchical and reinforce suppression and silence of individuals who would like to make change.

3.2 Secondary Themes: Emotions used in stages to fuel or inhibit HC advocacy

From our codes, we found secondary themes that related emotions to advocacy around HC in engineering: (a) emotions and promoters of action (stepping up) and (b) emotions and deterrents of action (stepping down). A summary of these emotions are included in Table 1 and 2.

For stepping up (Table 1), the most prevalent fuelling emotion present in awareness was ***comfort***. Participants expressed feeling comfort when they knew about resources that can help them succeed despite a negative HC. Comfort was expressed through awareness of a community who shared similar experiences with HC. For the ignition stage, the most prevalent **fuelling emotion** coded was ***passion*** followed by ***frustration*** and then ***anger***. Being passionate about an issue appeared to be the most productive emotion for advocacy actions such as speaking up and raising awareness. For frustration, participants expressed it as a negative emotion that would be experienced after witnessing a HC that was not beneficial to the individual. This emotion also related to an internal resistance to HC, which did not reflect an externalization of this emotion into an action such as speaking up about an issue. Anger, also present in the ignition stage, was seen as a prompt that individuals can use to raise awareness about HC. For the conservation stage, ***passion*** and ***hope*** were highly coded. These primarily positive emotions, resulted in the most intention by the participants to sustain an action even in light of pushback. Like passion, hope was associated with raising awareness of HC.

Table 1. Associated fuelling emotions to step up stages

Order	"Stepping Up" Stages	Associated Fuelling Emotion	Describing Attributes of Fuelling Emotion in Stepping up Stage
1	Awareness	Comfort	The feeling of being soothed, consoled, or reassured. The individual feels more at ease because of a shared experience or intrinsic motivator (e.g., community, confidence).
2	Ignition	Passion	Passion involves a willingness to make change. It shows a conviction and compelling desire to help others or make long lasting change.
		Frustration	The feeling of being upset or annoyed especially because of their inability to change or achieve something that is affecting them directly.
		Anger	A strong feeling of displeasure and belligerence aroused by a perceived or actual injustice. Anger is often a response to being hurt by something or someone. Anger can result in verbal or physical outbursts by the individual.
3	Conservation	Passion	Passion involves a willingness to make change. It shows a conviction and compelling desire to help others or make long lasting change.
		Hope	Hope is the feeling that what is wanted can be had or the events will turn out for the best despite challenges.

For stepping back (Table 2), the most prevalent **inhibitory emotions** were contentment, apathy, fear, exhaustion, and hopelessness. For the status quo stage, the most prevalent emotion present was ***fear***, particularly amongst the associate professor population. ***Exhaustion*** later followed for this stage and it resulted from individuals that had accumulated stresses associated with a sense of powerlessness to take action. ***Hopelessness*** resulted from a person's lack of confidence that they could personally enact meaningful change. Disbelief, which was the least prevalent of the three stepping back stages, was mostly associated with the emotions of ***apathy*** and ***contentment***. Apathy showed a lack of desire or willingness to enact an action based upon identified negative HC while contentment involved a sense of satisfaction with the current organizational system.

Table 2. Associated inhibitory emotions to step back stages

Order	"Stepping Back" Stages	Associated Inhibitory Emotion	Describing Attributes of Inhibitory Emotion in Stepping Back Stage
1	Disbelief	Apathy	An individual who is apathetic does not show personal interest about revealing HC or issues of access and inequity within engineering. While they may be aware of these issues, they have no desire or willingness to change them.
		Contentment	The feeling of contentment or happiness connotes an individual being happy with the current organizational system. Often, these individuals are benefiting from the system and may be in a position of privilege. Subsequently, they do not have an intrinsic need to be aware of these issues since they do not suffer negative consequences of HC.
2	Lack of Value	Apathy	An individual who is apathetic does not show personal interest about revealing HC or issues of access and inequity within engineering. While they may be aware of these issues, they have no desire or willingness to change them.
3	Perpetuating the Status Quo	Fear	Fear is a distress aroused by a threat (real or imagined). Since taking action can carry with it a personal risk, individuals may experience fear at the thought or possibility to speak out or take action, which inhibits their willingness to act.
		Exhaustion	Emotional exhaustion results from the accumulated stress of being drained or worn-out. It is associated with a sense of powerlessness, which may result in decreased motivation and burnout.
		Hopelessness	An individual who expresses hopelessness believes that the current state of things in their lives will not change. They will likely care about revealing HC or issues of access and inequity in engineering but believe that nothing can be done about it so there is no point in trying. This emotion can result from constantly seeing or experiencing failed attempts to change the status quo in engineering.

3.2 Conceptual Model to Step Up or Step Back in engineering

Taken together, the coded themes and emotions were placed in a conceptual diagram to represent the inhibiting and fuelling emotions for the stepping up and stepping back stages for HC advocacy in engineering. As shown in Fig. 1, each pathway is individual and dependent on a particular emotion. It is important to note that while these stages and related emotions are presented in a continuum, the reality may be that these are either iterative or concurrent depending on the nature of the HC and the influence it may have on a particular individual.

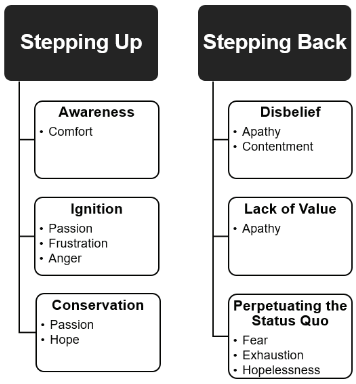

Fig. 1 Emotion-Informed Conceptual Model for HC Advocacy in Engineering

4 DISCUSSION

The data presented here, while not disaggregated by group, provides an overview of the important role that emotions have in fuelling or inhibiting actions related to revealing HC and advocating in turn for issues of access or inequity in engineering. The literature suggests that emotions are an important factor for processes that involve decision-making and cognition [11]. We also found that emotions can either fuel or inhibit action, in part due to an individual's intrinsic beliefs and expectations, as supported in the literature [11].

In this exploratory study, we showed that around stepping up stages, awareness is needed to ignite the emotions necessary to conserve an action. However, it is important to note that these actions have to be strategic as these can vary by an individual's relative role and power within an organizational structure and disciplinary culture of engineering. This finding supports Lewin's theory of organizational change force-field theory [15], which suggests that a variety of forces arise from the way an organization operates: its structure, culture, and control systems that can make it resistant to change and place it in a condition of opposition. However, in order for an organization to change, there has to be an increase in the force for change or a decrease in the resistance to change [15]. This cannot happen without implementation of strategies and resources that will support these modifications.

On the other hand, stepping back stages involves either a lack of knowledge or desire to take action, either because of their personal experiences or their satisfaction with the organization or sub-culture. It is also possible that the risk of stepping up far outweighs the benefits, which may impact a person's extrinsic motivation for an action [16]. It is important to mention that when unquestioned over time, HC, both with its benefits and disadvantages, becomes a norm [1]. Without a mechanism or model that can be developed to help individuals evaluate such a HC, it will continue to lie in the liminal spaces of the unconscious mind and action becomes an afterthought, at most.

Together, our work supports the notion that emotions are integral in a person's decision-making process to identify the necessary actions and potential strategies needed to navigate HC. Without this knowledge, engineering students may struggle to successfully navigate their engineering education. Also, it presents a unique model that emphasizes that emotions are pivotal in guiding action or inaction to address hidden curriculum in engineering. This study demonstrates an alternative perspective to addressing change in engineering education related to issues of access and inequity.

5 SUMMARY, LIMITATIONS, AND ACKNOWLEDGMENTS

The data supports a preliminary conceptual model that supports the notion that emotions are pivotal to a person's willingness to step up or step back around issues of HC in engineering [7]. Our finding suggests that some of these emotions can be fuelling for action or inhibitory for advocacy.

Some of the limitations of our study could include the need to disaggregate populations to understand more contextually-specific stages to step up and step back. Also, we acknowledge that this data collection is merely a snapshot in time and that these may change by situation or context.

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Student Perceptions of Complexity in Engineering Education

Tom Goldfinch
University of Sydney
Sydney, Australia

John Vulic
University of Sydney
Sydney, Australia

Elyssebeth Leigh
University of Sydney
Sydney, Australia

Keith Willey
University of Sydney
Sydney, Australia

Conference Key Areas: New notions of interdisciplinarity in engineering education, New Complexity quest in engineering sciences

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ABSTRACT

The complex and socially connected nature of modern engineering practice is well documented, motivating new approaches to engineering education across the globe. The challenge now is to bring about change at scale to traditional curricula [1].

The University of Sydney has implemented a core program designed to improve students' learning and preparation for professional practice. The program seeks to help students develop an appreciation of complexity in engineering practice and illustrate its interdisciplinary, connected nature. The program serves a cohort of ~800 commencing students annually and is delivered within the bounds of a traditional program structured in units of study. Standardised student satisfaction survey results have been below or well below faculty average, indicating that on this measure, a majority of students are not satisfied with their learning experience. To better understand why, student comments on these surveys were analysed through the lens of the Cynefin framework, a sense-making tool that provides a useful characterisation of complexity experienced in professional engineering [2, 3].

Analysis suggest students may be aligned along a continuum between two positions in regard to the perceived degree of complexity in the learning experience: *Comfortable with complexity* – Those who recognise and adopt strategies needed to succeed in complex projects; and, *Resistance to complexity* – Those who see the learning design as unsupportive and unnecessarily ambiguous.

The results highlight issues around student perspectives of what 'learning' is, as well as structural issues existing within standardised student satisfaction surveys, each of which pose potential barriers to curriculum reform.

1 INTRODUCTION

The Faculty of Engineering at the University of Sydney began implementing an Integrated Engineering (IE) program consisting of four core units of study, one for each academic year, across all engineering majors in 2016.

The units are delivered alongside the standard array of engineering disciplinary units. Students work in cross-disciplinary teams on projects intentionally designed to help them engage with peers undertaking disciplinary studies other than their own. While complex systems are a fundamental aspect of many domains, they are especially characteristic of engineering. The IE program is designed to improve students' appreciation of the complexity they can expect to find in engineering practice and illustrate its interdisciplinary, interconnected nature. Once fully implemented the program will engage with up to 3600+ students per year.

This paper presents the findings of a qualitative analysis of 778 student satisfaction survey responses received from students in each of the four IE units. The goal of the research is to gain insight into factors that influence student adoption of / comfort with complexity and/or their resistance to complexity designed into the program. It is anticipated that this in turn will help to inform the design and implementation of educational practices for supporting the transition of novice engineering students into early career professionals who are aware of the complex nature of their probable future workplaces.

1.1 Difficult vs Complex - creating workplace-oriented learning spaces

In engineering practice, activities are rarely characterised by an ideal answer but rather are complex, requiring trade-offs and/or the combining of non-optimum solutions. Hence, to authentically develop engineering skills, students need to learn to manage complexity. Many students resist working with complexity, describing it as too difficult, too much work, less valuable and not real engineering [4]. Dealing with complexity requires students to use judgement, subjectivity, and reasoning to make decisions instead of relying primarily on the scientific evidence and facts that are often more highly valued by engineering academics and students [4]. Many engineering students resist this change, expecting their learning to be the simple transition from the 'knowable' to the 'known' [2], finding it difficult to make the transition from dichotomous reasoning to thinking contextually and dialectically. This transition challenges students' feelings of competency. Self-determination theory [5] lists competence as one of three basic cognitive needs required for motivation. Reduced feelings of competence inhibits students' learning motivation and their interest in addressing and benefiting from complex learning activities.

Since the IE Program focuses on educational and assessment practices intended to enable students to improve their capacity for managing complexity, it is important to be clear about the distinction between two related terms, 'difficult' and 'complex', which are frequently, and incorrectly, used interchangeably. Things that are '*difficult'* are hard to do, make, or carry out. In a physical context they may be arduous and hard to deal with, manage, or overcome. In an intellectual sense they may be hard to understand and puzzling. However, in all contexts there are known and knowable solutions that are repeatable.

Conversely, things that are 'c*omplex'* have no readily achievable solution and remain problematic, in that any outcome will not necessarily fit any future similar context.

Thus, complexity can be explored and instances resolved, but solutions have remaining uncertainty that may only be resolved, if at all, in retrospect after implementation [2] [4]. The term 'wicked problem' is often applied to issues identified as complex.

Difficult can be characterized as a perspective. *Difficult things* become easier through acquisition of relevant knowledge, skills, and experience. *Complex,* by contrast is an attribute; more knowledge and enhanced skills do not of themselves change anything. *Complex* is always *complex,* regardless of knowledge, skill and experience. Kurtz and Snowden [2] provide a very useful characterisation of *complex* in relation to other attributes of a problem or scenario (see *Fig. 1*). IE projects are situated in the Complex domain, characterised as 'Un-Order,' while traditional teaching modes tend to be centred in the Visible and Hidden domains characterised as 'Order'. In the latter domains problems, projects etc. tend to be resolved through well established paths applying the 'right' knowledge and skill and with appropriate support.

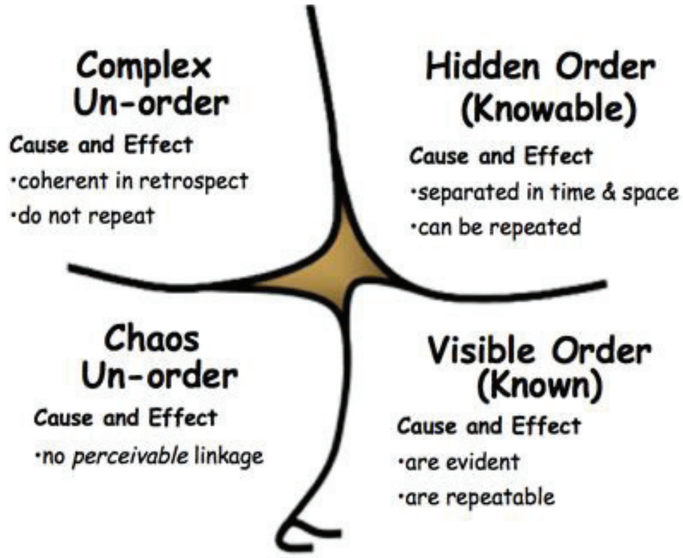

Fig. 1. The Cynefin Domains of Knowledge [2]

Teaching and learning processes used in Integrated Engineering units focus on building students' capacity to manage issues arising in the Complex domain more effectively, while recognising that each encounter has unique non-repeatable characteristics. Projects to be completed, and the educational designs that facilitate them, are not intended to lead students to pre-defined 'answers' or 'resolutions' since these do not arise in the Complex domain. To illustrate, consider the design of a bridge, an easily recognisable 'complex' problem. There are multiple options, each having benefits and drawbacks. However, once it is decided to complete the bridge, the outcome, while perhaps not the best of all possible solutions, is the one agreed to be the most appropriate fit given all contemporary constraints and opportunities. Moreover, the same solution will not be directly applicable the next time a similar task arises.

Thus, the educational strategy underlying the IE suite is intended to support students in developing judgement, acquiring the capacity to work effectively in the face of multiple possibilities, competing demands and assumptions, through creating original, well founded and argued solutions to complex real problems. This is achieved through three essential components of the curriculum [adapted from 6]:

1. learners taking action to create contextually relevant knowledge;
2. aligning methods chosen for engagement with the course content and its underlying principles (ie. simulation of industry practices); and,
3. utilising assessment tasks to promote ongoing learning, potentially extending learning outcomes far beyond input from the educator, peers or materials

IE, as with a range of similar experience-based learning strategies, emphasises the 'primacy of praxis', through a focus on creating environments that allow learning to follow the flow of novelty and emergent practice, rather than organizing for learning around a fixed set of lectures, highly defined exercises, and infrastructures [7 p. 22].

Instead of delivering pre-packaged 'pieces' of knowledge to be memorized, IE creates a planned sequence of learning containers enabling the emergence and growth of knowledge about, and understanding of, engineering as a contextually responsive profession. In doing so, IE can begin to unsettle student assumptions about such things as 'how to be a student', how knowledge is created, and who has authority to define and create new ideas. In effect it places the learning process and the learner's engagement with it, at the centre of the action. Thus, it is quite distinct from conventional lectures and lab work where the academic, as an external authority figure and acknowledged expert, directs the learning focus and carries the burden of all decision making.

Concurrent work in the integrated engineering program has focused on developing a language and framework for managing complexity to facilitate instructors to scaffold, articulate and model learning methods and expectations, students to be able to discuss, evaluate their competence and understand their learning, and for instructors and students to co-construct the learning outcomes and expected academic standards [4].

2 METHODOLOGY

This investigation into students' responses to this intentional focus on complexity is being undertaken as part of a larger evaluation of the IE program. This paper reports on analysis of the standardised Unit of Study Survey (USS) results - an end of semester, anonymous survey of student satisfaction conducted for all units of study. The survey is conducted online and participation is voluntary. The sample analysed here includes 778 student responses across first, second, third, and fourth year units in the program, with an average response rate of 38%.

The survey included 10 Likert scale questions typical of student satisfaction surveys. These questions solicited opinions on perceptions of learning, teaching quality, and general satisfaction. The survey also included the following open-ended response questions:

1. What have been the best aspects of this unit of study?
2. What aspects of this unit of study most need improvement?
3. Are there any other aspects of this unit of study that you would like to comment on?

Analysis of these open responses was the focus of this study. The sample covered two instances of the 1st and 2nd year units, and one each of the 3rd and 4th year units.

Table 1. Summary of survey data sample

Cohort/unit year	n	Enrolled	Response
1st year	214	580	37%
1st year	79	237	33%
2nd year	26	54	48%
2nd year	309	696	44%
3rd year	102	321	32%
4th year	48	168	29%

Analysis was conducted using an inductive coding approach in QSR Nvivo by an independent research assistant not involved with the teaching or design of the IE program. To preserve the conditions of anonymity and data usage originally provided to survey participants, original quotes have not been published here. Results presented are thematic analyses findings only.

3 RESULTS

Initial inductive coding of the open-ended question responses revealed a distinct dichotomy in participant sentiment towards key elements of their unit of study. These key elements were coded as:

- **Resources** (positive or negative sentiment): Course related resources that either students, lecturers or tutors utlised. Examples included handouts, lecture slides, online content, videos, assessment rubrics.
- **Activities** (positive or negative sentiment): Student class-based activities.
- **Assessment / Evaluation** (positive or negative sentiment): Both formative and summative assessment/evaluation mechanisms.
- **Lecture / Tutorial support** (positive or negative sentiment): Sentiment references to either individual Tutors or Lecturers.

Another category emerged around participant **skills or insights** (positive or negative sentiment). This category captured both direct and incidental skills students felt they had or had not gained in the program. Direct skills related closely to course learning outcomes to individual skills, such as teamwork, communication and critical thinking skills. Incidental skills also emerged as a result of the direct skills, such as improving English language skills and making new friends.

This category also captured deeper personal insights about the program. This included where students felt they had personally benefited from, or been disadvantaged by, the program. Positive insight examples included expanded insights into what Engineers do, and examples where students had gained a better understanding of engineering through exposure to real-world engineering projects. Negative insight examples included perceived excessive workload related to unit credit points, or failing to understand the purpose of the IE program.

A large majority of participant responses were expressed as either strongly positive or strongly negative in sentiment. Only a very small number of participants expressed neutral sentiment across the open-ended response questions. It was apparent that the responses were quite polarised, with strongly positive or negative sentiments expressed around the same issue. This was also reflected in the quantitative survey questions where sentiment was typically split between positive and negative, resulting in an overall result for most survey items in each unit as neither strongly positive or negative (agreement or disagreement with the questionnaire item).

Drawing meaningful conclusions from the initial analysis was challenging. For every ‘like’ expressed in student comments, there appeared to be an equal and opposite ‘dislike’. It was at this point that the decision was made to undertake a more structured analysis of the data to explore the extent to which perceptions of the focus on developing students’ comfort with complexity were evident in responses. The categories were subsequently integrated and examined via the ‘Complex’ component of Cynefin theoretical framework lens with a focus on:

- What are the ways in which students indicate adoption of, or comfort with, complexity in the learning experience?
- What are the ways in which students indicate resistance to complexity in the learning experience?

Within the full sample, a total of 121 participant comments were coded as indications of comfort with or resistance to complexity in the educational design (63 – Comfort with complexity, 58 – Resistance to complexity). Responses coded as evidence of response to complexity were typically longer comments that provided insight into both the students’ position, and the reasoning for it. The two high level categories were then further analysed to explore the components of the student experience that made up their prevailing comfort with or resistance to complexity. The results are presented in *Table 2*.

Table 2. Summary of themes relating to complexity in the learning experience

Comfort with complexity (no. of references)	**Summary of participant comments**
Relevance, authenticity and professional formation (33)	Remarks on the relevance to professional practice and ‘the real world’. Skills development as important for future/other contexts, particularly professional and communication skills.
Collaboration (22)	Forming new professional connections and building networks through the learning experience. Integrating different skills of individuals.
Learning support (20)	Curriculum design or teaching staff were supportive through the learning process. Comments typically expressed in relation to support provided for working through tasks, not giving answers.
Resistance to complexity	

Lack of clarity (18)	Complaints about not being clear on tasks, seeking examples to follow. These comments typically implied that the path and the desired outcome should be made clear through the learning design.
Lack of support/Deferral of responsibility (17)	More forthright comments suggesting that students should be shown what to do throughout the process. Differentiated from 'lack of clarity' in the extent to which student assigned responsibility to teachers or curriculum. Comments on teaching staff not providing help, not 'teaching'.
Too hard, lack of value (8)	Complaints about unreasonable expectations, unreasonable level of difficulty. These comments generally implied that the skills focus of the units were not valued.
Irrelevance (19)	Comments mentioning lack of relevance tended to focus on relevance to the program of study, rather than relevance to professional practice. A minority of students also commented on the relevance to their own very specific circumstances.

4 DISCUSSION

Overall, statements made in the negative tended to have less clarity of meaning and were more varied in focus. It must be noted that those who resist complexity are not regarded as 'poor' students. Rather, the results suggest that views on what a valuable learning experience is, is influenced by their conception of what 'learning' is, or their views on the realities of engineering practice. This could be seen most clearly in the comparison between comments discussing the relevance or irrelevance of the learning. Relevance of the learning experience tended to be discussed in a positive sense in relation to professional practice, whereas it was typically discussed in the negative in relation to the wider (and more traditional) curriculum.

This is a particularly important finding for the IE program as it is delivered within a traditional engineering curriculum. As long as the learning experience in the program differs significantly from students' contemporary experience in other units, it is at risk of being viewed as an outlier, and atypical, despite its alignment with industry practices.

Students' views on what 'learning' is were also apparent in comments relating to the curriculum design and learning support offered by teaching staff. Those who were positive seemed to discuss guidance provided by tutors, or the sequenced arrangement of learning activities and assessments. Those who were negative indicated expectations of being shown what to do and being provided with exemplars to model their own work on, and attributing the difficulty they experienced to the perceived 'vagueness' of tasks.

These findings may also provide insight into the polarized nature of quantitative survey results. Some students may be reflecting on their experience in the unit at face value with respect to their preparation for an engineering career, whereas others may be comparing it to their experience of learning in other units of study and prior education.

4.1 Limitations

The use of data from standardised Unit of Study Survey (USS) results is both a strength and a weakness of this study. The voluntary nature of the survey and the anonymity of responses may have elicited a disproportionately dissatisfied (negative) sample of the student cohort.

However, the unsolicited (as in, not asking directly about complexity) remarks giving insight into complexity helped us to understand the different ways in which students resist it in the learning design. Other research undertaken in the larger IE program evaluation has involved face-to-face focus groups with students, staff and graduates, and analysis of end of semester reflective assessment submissions. These have both provided deeper insights into how student engage with the learning and navigate complexity in a predominantly positive sense. This is possibly due to the influence of the interviewer/facilitator being seen to be an employee of the institution, or the positive bias in students' responses to an assessable reflective task. The analysis of anonymous comments presented a negative perspective largely absent in these other, more targeted, data collection and analysis approaches.

5 IMPLICATIONS AND CONCLUSION

These findings have significant implications for the IE program and potentially other similar programs emerging globally. Where evaluation of teaching is largely limited to quantitative results of student satisfaction surveys, there is a high risk of support for such a curriculum innovation being undermined by 'poor' quantitative survey results that don't adequately reflect student perceptions evident in the qualitative data. The deeper analysis of qualitative results shown here suggests that the numbers don't tell the full story. The learning outcomes and curriculum design employed are in fact recognised and appreciated by a significant proportion of the cohort, while being opposed and resisted strongly by others. We must remember that these surveys evaluate student satisfaction, not necessarily their learning or their professional development. As Brookfield reports, "learning that challenges and stretches students, asks them to think critically or use their judgement to deal with uncertainty and complexity, often induces resistance" [8]. This resistance as shown in this study can result in poor student satisfaction and hence low survey scores. This highlights another issue - that we need to also develop students' ongoing learning identity trajectory. If we want students to embrace and learn from the challenges of managing complexity we need to do more to change some students' learning culture and perceptions of legitimate learning to promote engagement, participation and realise the benefits.

Furthermore, to address the potential risk of students viewing the IE program as an outlier in terms of the learning experience, the program needs to have closer connection to pedagogies used in parallel units of study. At a minimum this could be verbal endorsement of the program and linking its learning outcomes to their technical subject studies. We suggest a longer term approach would require significant changes to academic culture to integrate management of complexity into learning and assessment activities across the curriculum.

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She VS She:
Are female Mexican engineering students "real women"?

G.L. Gomez Anguiano[1]
ITESM Monterrey
Monterrey, Mexico

M. F. Mendoza Cantu[2]
ITESM Monterrey
Monterrey, Mexico

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ABSTRACT

Women's lack of representation in STEM majors is an ongoing issue in Mexico due to the "Machismo" ideology that predominates its culture. The purpose of this research presented as a qualitative phenomenological study is to answer the following question: What are the stereotypes Mexican female students have against female Mexican engineering students? Our study focuses on 70 Mexican female students that were enrolled in different majors other than engineering pertaining to a northeastern private Mexican university. Their opinions on stereotyping were collected through an 11-question online interview. The first finding was that Mexican female students do hold stereotypes against female engineering students. They vary from levels of intelligence and skill sets, femininity and beauty standards, and lastly, sexual orientations. The second finding was that the transmission of these "Machismo" stereotypes can be traced back to their family upbringing. Overall, these findings contribute to the idea that women's underrepresentation in STEM majors originate before they even start a higher-level education.

[1] G. L. Gomez Anguiano
A01410339@itesm.mx
[2] M. F. Mendoza Cantu
A01176270@itesm.mx

1. INTRODUCTION

Female engineers are a constant reminder of what those willing to transform their lives are capable of; they are able to break the status quo and open a world of possibilities for young girls who want to succeed in any field of study they want. The research conducted by Mexico's National Survey of Occupation and Employment (2018), exhibits a clear imbalance of gender representation on the three more occupied professions related to engineering.

By the end of 2018, the areas of 1) Industrial Engineering, Mechanics, Electronics and Technology, had almost 310,081 professionals occupied, and only 20.6% were women; in 2) Mechanical Engineering and Metallurgy out of the 257,050 professionals occupied, only 9.7% were female; and finally, in 3) Computer science and technology, of the 290,452 thousand only 19.9% were women. Such disciplines are considered "hard sciences" and what several authors classify as STEM (Science, Technology, Engineering, and Mathematics).

This gender disparity has been backed up by harsh stereotypes that have impeded women a full autonomy and entrail a deep rooted misogynist and discriminatory logic that, in later years, has even reached the extreme point of femicides. The last one, as reported by the National Citizen Observatory of Femicide (OCNF), aids to the perpetuation of cultural patterns that have been historically assigned to women, such as: "subordination, weakness, feelings, delicacy, femininity, etc., which are rooted in misogynist ideas of man's superiority, discrimination against women and contempt against her and her life" (OCNF, 2018, p. 16).

According to the statistics collected by the Executive Secretariat of the National Public Security System (SESNSP), from 2014 to 2017, a total of 6,297 women were killed in 25 states of the country, from which only 30% of cases were classified as femicides. These figures reflect an increase in the percentage of women killed to be close to 52%, from the years 2014 to 2017. It's not always necessary to talk about the extremes, however, sometimes the worst has to be illustrated in order for the problem to be acknowledged.

Discrimination against women has become so dire that in just three years the rate of murders has doubled. In 2018, the National Survey of Occupation and Employment registered a female economic participation rate of just 43% against a 77% male participation rate. Out of those 43%, merely 14% were female engineers.

In Mexico, women often face discrimination in their work environments. From being forced to take pregnancy tests, being harassed by coworkers in their workplace, or being generally subjected to emotional violence. All this implies that as women are seen as the weaker gender, playing a subordinate role to men, they do not belong in this workforce. With women still trying to fit an ideal gender role, those that do branch out face the issue of a lack of gender cohesion within the work and academic environments.

According to Cortés, Kral & Ramón (2015) an unfriendly environment for women (in engineering) is due to the "masculine engineering culture" and symbolic violence at school and the workplace. For example, male professors' constant usage of chauvinist comments or jokes about women's physical capabilities. It is also mentioned that female teachers and students make the same comments and jokes about themselves. This means that not only the male portion of the equation is the problem, but also the women themselves.

1 MOTIVATION

The purpose of this qualitative study is to identify the stereotypes created by female Mexican university students on female students who study engineering. The study is relevant due to the pressing matters in society as a whole and engineering career paths specifically.

1.1 Delimitations

Our study focuses on 70 Mexican female students studying fields other than engineering during the Spring semester of 2018, in a northeastern private university.

1.2 Research question

To help us comprehend the magnitude of the problem, the main question is: What are the stereotypes Mexican non-engineering female students hold on female Mexican engineering students?

2. LITERATURE REVIEW

It is important to analyze different aspects of women's upbringing, such as their home education, their experiences in school from the first steps up until higher education, and finally their experience during their professional career, in order to trace what originates the problem.

2.1 Women's upbringing and parental expectations

We start off with a disturbing pattern, which is described by authors Corbett and Hill (2015), in a research conducted in the United States of America:

> *"Despite early similarities between girls and boys in math and science achievement, by high school, boys are more likely than girls to take the standardized exams most closely associated with the fields of engineering and computing. Among first-year college students, women are much less likely than men to say that they intend to major in engineering or computing. This disparity continues into the graduate level. In the workplace the discrepancy persists and, in some cases, worsens, as women leave engineering and computing jobs at higher rates than men do" (Corbett and Hill, 2015, p. 2).*

This illustrates the main topic of discussion: from a young age, women are either dropping out of or not even taking part with anything related to engineering for ambiguous reasons.

Taking this into account, the primary source of education, should be scrutinized. According to authors Ginevra, Nota and Ferrari (2015), the influence parents have on their children must never be underestimated. It was discovered that high school and college students' perceptions of parental support had a direct and positive impact on their career interests and career choices, specifically with regard to their opting for majors in information technology.

The answer behind this absence of support is attributed to stereotypes imposed by society. Them being defined as "socially shared beliefs about what qualities can be assigned to individuals based on their membership in the female or male half of the human race...or any other distinction that can be used to divide people into groups" (Lips, 2017, p. 3). Lips also states that:

> "An implication of stereotyping two groups as polar opposites is that any movement away from the stereotype of one group is, by definition, a movement toward that of the other group. For instance, a man who acts less rational than the male stereotype is seen not only as less masculine but as more feminine; a woman who acts less emotional than the female stereotype is viewed not only as less feminine but as more masculine" (Lips, 2017, p. 3).

Ergo, women who prefer a more intellectual masculine job are accused of behaving like men.

According to Cheryan, Master and Meltzoff (2015) this is due to the stereotypes engineering carries. These stereotypes can often act as educational gatekeepers, constraining who enters into these fields and driving girls away. The situation they present is related to Computer Science and Engineering. These majors are widely seen as male-oriented fields that involve social isolation, an intense focus on machinery, and inborn brilliance. In the present media, outstanding people that created or are involved with technological advances, are often male figures. Bill Gates and Mark Zuckerberg are some of the most famous examples. In comparison, the scarcity of female famous engineers results in girls having less interest in these fields.

Unconsciously, stereotypes are passed on by generations from a young age, and they can often damage in the future since “we all hold gender biases, shaped by cultural stereotypes in the wider culture, that affect how we evaluate and treat one another. While explicit gender bias—that is, self-reported bias—is declining, implicit or unconscious gender bias remains widespread” (Corbett and Hill; 2015; p. 2).

2.2 Experiences of women in higher education

In high school, girls tend to avoid computer programming classes and any derivative of them, since they are perceived as being “reserved” for boys. In university, this avoidance leads to an ever diminishing female population in engineering majors.

The number of women that abandon STEM majors is distressing but the issue starts with them not even enrolling in these majors to begin with. If they do choose to study engineering, they are at a numerical disadvantage, according to authors Jones, Ruff and Paretti (2013). In university, women almost always comprise a minority in engineering programs. Jones et al. (2013) claim that a thick “engineering culture” prevents women from completely integrate themselves and it is a reason that they prefer to switch majors to one that has a less chauvinistic environment.

Jennifer Hunt (2016) proved that the exit rate for women compared to men is higher from engineering than from other fields, resulting from excess female exits to jobs in another field. She wanted to prove if the considerable literature on women leaving Science and Engineering had to do with the difficulty of balancing long work hours and family.

However, there was no evidence of an impact or influence on having children for women trained as engineers. Rather, she found that the most important driver of female desertion from engineering is due to dissatisfaction over the gender pay gap and less promotion opportunities. This situation is also present in Mexican society.

According to Dharmavarapu & Angolkar (2016, p.1), “women comprise more than 20% of engineering school graduates, yet only 11% are practicing engineering”. As previously stated, a similar percentage (14%) is present in Mexican society, of women actually practicing engineering.

The Mexican university that this study was conducted on has had, since its foundation in the 20th century up to 2018, 111,220 students graduated as Engineers. Only 33% of female students have graduated as Engineers, which includes undergraduates, Bachelor's degrees, Master’s degrees and PhDs compared to the 66% of male graduates.

2.3 Female engineers in the work field

In spite of everything, there are women that decide to break from these gender roles and graduate from STEM majors. However, they encounter that the work environment is harder for those that feel that do not belong or that are treated as if they did not belong.

To define this concept of “belonging” in the work field, Wendy Faulkner, in Waltraud & Horwath (2014), analyzed the results of a survey applied to female engineers working in a UK oilfield engineering company. The results indicated that the lack of integration can be easily seen, since men bond through the usage of what are considered masculine conversation topics, with sexual language.

This in turn, makes women feel alienated and in order to fit in, they have to adapt by modifying the way they present themselves. Whereas, some would rather change the way they dressed and acted in order to reduce their femininity; others would rather accentuate their femininity in order to stand out as a novelty. This was also the case in a US software development department.

These two environments created the atmosphere which Faulkner sees as a paradox for women. By making them choose between feeling as not quite “real engineers” nor “real women”. This happens when they either have to exist as the ideal image of a competent engineer which has the consequence of giving up their femininity or being extravagantly feminine and not being considered a real engineer. Women have to reconstruct their identities and potentially give up important parts of themselves or risk becoming ostracized by their work environment.

3 METHODOLOGY

This project is classified as a qualitative phenomenological study, in which an online eleven question interview, was used to collect data (see Annex 1).

The data was a random sample, collected from the 70 responses. It was distributed to the population of non-engineering university female students, through Social Media, mainly Whatsapp and Facebook, and guaranteed their anonymity. The survey was divided into three parts. The first one, basic information about the participant was asked, including age, gender, major and the main reason why they chose to study that major. The second part involved a series of multiple questions regarding their opinions on which major females choose often and which were avoided and why they believed it happened. The last part was an open set of questions, furthering their experience through their studies, asking them to write stereotypes they have encountered or used. The last question asked participants why they believe these kinds of stereotypes exist in society and who passes them on.

We used this methodology in order to analyze the experience that women went through, both as victims and victimizers of stereotypes in STEM majors. The participants ranged from ages 16 to 25 and were currently enrolled in a private, northeastern Mexican university that is often seen for the upper classes. It offers majors of the School of Social Sciences and Government; the School of Humanities and Education; the School of Medicine and Health Sciences, and the School of Business.

The initial codification was to separate psychological and physical stereotypes that students had of the female engineering students. The data was then divided into these new sub categories; the psychological category involved sexual orientation, levels of intelligence and skill sets perceived of women in engineering. For the physical category, answers were further divided into beauty and image standards and social interaction standards.

4 RESULTS

In order for the participants to acknowledge the status female engineering students face, they were asked their general thoughts on the matter. For instance, they were questioned as to which major they thought women choose which one they considered more difficult and finally why they thought women made such decisions.

As results of the first part of the interview suggests, the participants believed that most women chose to study Business and Administration majors, whereas STEM majors were usually avoided due to the alleged difficulty it presented towards the ideal female gender role. Studying a STEM major would be time consuming for them to perform duties for the family. Thus, women were suited for major pertaining to the School of Humanities and Education as these are perceived as easier and more “people and emotionally” oriented. The second reason had to do with representation, and how comfortable the work environment is for students after graduation. All the participants were aware of the potential discrimination and unequal treatment women receive, such as salaries and preferring men because of maternity leave issues.

For the second part, the participants were asked to think about experiences women go through when choosing engineering as their major. Overall, they said that stereotypes surrounding women studying engineering exist. This made it possible to classify the perceived stereotypes in two categories: psychological and physical. As for the psychological, participants mentioned sexual orientation as the most common stereotype labeling them as tomboys, lesbians and less feminine. A Mexican term that was repeated by 95% of the participants, mentioning that engineering students were “marimacha or machorra (lesbian), masculine”. The low percentage of participation was attributed to the acknowledgement that females had an insufficient level of intelligence and skill set for this field of study. They believe “*women are too delicate and not intelligent enough to study engineering or numbers”*.

The second category regarding physical characteristics was linked to the feminine body and dress claiming that a suit or uniform did not fit the female form as well as a skirt, dress or heels. The consensus defined female engineers as ugly: “*They are less pretty, ugly; the typical nerdy girls: with glasses, badly dressed, and don´t care for their image”.*

Finally, participants were asked how they believed these stereotypes are perpetuated. The most common answers had to do with the empirical learning throughout their life, predominantly by female members of their family and professors. They believed it is an innate practice due to the “machista” culture predominant in Mexico.

5 DISCUSSION

After considering the literature review and the results from the online survey, it can be inferred that the main reason behind this social issue is the gender stereotypes of the ideal female role created and imposed by men and females alike.

This ideal image starts being constructed from a young age at the core of their upbringing, the family. Predominantly the female members of the family in a “macho culture” create the idea that women should be delicate and feminine which can often be linked to the idea of gender being self-sacrificing, family oriented and overall, weaker. As girls grow up, their ideals are coerced into fitting a predesigned mold and whoever does not adhere to it, will be criticized and becomes that society´s pariah.

Yet, there are few women that do decide to go against the norm and once they prove these stereotypes as farce during their higher education, they encounter a hostile work environment that compels them into adopting new identities in order to fit the standard of “real engineers” which often leads other non-engineering women to deny their status as “real women”. In many instances, these women are victims of the hostile environment caused by chauvinistic comments from both men and women.

Since it ends up being a predominantly male environment, society dictates that it is not a suitable environment for the gender since it will be harder for females to integrate, *"It is not an environment for good girls"* as some participants mentioned. Cortés et al. (2015) sustained this belief with their own data analysis. Women adapt in order to deal with these hostile environments and they are constantly "navigating between two seas" torn trying to fit into both. This, "by behaving according to the traditional codes of gender (to be quiet, passive), but at the same time exhibit an exceptional intellectual capacity" (Cortés et al., 2015, p. 51).

6 CONCLUSIONS

The initial research question of "What are the stereotypes Mexican female students hold on female Mexican engineering students?" was examined through this study. Even though society strives for diversity and gender inclusion, engineering careers in this type of countries with a patriarchal ideology, seem to fall behind. This study was conducted in order to know what female non-engineering students thought of female engineering students.

Based on the data gathered and the literature review, it can be concluded that most female students acknowledge the existence of stereotypes for female engineering students. These stereotypes are created based on physical and psychological characteristics. As for psychological characteristics, the first characteristic to be identified was the matter of sexual orientation; how women in STEM majors were generalized and said to be attracted to their same gender. The second one, had more to do with levels of intelligence and skill set, and how compared to the male gender, it was inferior. According to the study, females were perceived as less capable, less intelligent and less ambitious, so they are less likely to accept the challenge these presumably difficult major represented.

For the category of physical attributes, the participants agreed that women in this field were perceived as unfeminine and less attractive.

When analyzing the results, it was clear that they recognized how society constructed that the work environment of STEM careers was male oriented and therefore, unsuitable for their gender. This can be a traceable reason why females tend to dismiss anything engineering related as early as elementary education.

The interviews portray a vicious cycle. Due to the lack of female representation, less females enter these fields, because they do not want to feel inferior next to their male coworkers. As a minority, they face gender discrimination by being marginalized, or even overlooked for better job opportunities since they are women. Consequently, less women choose to study anything related to engineering.

Based on the study conducted, the best way to eliminate stereotypes is by attacking the problem from the root. The image of a female engineer should become a more accessible and common image, making the Mexican household acknowledge it as normal, hence, creating the interest for young girls towards STEM majors.

7 LIMITATIONS & FUTURE STUDIES

The limitations of this study included only considering female students enrolled in a private Mexican university and female perspective, dismissing those of males. In future research studies, the perception of male students can be considered in order to know how they perceive these women and how they have experienced certain types of stereotypes within STEM careers. The sample size could also be increased to obtain more precise results.

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ANNEX 1

Welcome message: Hello! This questionnaire is about majors in university, its anonymous and confidential, we appreciate your honesty.

1.Gender? (Multiple choice from Female, Male, Other)

2. Age (Open question for them to reply with a number)

3. Major (Abbreviation of the major they study)

4. Semester (multiple choice from 1 to over 10th)

5. Why did you choose your major? (Three options from “For personal taste”, “Family ideology or pressure” and “Work opportunities)

6. Which field of study do you think women chose more often? (Multiple choice from Bachelors-Administration, Engineering, Medicine, Architecture, Humanities)

7.Which field of study do you think women find more difficult? (Multiple choice from Bachelors-Administration, Engineering, Medicine, Architecture, Humanities)

8. Why do you think that? (Open question for them to give a long answer)

9. Do you think there are stereotypes for women that study engineering? (Yes or No)

10. Which examples of such stereotypes? (Open question for them to fill it in freely)

11. Who do you think conveys such stereotypes within our mexican society? Explain your answer (Open question for them to answer freely).

Peer assessment of individual contribution in group work: a student perspective

R Grammenos[1]
Md Pilar Garcia-Souto
I Chester
L Albelda Gimeno
University College London
London, United Kingdom

Conference Key Areas: a) Strong demand for democratic involvement in educational processes, b) Another topic relevant to the conference but not listed in the key areas.

Keywords: Peer assessment; individual contribution; group work; student perceptions.

ABSTRACT

With group work increasing in popularity at universities, students no longer feel it is acceptable to be awarded the same group mark. This presents a significant challenge in awarding an individual mark which reflects unequivocally the time and effort a student has invested in a group project. To address this challenge, a tool to evaluate individual peer assessed contribution (IPAC) has been developed at University College London (UCL). The aim of this paper is to report on the perceptions of students regarding their experience of peer assessment in group work, since these perceptions are key to ensuring that a tool, such as IPAC, is accepted and used effectively by staff and students alike. The views of 133 students were acquired through anonymous surveys and focus groups ranging from first year undergraduate to doctoral students across 12 different departments. Results showed that 92% of students are in favour of peer assessment with a positive trend to using the IPAC tool. Receiving constructive feedback was considered imperative amongst respondents, which in turn should identify clearly the points of error; highlight explicitly the areas for improvement; and thus reflect accurately the mark being awarded. The attributes that students valued to be important when assessing their teammates were, in decreasing order of priority, attendance at meetings, listening and communication, actual contribution to the project deliverables, quality of the work produced, personal circumstances, and finally time management and organization skills. The detailed analysis and conclusions drawn from this study are the focus of this paper.

[1] R Grammenos, r.grammenos@ucl.ac.uk

1 INTRODUCTION

Engineering design is at the core of engineering education. Engineering design practice in turn is a "deeply social process" requiring regular interactions and collaborative group work between people [1].

Yet, it is a well-known fact that in group work, not all members of the team invest the same amount of time and effort into the project. Awarding the same group mark to all team members is thus considered to be an unfair method of assessment. It is argued that the students who have first-hand experience of working within the team should themselves be able to assess the contribution of each member. This method of peer assessment though comes with its own set challenges, as examined in this paper.

1.1 Group work

A group can be defined as a collection of people who recognise the existence of the group, help each other when necessary and share the same aims and objectives. Membership of each group can be determined by how well the individuals integrate with each other including communication and work exchange [2]. In an ideal scenario, the tasks are split equally amongst members who all have the same drive to succeed in the project [3]. Each member's contribution, effort and behaviour, as well as the appreciation of social organisation, various roles and power positions, directly affect the interactions between individuals and subsequently the performance of the group.

For a group to perform well, they must agree on a set of methods, rules and structure to facilitate cooperation [4]. Communication between members is vital to the team's cohesiveness, irrespective of whether members are located in the same physical location or not, and is key to building enthusiasm and dedication within the group.

While students have mixed opinions regarding group work, those who value it consider group work to be inspiring, motivating and central to fostering deep and active learning, as identified by Hall [3] and Swaray [5]. Students also consider group work to be a time-efficient way to complete a project through splitting up tasks, while concurrently developing their teamwork and communication skills, as found by Taqi and Al-Nouh [6]. Students may also benefit from a more fulfilling learning experience since they are likely to receive more detailed and frequent feedback as a group compared to individual, isolated feedback [2].

In the study by Chiriac [4], 97% of a 210-student cohort concurred that working in a group enhanced academic knowledge, collaborative abilities or both, through discussion and questioning each other's ideas and opinions. Such creativity would not occur if they were working independently, as they would not feel inspired or provoked to think differently. Group work allows students to gain credit for developing and refining these skills [7] encouraging them to work harder to improve these attributes. Furthermore, communication, leadership and working effectively in teams are considered essential transferrable skills that can increase students' employability [8].

1.2 Peer assessment of individual contribution in group work

Despite the benefits offered by group work, students may encounter unpleasant experiences as a result of a dysfunctional group, poor communication or conflict. In Hall and Buzwell's study [3], almost half the respondents commented on negative and stressful experiences during group projects caused by different work styles (10%), impact on personal learning (20%), as well as group dynamics and workload allocation (27%). Above all, 61% felt that their own individual contribution was not reflected in the mark they received. The contribution of a team member to the group project will depend on their level of ambition, and their interest and commitment to the project. This in turn will affect how willing they are to complete the tasks to high standards [4].

Awarding the same final mark to all members in a team is generally considered to be an unfair approach causing frustration amongst students and having significant impact on group dynamics [3]. This is particularly the case with 'free riders' who are reluctant to participate and commit to the aims and tasks of the project. Worse, however, this issue may cause more capable students to reduce their input to the team, an issue referred to as "*inequity based motivation loss"* [2].

Peer assessment aims to address this issue by giving students 'a voice' to comment on their own contribution and that of their fellow team members [3]. In a survey by Willis et al. [7], 66.4% of the 156 respondents agreed that having a final mark consisting of an individual mark and a separate group mark would be a fair approach to a group project, as corroborated further in a study by Shiu et al. [9]. Peer assessment helps students reflect on their own and group, development and progress. This can enable them to focus on their strengths and become aware of their weaknesses, while gaining an insight into how they are valued within the team [7] [8].

While there is a clear need to assess individual contribution, a study by Zou and Darvish [10] emphasizes the importance of not impeding the collaboration and cooperation of the team itself in the process. Even though free riding could be seen as a sign of apathy or laziness, it should be noted that there may be a host of reasons for which a member is not contributing to the project. For example, some students might feel uncomfortable or feel that they lack the necessary skills to contribute; this could be particularly the case for international students whose first language is not English [3]. As a result, such students may be asked or forced by the remaining team members to carry out a different, maybe inferior, role, which in turn could result in those students being marked unfavourably during the peer assessment process.

2 METHODOLOGY

To address this challenge of peer assessment in group work, a tool to evaluate individual peer assessed contribution (IPAC) [11] has been developed at University College London (UCL). Using IPAC, each student is held accountable for their level of contribution to the project and their interaction with the team's members. Therefore, the goal of IPAC is to reduce the amount of free-riding that occurs within a team, since the prospect of receiving poor marks and negative feedback may be sufficient to motivate free riders to work with the team [3].

Over one hundred students from 12 departments (see Fig. A1 in the appendix) across UCL at different stages of their degree, as depicted in Fig. 1, were invited to participate in focus groups and to complete surveys. This was achieved by distributing a link to an anonymous online survey, as well as an invite to attend a focus group on a first-come, first-served basis. The focus groups and surveys were run independently, yet alongside each other with separate results acquired from each medium. It is worth noting that participants or respondents might not have necessarily used the IPAC tool.

This study was aimed at gathering students' experiences and views of marking schemes used in group work; the effectiveness of these marking schemes, particularly with regard to reflecting accurately the work carried out; and their opinions on peer assessing their fellow students. The focus groups were ran by student representatives in absence of faculty staff, to allow students to express their views freely and honestly while maintaining anonymity. The survey questions in their complete format are listed in Table A1 in the appendix.

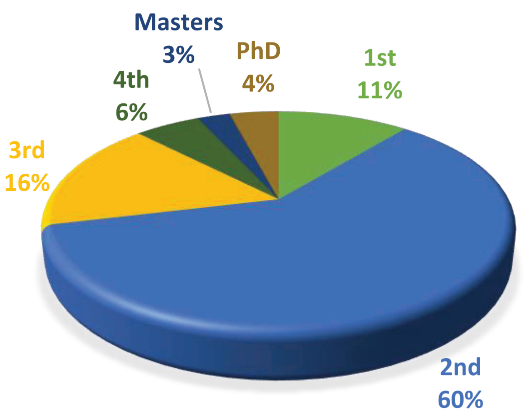

Fig. 1. Student demographics according to degree year

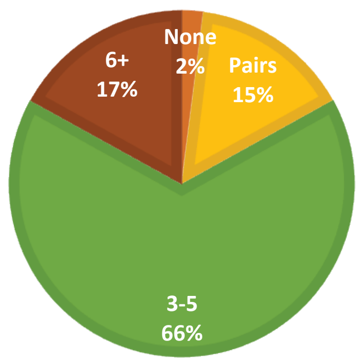

Fig. 2. Taxonomy of group sizes experienced by the respondents

2.1 Focus groups

Four focus groups with a total of 44 students were ran with participants mostly from the engineering disciplines but also from the arts and sciences. Hence, it was likely that some of the participants knew each other but this was not necessarily the case for all focus groups. Qualitative data on the following questions and topics was obtained; Who should be responsible for awarding marks and how would this reflect the group work? What attributes and factors should be considered when assessing a team member? Is peer assessment a reliable method of assessment, and if so, under what conditions? How often should peer assessment take place? In what form should feedback be provided?

Through discussions, it became apparent that assessment criteria and transparent justification for the marks given were of paramount importance.

2.2 Surveys

The survey questionnaire was divided into two sections. The first section collected students' academic data, such as the department they were affiliated to, their year of study and the group size they typically work in, as shown in Fig. 2. The second section focused on obtaining their views of peer assessment by answering 20 questions on a 1-to-5 Likert scale (strongly disagreeing to strongly agreeing). Yet, to improve visualisation, points 1-2 and 4-5 on the scale were combined giving the three-colour bar (red [1, 2] – yellow [3] – green [4, 5]) shown in Fig. 3. We included the very few respondents who had not experienced group work, in order to get their open-minded views of the perceived benefits and drawbacks of working in teams.

The questionnaire included questions with free-text responses offering us greater insights into students' opinions and helping us with our subsequent analysis. Responses were consolidated into three levels with the individual responses tallied against these levels. As evidenced in Fig. 2, 83% of the respondents had experience of working in groups, defined here as working in teams of three or more people, thus ensuring the results acquired were relevant to the analysis under consideration.

3 RESULTS AND ANALYSIS

When looking at the results from both the survey and the focus groups, we are assuming that all respondents are answering in an honest manner. We are also assuming that each respondent answered the questions on their own initiative, that is, without peer pressure or direct guidance by a third party to respond in a certain way.

Figures 3 and 4 summarise the results obtained from the survey. The results show that there is strong support from students for the introduction of a method to assess individual contribution in group work. As shown in Fig. 3, 79% of respondents agreed that being awarded an individual mark based on the individual contribution of each team member is fairer compared to all team members being awarded the same group mark. The positive trend of this result is also highlighted in the box plot in Fig. 4, which shows that the response to this question (Q2) received a mean score of 4.11 with a standard deviation of 0.83. The same argument is corroborated by the fact that 66% of respondents disagreed with the idea of everyone in the team receiving the same mark with the response to this question (Q1) receiving a mean score of 2.11 and a standard deviation of 1.09.

The results also demonstrate that over 70% of the respondents agreed that the introduction of IPAC would motivate them to contribute to the team (Q19-74%) and would encourage them to be more professional and respectful (Q20-71%) with a mean score of 3.92 and 3.88, respectively.

Feedback was considered to be paramount to students with three of the top four most agreed statements related to this idea. 69%, 66% and 67% of students agreed with the statements "It would be valuable to know how I was perceived", "Comments would be appropriate", and "Justification for the marks given should be provided", respectively, with the latter (Q10) receiving a mean score of 4.55.

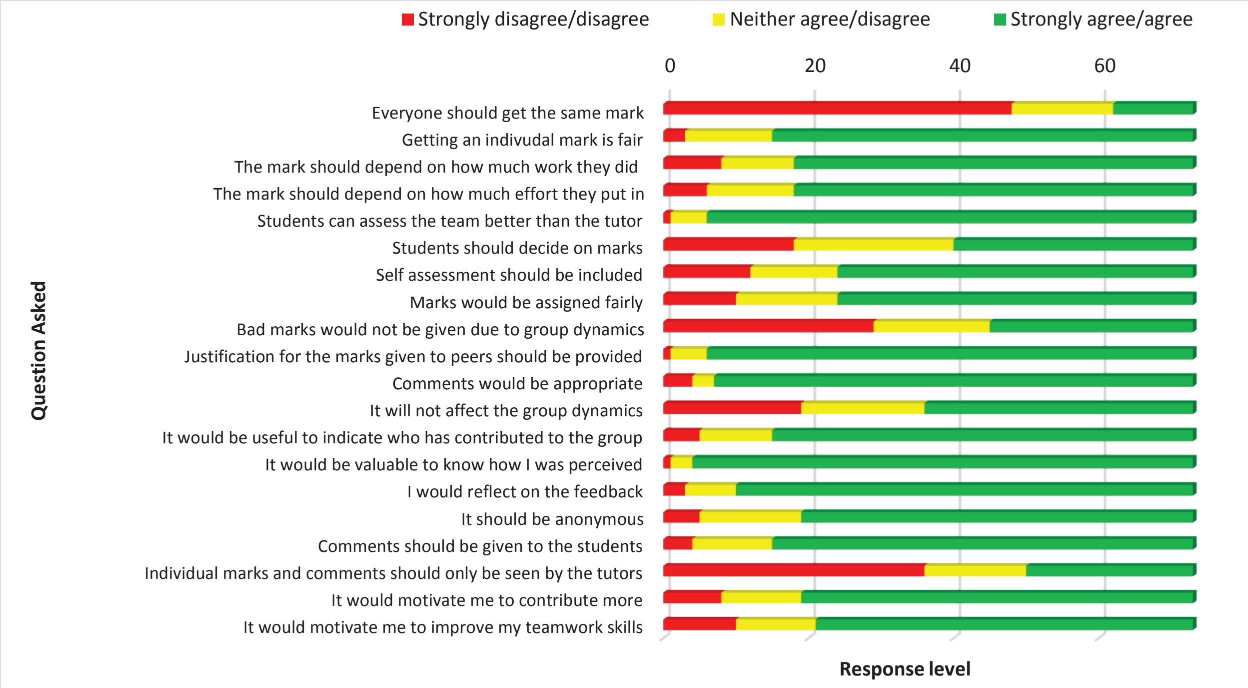

Fig. 3. Grouping of survey results according to three levels

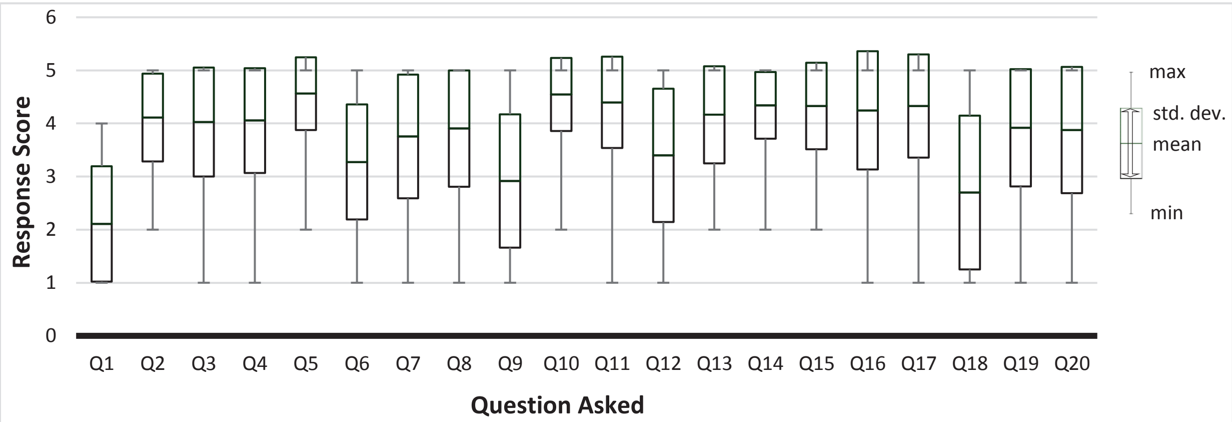

Fig. 4. Boxplots of survey response scores on a Likert scale of 1-5 showing the mean, the standard deviation, and the minimum and maximum scores per question

From the free text responses regarding peer assessment of individual contribution, the attributes that appeared most frequently were those referring to attendance, time invested into the project, and teamwork skills, as depicted in Fig. 5. Students felt that they were in a better position to comment on the performance of their team members rather than the instructor with this response (Q5) having a mean score of 4.56. This view was echoed strongly by engineering students, particularly those who partake in week-long, problem-based, group projects in teams of four to five students. They felt that the instructor did not have sufficient evidence to judge an individual's contribution in view of the fact that a significant amount of work was completed outside the scheduled contact hours.

If instructors are to be involved in the peer assessment process, Fig. 6 lists the attributes that they should take into account, as perceived by students. Being aware of the students who are actively engaged in the project versus the free riders is of utmost importance followed by acknowledging the different skillsets of members in a team. Confidence, commitments and personal issues outside the project were also deemed important factors to be borne in mind during the assessment process.

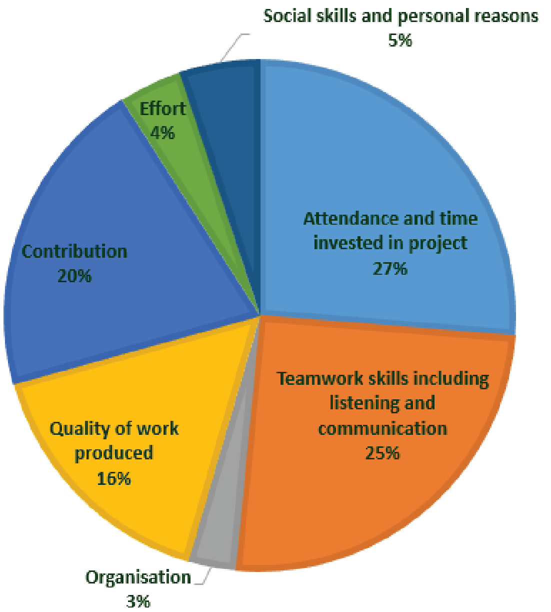

Fig. 5. Considerations in peer assessment of individual contribution

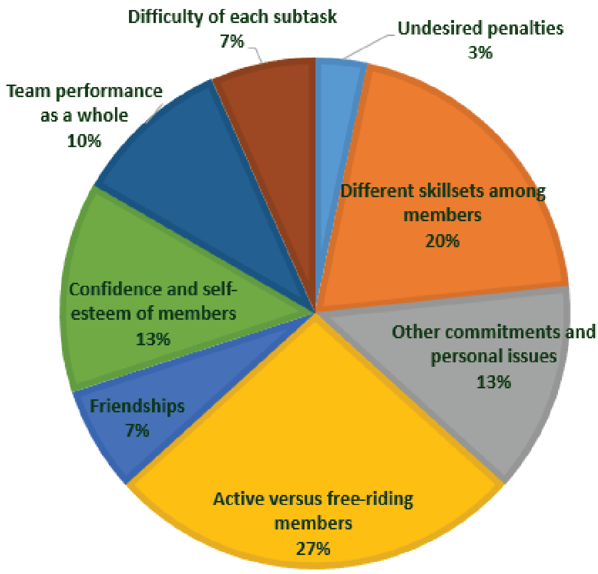

Fig. 6. Instructor's considerations when assessing students in a group

4 DISCUSSION

Goldfinch and Raeside found that assessing individual contribution improved group dynamics [12] as it coerced members to contribute to the team. Further evidence is provided in yet another study by Shiu et al. [13], where 58% of students felt that peer assessment helped improve the quality of the teamwork.

The issue of who marks the group project, and whether this is reflective of the work that has been carried out, is a key factor in assessing how each member contributes to the team. From our survey 75% agreed that the students should be involved in determining the marks, with 92% agreeing that the team members are more aware, and thus in a better position to judge, an individual's contribution to the project.

Self-assessment was perceived to be a necessary element in the IPAC process, as indicated by 67% of respondents in our study, and further supported by 68% in Kuisma's study [8], taking into account that self-assessment allows each member to reflect on their own personal contribution to different aspects of the group project.

Students consider it imperative to know what criteria are being used to assess them, as well as the tasks and skills they are being assessed on [15]. Justification of marks is crucial as supported by 90% of the respondents and indicated by the boxplot with a high mean of 4.55 and very small standard deviation of 0.68.

In terms of feedback, students indicated that they would rather receive comments with regard to teamwork qualities directly from their peers instead of the instructor provided that these comments were anonymous; they were written in a professional and constructive manner enabling them to improve; and that the system would allow students to question the comments or feedback if necessary. This feedback approach is considered to be an effective way for reflection and for rewarding individual contribution [9]. Instructors can facilitate this form of feedback by holding regular meetings with the team members to monitor the progress of each individual member, as well as that of the group overall [10].

On the issue of anonymity, our survey results indicated that attaching a name to the feedback could result in the peer assessment becoming a popularity contest. Maintaining anonymity can reduce problems during the reporting and feedback process while using the same method of peer assessment consistently across different courses can lead to improved teamwork and transferrable skills [8].

Students agreed that the IPAC marks should be moderated by the instructor, particularly with regard to identifying the free riders, since as quoted by one student "Some students appear to do a lot in the eyes of the instructor [taking charge in presenting to the instructors] but might not have actually done the work [though taking credit for the work other people have done]". Based on the above, respondents felt that the final mark should be a combination of the instructor's mark with a moderated IPAC mark, with this technique being amongst those favoured the most by students [12]. Literature has shown that similar views are shared by students in other domains, for example, in the physiology of vision and practice management as described in the study by Conway et al. [15].

In terms of weighting, results showed that the IPAC element should count between 15% and 30% of the final mark with 20% being the general consensus. Yet, if the final mark is provided as a combination of the peers' and instructor's mark, students indicated that they would prefer to know these marks separately, in order to understand why one mark might be different to the other.

In terms of frequency of assessment, this was very much dependent on the length of the project. Overall, students agreed that it was necessary to carry out the assessment more than once to increase the robustness of the assessment, a view echoed in a study by Jones et al. [7]. This study states that peer assessment should be a formative and dynamic process, instead of a single view at a single instance in time, and should be aimed at improving group dynamics and thereby the productivity of the team. For long projects taking place over one academic term, students felt that two reviews, one half-way through the project and one at the end, would be appropriate with the middle term review used to effect behavioural changes and resolve any problems within the team. On the other hand, shorter projects of five to six weeks duration, would benefit from weekly reviews to allow team members to receive feedback promptly and act upon it in good time before the final deliverable is due.

5 CONCLUSIONS

There is a wealth of literature evidencing the impact of using peer assessment in higher education in general, and in engineering education in particular. While the pedagogical practices of collaborative group learning can yield many benefits, these can often be hindered or counteracted by issues of fairness in the marking process. Peer assessment is particularly important in teams which engage in project and problem based learning, commonly encountered in the engineering sciences.

This paper examined students' perceptions on assessing individual contribution of team members in a group project. Students strongly supported the idea of peers contributing to the marking process with the final grade being determined as a combination of instructor and peer marks. Nonetheless, this process should be closely monitored and moderated by the instructor to ensure that marks are awarded fairly.

Running the system online while maintaining confidentiality and anonymity throughout the assessment and feedback process, were considered key success indicators for the IPAC tool. By means of doing so, the process can be completed rapidly and efficiently while drawing honest views from team members. Clear and unambiguous marking criteria coupled with a transparent peer assessment process were regarded paramount, as was the justification for the marks given. Students felt that this approach would improve the quality of the work while making the tasks more enjoyable and fair.

Group size and project duration were considered crucial factors in determining the style of assessment. While friendship could skew the marks awarded during the peer assessment process, most students agreed that they would award reasonable marks in line with the work carried out regardless of friendship. In terms of frequency of the IPAC assessment, this depended on the weighting of the IPAC element to the final mark. Students suggested that a larger weighting should call for more frequent and robust assessment, using IPAC in a formative manner during the initial project stages.

Finally, students pointed out that IPAC could potentially have a negative impact on group dynamics if not implemented carefully with students' perceptions in mind. Such concerns, however, could be prevented if comments were written in a professional manner and returned to students anonymously. Students were strongly against member ranking and competitive marking and were of the opinion that such approaches would cause more problems than the IPAC tool aims to solve.

6 ACKNOWLEDGMENTS

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APPENDIX

This appendix provides supplementary information regarding the survey respondents' background and questionnaire design.

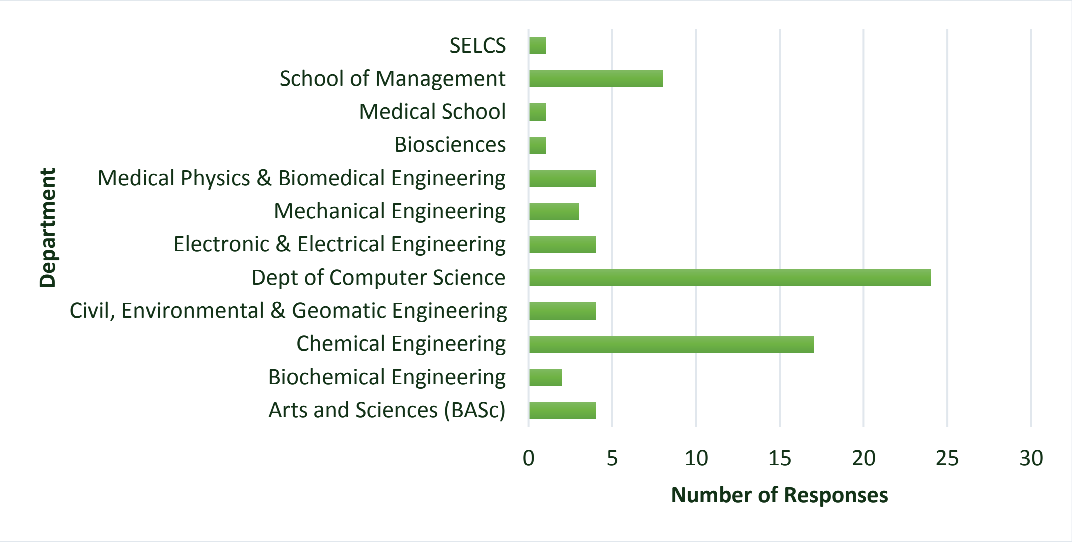

Fig. A1. Student demographics according to degree type

Table A1. List of survey questions in full format

Q1	When working in a group everyone should receive the same mark.
Q2	In a group, getting an individual mark based on the individual contribution level is fairer.
Q3	Each member of the group should receive more/less marks depends on how much work they did.
Q4	Each member of the group should receive more/less marks depending on how much effort they put in.
Q5	The students are better aware of the individual student performance than the tutor.
Q6	The students, rather than the tutor should decide on who gets extra/less marks.
Q7	When assessing the individual peers' contribution, self-assessment should be included.
Q8	I would assign marks fairly, regardless of whether someone was my friend.
Q9	I would not give bad marks to my teammates because it might affect the group dynamics.
Q10	Justification for the marks given to peers should be provided.
Q11	I would write comments in a professional and constructive manner.
Q12	Marks and comments, if written in a professional and constructive manner, will not affect the group dynamics.
Q13	I would find it useful to be able to indicate who has contributed more/less to the group work.
Q14	I would find it valuable to know how the other team members perceived my work and my contribution.
Q15	I would use the feedback given by my peers to improve my performance and teamwork skills in the future.
Q16	I would like that the marks and justification comments are anonymous.
Q17	If the comments for mark justification are anonymous, I would like that these are given back to the students.
Q18	Individual marks and comments should only be seen by tutors.
Q19	If IPAC is used as part of the assessment, this would motivate or encourage me to contribute more to the group project.
Q20	If IPAC is used as part of the assessment, this would motivate or encourage me to work more professionally and respectfully with the rest of the team.

Software Engineering Education Beyond the Technical

A Systematic Literature Review

Wouter Groeneveld
OVI and LESEC, Department of Computer Science, KU Leuven
wouter.groeneveld@kuleuven.be
https://orcid.org/0000-0001-5099-7177

Joost Vennekens
OVI, Department of Computer Science, KU Leuven
joost.vennekens@kuleuven.be

Kris Aerts
OVI, Department of Computer Science, KU Leuven
kris.aerts@kuleuven.be

Conference Key Areas: Lifelong Learning, New Notions of Interdisciplinarity in Engineering Education

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ABSTRACT

Higher education provides a solid theoretical and practical, but mostly technical, background for the aspiring software developer. Research, however, has shown that graduates still fall short of the expectations of industry. These deficiencies are not limited to technical shortcomings. The ever changing landscape of '*lean*' enterprise software development requires engineers to be equipped with abilities beyond the technical. How can higher education help students become great software developers in this context? As a first step towards answering this question, we present the results of a systematic literature review, focusing on *noncognitive abilities*, better known as '*soft skills*'. Our results identify self-reflection, conflict resolution, communication, and teamwork as the top four taught skills. Internships and capstone projects require more attention as a teaching aspect to facilitate the learning of multiple skills, including creativity. Interdisciplinary teaching and group composition are other important factors that influence learning. By providing novel insights on relationships between noncognitive abilities and teaching aspects, this work contributes to the continuous improvement of software engineering curricula. These findings may also serve as a springboard for further investigation of certain undervalued skills.

1. INTRODUCTION

When teaching aspiring software developers, educators are faced with the question: '*What makes a software engineer stand out in his or her profession?*'. Possible answers might include the ease of coming up with sound technical solutions, or the empathic ability to work well with others. Technical proficiency used to be the primary condition for success [1], but this knowledge is no longer enough [2]. Researchers, educators, and practitioners have all tried to answer the question what makes modern developers stand out. Papers ranging from 1994 [3] to 2018 [4] share a global message that still does not seem to be fully carried out by higher education. There is still no general consensus reached.

In this paper, we perform a *systematic literature review* to gain a deeper understanding of how modern engineering education has been shaped towards this new skillset. The formalized process of a systematic review has proven to be very insightful for identifying the current state-of-the-art on a given subject, and has been used widely in different fields, including software engineering research [5]. We focus our review on software engineering education, aiming to answer the following research question:

> ***What is the current state-of-the-art of teaching noncognitive abilities in software engineering education?***

The remainder of this paper is divided into the following sections. Section 2 describes background information on noncognitive skills and abilities, and why they are of growing importance, including related work on this topic. Section 3 clarifies the systematic review process we have used. Next, in section 4, we present and discuss the results of the review. Possible threats to validity are identified in section 5, while the last section, part 6, concludes this work.

2. BACKGROUND AND RELATED WORK

Defining boundaries for the term '*noncognitive abilities*' is becoming increasingly hard as different authors interpret it differently [6]. We have found other frequently used terms that slightly differ in meaning, although they have been used as synonyms in the literature. These terms range from *soft skills*, *21st century skills*, *intangible skills*, *human factors*, *interpersonal skills* and *generic competencies* to *social & emotional intelligence* and *people skills*. Multiple interpretations make the comparison of papers quite difficult. For the purpose of this literature review, we used all these different synonyms in our search, in order to obtain a broad picture of the domain.

A large amount of research on soft skills for software engineers exists, including specific industry studies [2,7]. Most of these studies do not explicitly focus on the education system itself. Instead, they highlight shortcomings from the point of view of the industry with the help of e.g. job ad analysis and focus groups. For instance, the SWEBOS (*Software Engineering Body of Skills*) framework by Sedelmaier, et al. [2] highlights the shortcomings of soft skill inclusions in the conventional SWEBOK (*Software Engineering Body of Knowledge*) model [1].

Examples of recent literature reviews similar to ours are [8] by Garousi, et al. in 2018 and [9] by Radermacher, et al. in 2013. Although these works provide insight into required noncognitive abilities, they do not focus solely on education, as our research does. Other publications delve deeper into specific subjects, such as the impact of pair programming [10,11], and the added benefit of improved confidence and self-esteem. Lenberg, et al. conducted an interdisciplinary research of '*the psychology of programming*', redefining and reviewing behavioral software engineering [12]. This combination of practical psychology with software engineering yields promising results for understanding what makes great developers tick [13].

Another approach to identify skills is by investigating success stories in software development. Dutra, et al. explored high performance teams using a systematic literature review [14], while Li, et al. simply asked practitioners: '*what makes a great software engineer?*' [15] Unsurprisingly, more than 50% of the answers can be categorized as non-technical, attributed to external (teammates) and internal (personal characteristics) factors.

These publications all strongly indicate the need for a revision in software engineering education, beyond technical knowledge. However, academic knowledge and skill requirements do not always perfectly match the abilities required from a software developer in the industry. Radermacher, et al. use the term '*knowledge deficiency*' to describe this lack of skills [9]. It seems that these deficiencies are given little attention but are becoming more and more important in the industry because of the way software is created: together, in close collaboration [4,6]. By providing a literature overview on noncognitive skills in software engineering education, we identify the current state of knowledge on teaching noncognitive skills to future software developers.

3. METHODOLOGY

The Systematic Literature Review (SLR) procedure we followed is an adaptation of Kitchenham's guidelines, which was adapted specifically for software engineering [5,16]. After establishing a review protocol, we formulated two research questions to steer the reviewing process. These questions, together with the search strings and criteria, helped us narrow down the publication result list, filtering out irrelevant papers.

The following research questions were identified:

- **Q1**: *Which noncognitive abilities have been identified by educators as important to teach software engineering students?*
- **Q2**: *How have those abilities been successfully taught?*

The ACM Digital Library and IEEE Xplore libraries were used as our main search services as they provide export functionalities, and our institution provides full-text access. Our focus is on software (1) engineering/development (2) noncognitive skills (3) in education (4). These are the search strings used to gather data, in conjunction with the many synonyms of '*noncognitive skills*' as described in section 2: `"software"` (1) `AND ("engineering" OR "developer" OR "development")` (2) `AND [synonym]` (3) `AND ("education" OR "educational" OR "teaching" OR "curriculum")` (4).

Additional ad-hoc searching via index aggregation services such as Google Scholar was needed to make sure we did not miss any major work. A technique called '*snowballing*' was adopted to consider publications from reference lists of papers in the review pool [16]. As part of the quality control, papers were required to contain at least some empirical evidence. Papers written in languages other than English were not taken into consideration. Also, to keep the results relevant for modern software engineering and to further limit the amount of results, publications older than 2014 were not included. However, this date limitation has not been applied while ad-hoc searching.

There is a lot of existing literature about engineering education in general. However, the software engineering discipline is unique compared to other engineering disciplines because of the complete absence of a fabrication cost and the increased speed of innovation [17]. This could result in different requirements of non-technical skills for each field. Therefore, papers in this review will not be included without the explicit mention of software. Also, to be able to answer question 2, we are only interested in success stories, thereby eliminating negative results.

1962 publications were initially screened based on their title, keeping 146 results. The next screening phase was based on paper abstracts, keeping 60 results. The last screening phase was based on the entire publication content, evaluating quality and applicability. In the end, 26 papers remained to be discussed in section 4. The complete dataset of all considered publications including extracted data can be found at https://people.cs.kuleuven.be/~wouter.groeneveld/slr/.

4. RESULTS AND DISCUSSION

A lot of different approaches towards integrating noncognitive skills into the curriculum have been found. These approaches maintain different time frames, ranging from one-day projects to extensive capstone projects and internships. The papers include diverse research methods, from single case studies to literature reviews [12]. The combined dataset has been published from 16 countries world-wide, with Germany (8 papers), Israel (3), and USA (3) on top. The advantage of our systematic review is that this combined data provides stronger evidence than each individual study.

Some papers have a narrow focus, targeting only a single skill [18,19] or a single teaching aspect [20–22]. Others are fairly broad, discussing soft skills in general [8,23]. We will discuss the results for literature review questions (Q1, Q2) individually, concluding with connections between the two.

4.1. Which skills are perceived as important? (Q1)

Table 1: Identified skills.

Key	Skill	#papers
S01_Comm	Communication	**25**
S02_Team	Teamwork/dynamics	**25**
S03_Refl	Self-reflection	**13**
S04_Conf	Conflict resolution	**13**
S05_Mntr	Mentoring	**10**
S06_Ledr	Leadership	**7**
S07_Moti	Motivation	**6**
S08_Role	Role awareness	**4**
S09_Cult	Cultural Intelligence	**4**

S10_Crea	Creativity	**4**
S11_Ethi	Ethics	**3**
S12_Lifl	Lifelong Learning	**3**
S13_Empt	Empathy	**2**

Table 1 contains a list of extracted non-technical skills, identified as important to teach software engineering students. Due to the vague definitions of each term, interpretations might overlap. Elaborate descriptions of the skills were mostly absent in reviewed publications, making it difficult to generalize or group results. We have refrained from using our own interpretation of these terms and only marked a term as present in a certain publication if it appears literally. Also, the absence of a term does not mean it is not deemed as important to teach by the authors, since it may yet be included implicitly in the program.

The reported non-technical skills in SWEBOS correspond roughly to the results in Table 1. SWEBOS uses the following skill groups: collaboration with others, communication, structuring one's way of working, personal competencies, consciousness of problems, problem solving, and further competencies [2]. It is difficult to say whether competencies from SWEBOS, such as '*acceptance of responsibilities*', can be seen as a combination of *role awareness*, *motivation*, and *leadership*. The same applies to '*handling criticism*' or '*working calmly and efficiently under stress*': they show overlapping but cannot be identified with a single result. As a consequence, the SWEBOS list is not directly visible in Table 1. *Time management* and *problem solving* are not part of our interpretation of the term 'noncognitive skills'.

Communication and ***teamwork*** were the most common identified skills, and have also been the most commonly identified in industry surveys [9]. We did not make the distinction between written and oral communication, such as presentation skills. Holzer, et al. advocate for a separate course devoted to communication [18] while others integrate it more implicitly into the curriculum [24–26]. There is a clear correlation between *communication* and *teamwork*: when one skill appears in a paper, the other also occurs. The term '*teamwork*' is also very common within software engineering education, as students usually need to finish at least one form of project within a team during the program.

Mentoring, and ***being mentored****,* has been identified as a skill for both students and teachers. Students can act as an 'advisor' (*mentor*) in special programs [27], or can be mentored by peers or the teaching staff. Most papers left room for mentoring as part of the (capstone) project. Most mentoring happens outside of classrooms, such as the 25% time spent as part of the 'Communications & Networks' course design outlined by Cukierman, et al. [23].

Conflict resolution also appears in conjunction with *teamwork* and *communication*. Most papers view this skill as the classic interpersonal mediation skill when working together on capstone projects [20]. However, some papers introduced *conflict resolution* as an intrapersonal skill when developing your own career [28] or thinking about global issues introduced in a communications course [18].

Leadership suggests taking on a leading role in student team projects [20,29] or group discussions [18]. It can also imply spontaneously taking on the role of mentor when a fellow student is in need of help. There are clear connections between *leadership* and *teamwork*: being a good leader demonstrates the ability to work well within a team.

Self-reflection comes in many forms, ranging from general self-improvement [27,30] to specific reflections on the skills learned in the form of surveys [22,26] or assessment tools [21]. The better the student's ability to reflect, the better the ability to absorb other skills. Ebentheuer, et al. reported on a soft skill guidance program that ran successfully for years at their faculty, in which *self-reflection* plays a central role [27]. It is also important when working with an interdisciplinary group of students [24], or when thinking about one's future role as a software engineer in society [28]. Educators acknowledge the importance of *self-reflection*: we found the term in 50% of our results. It can be seen as the main enabling skill that increases the likelihood of learning anything else:

> *"Self-reflection is a crucial enabler for self-improvement in all areas of life." [30]*

Motivation as a separate skill denotes the importance of being driven to learn new skills. Students are likely to be more motivated when consistently working together [31]. 4 out of 6 occurrences of *motivation* also included *self-reflection*.

Role awareness also requires some *self-reflection* to see how a software engineer can play a meaningful role in our modern society [2,32]. Acheson, et al. advocate for a deeper understanding of specific strengths in different engineering roles [28].

Ethics appears in conjunction with *role awareness* in the work of Li et al. [32]. Ethics of software engineering is a topic that usually appears in courses such as 'Soft Concepts of Computer Science' introduced by Hazzan, et al. [33].

Cultural Intelligence*/Diversity* has been explicitly mentioned in 4 papers. It is a critical skill for future developers as engineering teams can be culturally diverse. This is especially the case with global software development.

Empathy is closely related to *cultural diversity* and *ethics*, but there was no overlap found in the usage of these terms. Levy is the only author to completely focus on *empathy* in an interdisciplinary course [21].

Creativity scores surprisingly low at only 4 occurrences. It is mostly related to open assignments in project-oriented learning [22,27,34,35]. We firmly believe that *creativity* is important to arrive at a good software solution, although hardly any explicit attention is paid to it.

Lifelong Learning is the odd one out among the identified skills. It describes a set of skills, such as creativity, leadership and problem solving in general. Lifelong learning is an attitude, not an individual skill. However, since it was explicitly mentioned in several papers, we decided to include it in the results.

4.2. How have these skills been successfully taught? (Q2)

Table 2: Identified levels at which to integrate skills into the curriculum.

Key	Level	#papers
L1_Course	Lectures of a single course	13
L2_Projec	Projects within a course	9
L3_Curric	Throughout entire curriculum	5
L4_Capsto	Capstone projects	4
L5_Intern	Internships	2
L6_Module	Modules within a course	1

Table 3: Identified important teaching aspects.

Key	Teaching aspect	#papers
A1_Inter	Interdisciplinarity	7
A2_Group	Group composition	5
A3_Colla	Collaborative Tools	4
A4_Testi	Assessment Tools	4
A5_Activ	Active Learning	3
A6_Video	Video Watching	2
A7_Playf	Playful Learning	2

The skills identified in Table 1 can be taught in different ways. Table 2 shows the different levels at which the included publications try to integrate these skills into the curriculum. Table 3 contains a list of the different aspects of teaching on which these publications focus. Both topics are equally relevant for research question two, and will be discussed below, starting with levels of integration.

Lectures (13 appearances) as part of a specific course and ***Projects*** (9) are the most popular levels. These have always been the classic tools for introducing new goals in the curriculum. Project courses can be converted completely into 'service-learning projects', to contribute to the community and further practice soft skills [28]. These projects involve working on real-world problems beyond university boundaries. Service-learning projects also strengthen the bond between community and the university.

Curriculum-wide incorporation is the ultimate way to integrate noncognitive skills into every facet of the whole software engineering program. 'Soft skills must be included in curricula', according to Garousi, et al. [8]. Sedelmaier, et al. propose SWEBOS to guide curriculum changes, instead of looking at SWEBOK [2].

Capstone projects and ***Internships*** might require more time than a few seminars, but according to [20], the effort is worth it in the increased amount of skills learned. *Capstone* and *internship* projects pay off even more if they are real projects developed in-company instead of at the university [36]. These projects might not lead to students completely mastering skills such as *teamwork* and *conflict resolution*, but they will at least learn the relevance of these skills:

> *"We designed the course so as its main learning outcome is that students internalize how relevant it is having and developing critical soft skills to succeed in software development projects." [36]*

Modules within a course, such as *interdisciplinary* seminars, indicate the integration of specific parts in an existing course, without completely redesigning it. For instance, Acheson, et al. invite industry experts for seminars in their career development course. This integration is a good alternative, because, as stated in [28]:

> *"1) does not require much additional classroom time and instructor efforts; 2) can be seamlessly integrated into existing course materials; and 3) can start from the*

student's freshmen year and continues through their undergraduate study in the program."

Interdisciplinarity, as the most important teaching aspect (7 appearances), refers to the mixing of teaching staff and students between different faculties, but also between industry and academia. Chatley, et al. introduce industry-relevant content by inviting guest speakers that talk about real-world problems [37]. In the communications module of Holzer, et al., the staff of the Technology faculty worked together with the Social and Human Science faculty [18]. Vicente, et al. sent students divided into *interdisciplinary* teams across programs on a 3-day team-building event to reinforce team spirit [38]. This cross pollination has proven to be effective to teach *empathy*, *cultural diversity* and *ethics*.

Group composition is another major factor in enhancing teaching of *mentoring*, *conflict resolution* and *leadership* [39]. In particular, cohesion within a student team has shown to influence *motivation*, productivity and performance [31]. Teaching staff might assemble teams themselves, as was the case with the *interdisciplinary* teams of [38]. Alternatively, surveys may be used to group students with the same primary goal, strengthening certain competencies within the group [30].

Collaborative tools have proven to be effective in assisting the skill learning process. Papers reported on the usage of digital tools such as forums and social media to facilitate learning communication [23,40]. However, these tools can just as well be simple analog post-it notes when employing agile practices in a project [37], or when reflecting upon the learned knowledge [30].

Assessment tools have to be developed to evaluate students' abilities during and at the end of a course [41]. In comparison to hard skills, soft skills are difficult to pin down in terms of grading. The speed of evaluation matters: employing a '*fast feedback cycle*' allows students to practice their reflection skill more often [37].

Active Learning and ***Video Watching*** help foster further learning of soft skills. Galster, et al. opted for what they call '*Active Video Watching*', integrating interactive activities into videos to reduce the resource costs involved in teaching [25]. Videos are also used as supportive material together with classes [18]. Especially for soft skills, active engagement with others is required to construct mental models. This interaction itself again requires the application of soft skills [33].

Playful learning has been used in the form of gamification [34] and experimental investigations to discover unknown content [22]. Learning through play with supportive guidance creates more space to discover, improvise and challenge. Therefore, this method directly influences the *creativity* and *motivational* skills. *Playful learning*, however, is apparently still in an early stage of adoption in software engineering education, as witnessed by the fact that this term appeared only in 2 of our papers.

4.3. Relationships between results

Figure 1 visualizes the relationship between identified noncognitive skills and topics relevant for teaching these skills. To put emphasis on skills, contents from Table 2 and 3 have been combined in a single axis, totaling 13 topics. The following interesting connections have been discovered by interpreting the visual links between skill and teaching topic, or the striking absence of a link where we would expect one. These findings are even more easy to deduce from the interactive version of this diagram.

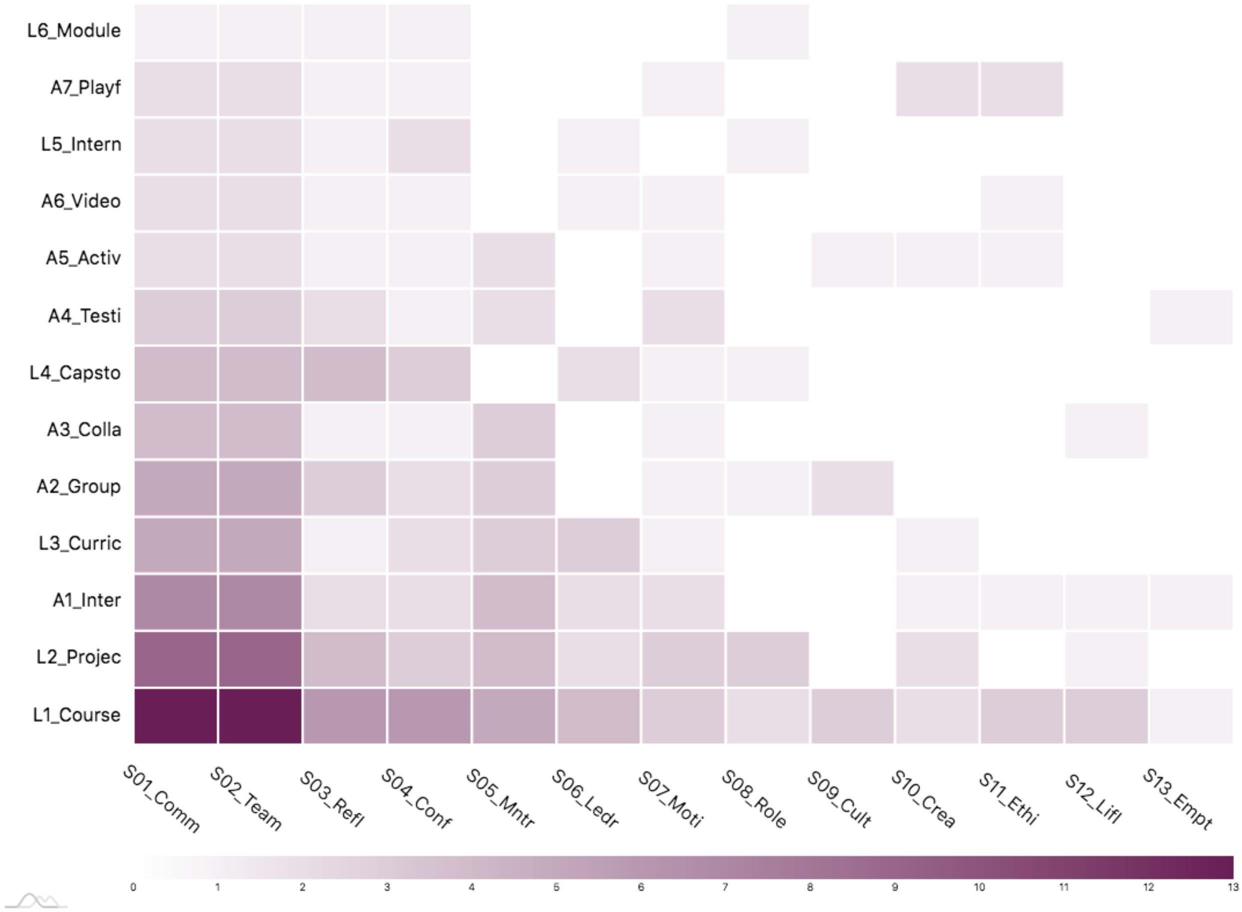

Figure 1: An overview of the relationships between skill, aspect and level, outlined as a heatmap. Keys can be translated into corresponding values via tables 1, 2, and 3. An interactive visualization is available at https://people.cs.kuleuven.be/~wouter.groeneveld/slr/.

Generally popular combinations: *self-reflection* and *conflict resolution* each appear in 13 out of 26 papers (50%) included in this study. Each time either is mentioned, all identified teaching aspects are also mentioned. The same effect holds for the two most common skills, *communication* and *teamwork*. These four abilities are the top studied skills in publications. *Motivation* is the next highly linked skill, missing only *internships* and *modules within a course*. It surprises us that *capstone projects* are not linked with *mentoring* (or *being mentored*), as one would expect that this kind of guidance is crucial to complete such a project.

***Collaborative Tooling* and *Test Assessment* show promise**: While *collaborative tools* assist the learning of *communication* skills, they are not yet used to facilitate the teaching of *ethics*, *empathy,* and *cultural diversity*. Forums and social media could also be deployed for these abilities. Testing students' behavior on non-technical abilities also shows encouraging results. We believe this can be further extended by involving *role awareness*, *ethics,* and *leadership*. *Creativity* is much more difficult to assess using tests.

***Internships* and *capstone projects* seem underused**: Besides the four top studied skills, *internships* are only connected to *leadership* and *role awareness*. *Capstone projects* are also linked to *motivation*. The lack of more links is surprising considering the outcry to bring industry and academia closer together. Strangely enough, there is only a very weak link between *leadership* and *internships*, and none at all between *mentoring* and *capstone projects*.

***Interdisciplinarity* is an advantage in teaching beyond the technical**: While *interdisciplinary* teaching aspects are only mentioned in 7 out of 26 papers (27%), they do cover all skills except *role awareness* and *cultural diversity*: 11 out of 13 skills (85%). The use of an interfaculty team, or even an *interdisciplinary* team across industry and academia, is strongly recommended [18].

***Lifelong learning* is perceived as a secondary goal**: The low number of appearances of *lifelong learning* (3), combined with the low number of coupled teaching aspects and levels (4 out of 13, 30%), leads us to conclude that teaching students the importance of *continuous training* is considered only a secondary or implicit goal. Perhaps educators feel that it is being (semi-)automatically induced by other skills. We believe it should instead be given the greatest attention, especially in an ever-changing world like software engineering. Figure 1 confirms the relationship between *lifelong learning* and *self-motivation* or *self-reflection*.

***Creativity* is absent in bigger project development**: *Creativity* appears in 4 out of 26 papers (15%). While it is related to a reasonable number of teaching aspects and levels (6 out of 13, 46%), it is not explicitly found when students embark on bigger projects such as *capstone projects* and *internships*. The papers included in our study never focus explicitly on *creativity* alone.

***Lectures* might not be the best way to induce noncognitive skills**: It is interesting to note that lectures, appearing 13 times (50%) and connecting with all skills, also seem to be preferred to induce more practical skills. Perhaps this is simply because it is a well-established method to teach theoretical knowledge. One could ask whether this is the most effective way to engage students.

5. THREATS TO VALIDITY

A possible threat to the correctness of our results is that the list of non-technical skills we identified in Table 1, or the teaching aspects and levels in Table 2 and 3, is incorrect or misaligned, and that some of these concepts are misinterpreted. Even though we recognize this possibility, we consider it unlikely, given the used methodology which reduces the risk of making these errors.

Limited visibility of publications may have led us to exclude certain important work. Most papers focus on soft skills in general, but some are more devoted towards certain individual skills. This will influence the visualization of the relationships between skills and aspects. Since the data extraction process is a manual process, we cannot guarantee that some papers, skills or aspects, have not mistakenly been excluded or missed. Therefore, we discuss our results as a whole and tried not to draw conclusions based on a single paper or identified relationship.

6. CONCLUSION

The results of our systematic literature review based on 26 papers identify which noncognitive abilities are perceived as important by educators, and how these are currently being taught, i.e. at which level they are integrated in the curriculum and to which aspects attention is being paid. We discussed each skill, aspect, and integration level individually to provide some context, highlighting the most and least common occurrences. By looking at the relationship between skill and aspect with the help of Figure 1, we discovered popular combinations and interesting trends in software engineering education.

It is clear to us that collaborating across academia and industry has had a major positive impact on the teaching of non-technical abilities. The first steps have already been taken to successfully blend practical psychology and philosophy with software engineering, but there is still room for improvement, both in depth and breadth.

Our findings may serve as a foundation to further investigate how to integrate the teaching of noncognitive skills into the curricula. For instance, this work can be compared to findings from industry surveys, further investigating certain skills or teaching methods based on the greatest common denominator. This will be our next step in contributing to research of soft skills in software engineering education.

Based on the results and conclusions of this study, we reckon that the following steps should be taken to strengthen the current software engineering curricula. First, the program should focus more on interdisciplinary teaching, not only by inviting lecturers from other faculties, but also from outside the university. Next, noncognitive abilities should be examined in more detail in combination with external internships and capstone projects. Lastly, skills such as creativity and a strong emphasis on lifelong learning should be induced in all available courses, including technical ones.

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Impact of a learning analytics dashboard on the practice of students and teachers

C. Hardebolle[1]
P. Jermann
F. Pinto
R. Tormey
Ecole Polytechnique Fédérale de Lausanne
Lausanne, Switzerland

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ABSTRACT

This paper reports results of the deployment of a learning analytics dashboard in the context of introductory Maths, Physics and Chemistry courses in the first year of the Engineering bachelor of a Swiss technical university. Informed by research on self-regulated learning, learning analytics dashboards and the social practice of learning in Higher Education, the tool includes a learning diary feature where students report their progress and the difficulties encountered in solving the course exercises. Both students and teachers have access to a dashboard showing an overview of the class progress and difficulties, the student view including personalized feedback. We present usage and survey data, and show how these help to identify key intervention principles to maximize the impact of learning analytics dashboards on the practice of students and teachers.

1 INTRODUCTION

The ability to solve complex problems is essential for engineers and teaching problem solving is therefore important goal of engineering higher education [1]. Problem solving and problem solving teaching and learning have been the object of research for decades. There is broad agreement in the research [2, 3] that students actually need a number of different things in order to solve problems. In particular, alongside content knowledge of the discipline and strategies for solving problems, students need self-regulation strategies which include planning, monitoring and evaluation. For instance, students who, when solving a mathematical problem, start

[1] Corresponding Author
C. Hardebolle
cecile.hardebolle@epfl.ch

by analysing the problem and making a plan are demonstrating self-regulated learning behaviours. This is also the case of students who, after solving a problem, analyse their solution to assess whether it is reasonable. Self-regulation strategies have been shown to differentiate expert behaviour from novice behaviour and to be key in the ability of students to solve previously unseen problems, where they need to “create” the solution method [2].

Students can be helped to develop self-regulated learning (SRL) and training for self-regulated learning has been in place for many years. Elements of such training are self-reflection questions, in particular questions which help students to self-assess their own performance [4]. Approaches such as “exam wrappers” [5] for instance, use postexam self-reporting questionnaires to draw students’ attention to the feedback they received, to guide them in the analysis of their difficulties and to lead them to evaluate the adequacy of their learning strategies. Learning diaries [6] are another example of self-regulated learning intervention where students fill-out self-reporting questionnaires regularly over a period of time.

With the development of online learning environments, research on and tools for developing SRL have also gone online and joined with the learning analytics community. In this context, learning analytics dashboards (LADs), which present learning analytics data visually to the user, are researched as a way to present actionable feedback to students [7]. LADs can and have been used to present students with self-reported data from self-regulated learning questionnaires [8]. However, as many authors point out (see [9] for instance), little empirical research has been carried out so far on whether such tools actually have an impact on learning and even less on whether they have impact on the *practice* of its users.

In order to help engineering students develop their self-regulated learning skills in relation to problem solving, we have developed a tool which combines an online learning diary and a learning analytics dashboard. After a pilot phase, the dashboard has been deployed and used during one semester in introductory Maths, Physics and Chemistry courses in the first year of the Engineering bachelor of a Swiss technical university. This paper presents a study of the impact of this dashboard on the practice of its users. After presenting the dashboard and the literature on which it draws, we describe the research method, present results and discuss their implications.

2 RELATED WORK

2.1 Self-regulated learning (SRL)

Self-regulated learning can be defined as “self-generated thoughts, feelings and actions that are systematically guided by personal learning goals” [10]. Teaching students self-regulated learning strategies has been shown to have a positive impact on learning, in particular when it is linked to the discipline in which they are to be used [11]. The mathematics learning diaries by Schmitz and Perels [6] are an example of such a discipline-embedded SRL teaching intervention. It has recently been argued that one interesting area for development is the use of measurement tools for self-regulated learning as intervention tools [12]. Thought of in this way, the process of reflecting on one's self-regulated learning, through undertaking a task such as a learning diary or a self-report questionnaire can trigger students to adapt their practices and has already have some positive results [6].

2.2 Learning Analytics Dashboards (LADs)

Learning analytics dashboards "support users in collecting personal information about various aspects of their life, behaviour, habits, thoughts, and interest" and "help users to improve self-knowledge by providing tools for the review and analysis of their personal history" [9]. They can be considered effective tools to support SRL by allowing users to both reflect on their practice when collecting data and get feedback on their practice when visualizing their data [13]. However, as emphasized by recent reviews [7, 9], LADs are usually deployed at small scale (less than 100 students / teachers) and few are used in authentic settings such as real courses. The impact of such tools on the actual practice of students and teachers in a real scale educational context has therefore seldom been studied.

3 THE DASHBOARD

Drawing on principles from the fields of SRL and LADs, the tool acts both as a diary and as a dashboard for students, and as a dashboard only for teachers.

3.1 Learning diary

The learning diary is designed to be filled out by students after they worked on the exercises and received some kind of feedback (e.g. feedback from a teaching assistant or written solution). It aims at engaging students in an active processing of the feedback they received in an after-exercise self-assessment activity.

Teachers setup the diary with a list of the different exercise sessions in the semester and, for each session, a list of exercises students are expected to solve. By completing a standard diary questionnaire for each exercise, students log the number of exercises they attempted, whether they succeeded or not as well as the difficulties they encountered in the process. The questionnaire includes a predefined list of difficulties which, while generic, relate to the quantitative type of problem solving that is specific to STEM disciplines. An example of a difficulty is: "I used the right method but I made calculation errors (arithmetic, algebraic, trigonometric, etc.)". Part of the difficulties target the methodological aspects of the resolution. For instance, "I could not see how to start" relates to problem analysis, whereas "I tried a method and got stuck" relates to debugging. By targeting the link between lectures and exercises, other difficulties relate to the transfer aspects, such as "I had understood the course but I did not manage to apply it to the exercise". In addition to the provided list, students can also enter their own difficulty in plain text if they want to. It is expected that, in filling out the questionnaire, students review each exercise and clarify for themselves what their difficulties are. As discussed in the previous section, students should benefit from this first step of logging their data in the first place.

3.2 Dashboard

The student version of the dashboard is designed to show them: a) what kind of recurrent difficulties they are having, b) targeted advice designed to help them address their most common difficulties and c) how they compare to their class more generally in terms of the number of exercises they are completing and the difficulties they are experiencing. Presented both in a visual and textual format, this feedback and the associated recommendations are designed to help them identify and better target areas they should work on improving, in a deliberate practice approach.

The teacher version of the dashboard displays the same information as the student dashboard but at the level of the class only. For each exercise, the teacher can see: a) the proportion of students who tried the exercise, b) the proportion of students who succeeded or partially succeeded and c) the difficulties the class had with this exercise (see *Fig. 1*). This information helps to identify if students are struggling with understanding part of the course early. It therefore plays an important feedback role [13], allowing the teacher to adapt his/her teaching to address difficulties that students are having by, for example, clarifying links between lectures and exercises, giving advice on how to analyse a question or addressing particular mathematical weaknesses. In addition, the teacher can better judge the difficulty of exercises.

4 RESEARCH DESIGN

This study analyses the impact of the dashboard on the practice of students and teachers in terms of a) their use of the dashboard as recorded by the tool and b) the self-reported use and opinion of students on the dashboard.

Nine teachers volunteered to use the dashboard during the Autumn semester 2018-2019 in their courses for a total of N=1’786 registered students. Seven of the teachers were teaching obligatory courses, all of them worth 6 ECTS in the first year of the Bachelor curriculum: 4 in Physics, 2 in Maths and 1 in Chemistry. The two other teachers were teaching Humanities courses, one an optional course in Master (3 ECTS), the other an optional course given in the third year of Bachelor in another institution (5 ECTS). *Table 1* lists the different courses involved with their respective discipline, level and number of registered students. Teachers were given a user guide with a description of the type of information the dashboard could provide them, as well as a model presentation to introduce the tool to their students. They also received suggestions as to how to use it in the class but were free to use it the way they wanted.

Teachers and students have interacted with the dashboard over the 14 weeks of the semester. Usage data has been extracted from the dashboard at the end of the semester. In the last two weeks of the semester, a survey questionnaire has been provided to teachers for a distribution in their classes. The survey asked students to self-report their use as well as the use of their teachers, to report on what motivated them to use it and on what they found useful in it, to give their opinion on its usability as well as the reasons why they eventually stopped using it.

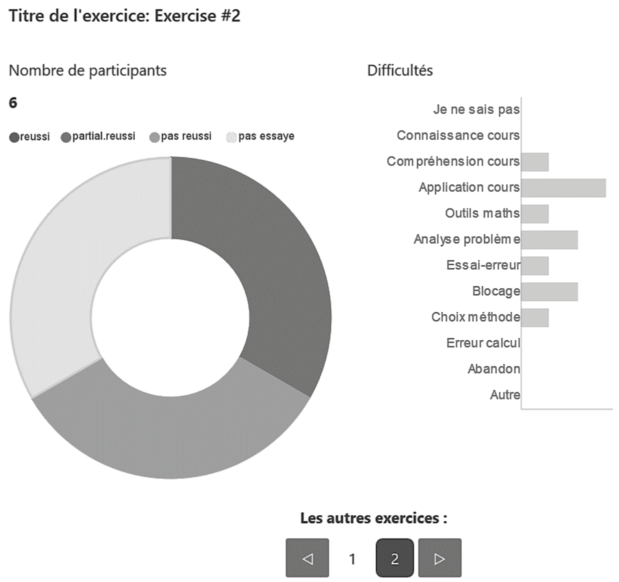

Fig. 1. Dashboard view for teachers

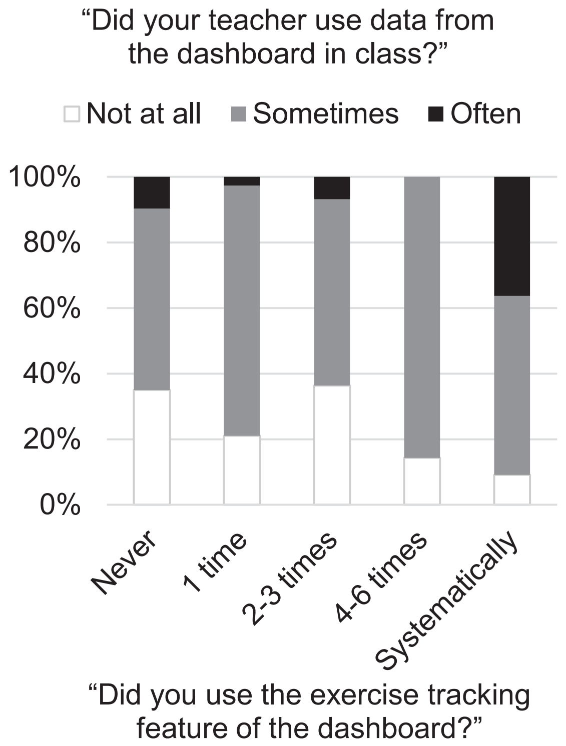

Fig. 2. Relationship between student use and teacher use of the dashboard Chi2 (8, N=190) = 21.7, p < .01

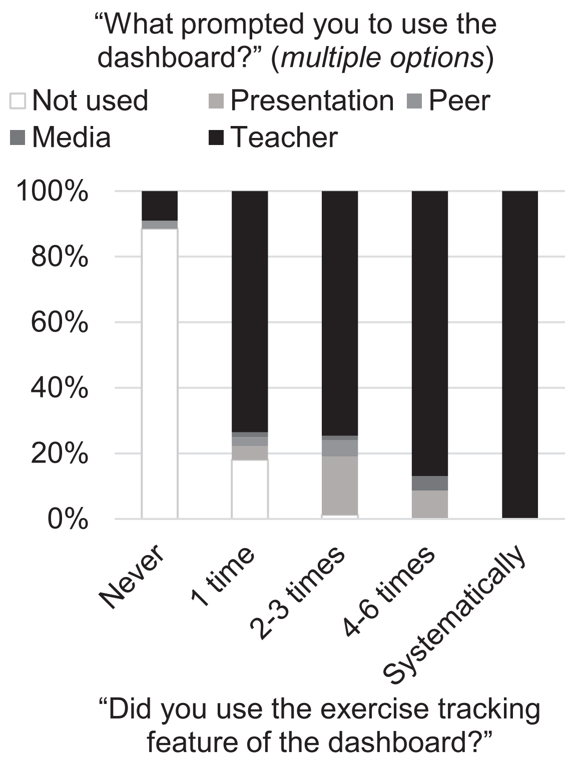

Fig. 3. Relationship between student use and prompt to use the dashboard Chi2 (16, N=347) = 263.3, p < .001

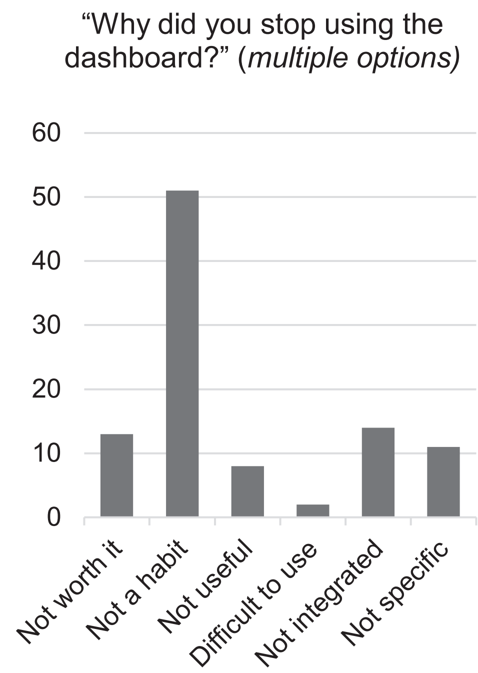

Fig. 4. Reasons to stop using the dashboard for students who learn from it (N=93)

5 DATA ANALYSIS AND RESULTS

5.1 Overview

Table 1 summarizes the data collected for the different courses. The data extracted from the dashboard shows that it was used effectively in 7 of the 9 classes. We believe that the fact that the dashboard was not used by all the teachers who volunteered, illustrates the difficulty for them to make room in their practice for such a tool, even when they are highly motivated to do so. In terms of actual use of the dashboard by students, we see that the proportion varies between 11% and 94% of the students registered in the courses. We hypothesize that the way teachers integrate the use of the dashboard in their teaching plays an important role in the participation rate of students. Survey data was collected from 4 of the 7 classes who used the dashboard. In the following analysis, we will focus on these 4 courses as example case studies.

Table 1. Courses involved in the study.

			Number of students		
Course	**Discipline**	**Level**	**Registered**	**Used the dashboard**	**Answered the survey**
1	Physics	Bachelor 1st year, 6 ECTS	203	64 (32%)	-
2	Chemistry	Bachelor 1st year, 6 ECTS	275	64 (23%)	160 (58%)

3	Physics	Bachelor 1st year, 6 ECTS	278	30 (11%)	-
4	Maths	Bachelor 1st year, 6 ECTS	273	72 (26%)	101 (37%)
5	Humanities	Master, 3 ECTS	61	-	-
6	Maths	Bachelor 1st year, 6 ECTS	260	-	-
7	Physics	Bachelor 1st year, 6 ECTS	190	110 (58%)	71 (37%)
8	Physics	Bachelor 1st year, 6 ECTS	229	33 (14%)	-
9	Humanities	Bachelor 3rd year, 5 ECTS External Institution	17	16 (94%)	15 (88%)
		TOTAL	***1'786***	***389 (22%)***	***347 (19%)***

5.2 Usage data

Overall, courses had an average of 45 exercises set up in the dashboard but with an important variation, from 4 to 118 exercises per course. Exercises were organized in sessions of around 6 exercises on average, with again an important variation from 1 to 13 exercises per session, thus illustrating the variety of the teaching contexts and pedagogical approaches represented in this study.

Table 2 presents the setup of the 4 case study courses and the respective number of students responses submitted to the dashboard. It is worth noting that 37 students were registered in more than one course, so the numbers of students cannot be assumed unique. The average participation of students, i.e. the number of responses they recorded over the number of exercises available in the dashboard related to the number of students in the course, varies between 10% and 98%. This number represents how active students were in using the dashboard, taking into account the amount of participation expected by the teacher. For example, a participation of 98% means that almost all students recorded their work on almost all the exercises set up by the teacher. The number of exercises to log in the diary seem to play a role in the activity of students on the dashboard but we hypothesize that the way teachers integrate the use of the dashboard in their teaching is an important moderator.

Table 2. Setup and student participation in the dashboard for the 4 case studies.

Course	Number of sessions	Number of exercises	Number of submissions	Average number of submissions per exercise	Average number of submissions per student	Average participation of students
2	13	118	780	6.61	12.19	10%
4	6	55	933	16.96	12.96	24%
7	8	43	1'022	23.77	9.29	22%
9	4	4	63	15.75	3.94	98%

5.3 Survey data

A total of N=347 students filled out the survey questionnaire. On the question "Did you use the exercise tracking feature in the dashboard?" (N=340), 51% report not having used the dashboard. Only 4% report having used it systematically, 6% report 4-6 times and about 20% report having used it once and 20% 2-3 times. On the question "Did your teacher use data from the dashboard in class?" (N=191), 29% of students report that their teacher didn't use it at all, 62% report that their teacher sometimes used it and 9% report the teacher using it often. For both questions, an important variation is observed over the different courses, again reflecting a range of practices and contexts.

More interesting is the relationship between the use of the dashboard by students and the use of data from the dashboard in class by teachers (as reported by students), as illustrated by *Fig. 2*. The use of data from the dashboard by the teacher in class has a significant positive impact on student's use of the dashboard, Chi2 (8, N=190) = 21.7, $p < .01$. But, as illustrated by *Fig. 3,* being asked by the teacher to use the dashboard has an even more significant and positive impact on student's use of the dashboard, Chi2 (16, N=347) = 263.3, $p < .001$. This tends to confirm our hypotheses from previous sections about the role of the teacher in students' use of the dashboard.

We also asked students to indicate what they learned from using the dashboard and the reason(s) why they eventually stopped using it. For both questions they could select one or more options. 46% of respondent selected at least one option representing something they learned from using the dashboard. The most selected option overall (42%) is the identification of recurrent difficulties, which reflects well the purpose of the dashboard. We looked at what the students who report learning from using the dashboard mention as reasons for stopping to use the dashboard. As *Fig. 6* illustrates quite clearly, making a habit of logging their work into the dashboard, thus changing their practices for the long term, seem to be a major difficulty even for students who feel that they learn something useful from using the tool. The perceived worthwhileness of using the dashboard, its integration into the pedagogy of the course and the specificity of the feedback it provides come far after. It is worth mentioning that, of the students who report having used the dashboard, more than 70% found the dashboard easy or very easy to use, only about 9% reported difficulties (N=326).

6 DISCUSSION

We have shown that SRL dashboards can provide both students and teachers with insight on the learning process happening in STEM classrooms, more specifically when students work on solving problems. While the potential benefits of such tools are clear, the results presented above illustrate that some factors play an important role on their impact on the actual practice of its users.

On the teacher side, we have seen that despite a high motivation and active technological and pedagogical support, integrating a new tool into teaching practices is certainly no easy bet. We believe that reallocating class time to include pedagogical interventions - even “just” instructing students to use the tool and giving feedback to the class regularly - is an adoption barrier, but this would have to be further studied.

On the student side, we have shown that participation is particularly affected by a) an active encouragement of the teacher to log data into the learning diary and b) the use by the teacher of information extracted from the dashboard to give feedback to the class. This finding illustrates how, when seen as embedded in a social context, practices are performed in social settings and interlock with the practices of others. While SRL and LADs research focus on how the learners can change their own practice, it does not ask how their practices interact with the practices of teachers or other learners and how changing one part of this system of interrelated practices may impact upon other parts. This particular aspect should be further researched.

Our study also tends to show that, while logging data into the diary is part of the learning process for students, recurrent use is difficult to induce (all the more when the amount of data to log is important) and even more difficult to transform into a habit. We think that this is an important point to take into account in the design of the pedagogical interventions by teachers around such a tool.

Based on these observations, we would recommend that at least instructions to log data in the diary should be embedded regularly into the lessons or exercise sessions and, when possible, logging could be made part of the in-class activities (with the limitation that it could increase barriers for adoption by teacher). Since feedback to the class has an important impact, specific support by teaching assistants could be put in place to multiply feedback opportunities. In the case of an important number of exercises associated to the course, only a subset should probably be selected for logging to limit the impact on motivation.

There are limitations to this study. The relatively low student survey response rates is one of them. Additional qualitative data (e.g. interviews or focus groups) would help us better understand the barriers to a greater engagement from the majority of the students, as well as the advantages classes with high engagement have seen from using the tool more frequently. On the teacher side, the informal feedback during the semester has been very positive – for instance, in one of our many exchanges, one of the teachers has told us: “It is interesting to have this feedback on the exercises. I usually ask the question to the assistants and normally they tell me that everything is fine and that students have no particular difficulties“. However, we could formally evaluate teachers’ opinion on the use of the tool through a focus group for instance. Much analysis work remains to be done on the rich usage dataset generated by the experiment. Among the many possible analyses of interest, we intend to look at the evolution of use over time, the correlation of use with academic achievement or the students' text responses when they have self-reported problem solving difficulties.

7 CONCLUSION

This paper has presented results from the deployment of a learning analytics dashboard targeting the development of student self-regulated learning in the context of problem solving. Designed taking into account evidence on teaching and learning in STEM Higher Education, this tool has been deployed effectively during one semester in several large-class introductory Maths, Physics and Chemistry courses in the first year of the Engineering bachelor of a Swiss technical university. The purpose of this study was to evaluate the impact of this tool on the practices of its users, namely students and teachers, by looking at their use and opinion on the tool. Drawing on both usage and survey data, we have shown that: a) integrating a new tool into their teaching practice can be a difficulty even for highly motivated teachers; b) the way the teachers integrate the tool into their teaching by prompting students to use it and giving feedback to the class has an important impact on student participation and c) changing their habits is a major obstacle for students to persist in using such a tool on the long term. Perspectives include additional analysis on the usage dataset generated by the study as well as additional qualitative data collection. We intend to continue the development of the dashboard with the addition of other features, in particular to facilitate its integration into the social context in which it is used.

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An Investigation of First Year Physics Students' Ability and Anxiety

The relationship between physics conceptual understanding, geometric thought, spatial reasoning, and related anxieties

R. Harding
Technological University Dublin
Dublin, Ireland

G. Duffy
Technological University Dublin
Dublin, Ireland

B. Bowe
Technological University Dublin
Dublin, Ireland

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ABSTRACT

Research has shown that spatial ability is important for success in STEM. Spatial ability is closely linked with mathematical ability, and as mathematics and conceptual understanding underpin the study of physics, an analysis of incoming physics students skill sets could show where improvements are needed in these areas. Affective factors of anxiety are also known to affect performance and confidence in these subjects, hence the reason for including these measures.

This study presents an investigation of the relationship between physics conceptual understanding, geometric thought and spatial reasoning abilities as measured by the Force Motion Conceptual Evaluation (FMCE), the Van Hiele Test, and the Purdue Spatial Visualisation Test : Rotations (PSVT:R) respectively. Measures of math and spatial anxiety are also employed. The tests were administered as part of an in-class session to a cohort of 1st year physics students.

The analysis shows a significant correlation between physics student's spatial ability and Van Hiele levels in this cohort of students. Spatial anxiety has a negative correlation with spatial ability, and it was significantly higher for female students compared to the male students. Math anxiety also has a negative correlation with Van Hiele levels, and was also found to be higher for the female cohort. This study could help to improve our understanding of first year students' abilities and related anxiety levels. This could potentially lead to more effective ways to educate students that fall into the low spatial ability and high anxiety levels, a group over-represented by females. Further research is necessary to make the sample representative.

[1] R. Harding, rachel.harding@student.dit.ie

1 INTRODUCTION

Physics knowledge underpins the study and practice of the engineering disciplines. Therefore, there is a strong rationale for investigating students' understanding of physics and other important concepts and cognitive skills for these domains, in order to help identify areas that students particularly struggle. As physics and engineering in particular has difficulty with obtaining a gender balance within the discipline, it is of particular relevance to investigate gender differences in physics understanding, and cognitive skills that are crucial to aid success in physics and engineering disciplines. Spatial ability has been consistently shown to be important for success in STEM disciplines [1-3] and particularly, many studies have shown there is a significant gender difference, most notably for spatial ability tests requiring mental rotation [4-6].

Furthermore, studies show that students entering first year physics programmes lack fundamental conceptual understanding, and that even after instruction in the topics, very little if any improvement is often observed [7]. Consistent, large gender differences have been observed for physics concept inventories [8]. Another study demonstrated that even after interactive engagement techniques were employed in the classroom setting, this was not enough to eliminate gender differences in the FMCE [9]. As physics problems are often abstract in nature, and require mental visualization of complex phenomenon, spatial ability is important for understanding physics concepts, and to aid in the problem solving process [10].

Although possessing the necessary concepts and cognitive skills required for successful completion of studies within the physics and engineering disciplines is crucially important to aid success within the discipline, these are not the only factors that come in to play. Studies have shown that affective factors, such as math and spatial anxiety affect students' confidence and performance [11-13]. Again, large gender differences were observed, with females exhibiting higher anxiety levels, and lower confidence in their approaches to math and spatial tasks and problems [14]. As physics and engineering disciplines are inherently mathematical and spatial in nature, this is quite a cause for concern.

Stereotype threat is also another factor to consider in this context. Studies have shown that achievement gaps in various psychometric tests can be affected by the participants' negative stereotype views [15-17]. A landmark study showed that African American college students performed worse on an intellectual ability test compared to White college students of the same academic ability, when the test facilitators highlighted that the test was designed to diagnose intellectual ability. Another study also showed that a sample of females in first year of university performed worse on a mathematics test when they were told that the maths test shows gender differences, compared to the group that were told the test does not show gender differences [16]. However, it has been demonstrated that altering the testing conditions can have a significant impact on the performance of the participants [15]. When the test was presented as a diagnostic of intelligence, the African American students performed worse, compared to the White students. In contrast, when the test facilitation was designed to alleviate this stereotype threat condition, the two groups were found to have equal scores in the intellectual test [15]. Therefore, it is important to be aware of testing protocols and situations which could lead to stereotype threat arising, and therefore influencing the results obtained.

In this study, the aim is to investigate the levels of physics conceptual understanding, geometric thought, spatial ability, and anxiety levels in math and spatial situations for a sample of first year physics students. If the relationship between these variables is better understood in this context, then this could lead to improvements in teaching practice, and help to aid the female students in particular to overcome their anxieties and build confidence to succeed in STEM education. The research questions for this preliminary study are:

- What is the relationship between physics conceptual understanding, geometric thought and spatial ability for 1st year physics students?
- What are the gender differences, if any, for physics conceptual understanding, geometric thought and spatial abilities, and for math and spatial anxiety?

2 SAMPLE AND METHOD

For this study, a class group of honours degree first year physics students were administered various concept, cognitive and affective factors tests, as part of an in-class session. This first year group consisted of 32 students. Due to class scheduling, it was not possible to administer all five tests on the same day. This would also likely have caused test fatigue for the students. Therefore data from 29 students out of the 32 that sat all five tests are presented and discussed in this paper. Out of these 29 students, 19 were male and 10 were female. 10 students had studied physics in second level at leaving certificate (end of secondary school exams), and 19 had no previous physics experience. The age range was between 18-23 years old. Ethical approval was granted for this study within the institution. The students were informed that the tests were part of a research study, and that the results would not affect their grades or position within the institution in any way. All students had the opportunity to read and sign an informed consent form for the study. The researcher administered the tests in class, adhering to the recommended protocol and time limit for each subsequent test.

In order to minimise the possibility of stereotype threat arising, the researcher was careful to emphasise that the tests administered were standard procedure for incoming first year students. The results from the tests aid the educators of the course to improve their teaching practice. The results do not affect their course grades or progression in anyway, and they have no obligation to participate. As the students entering third level would be highly unlikely to have previously come across the tests administered in this study, gender differences arising in these tests would not be common knowledge amongst this cohort. The tests were presented as reasoning and problem solving tasks. The students were encouraged to answer each question honestly. In this case, it was not possible to have a control group to check for the possibility of stereotype threat arising, and therefore this cannot be ruled out completely. However, the protocol for administering the tests was carefully designed to minimise anxiety, and to place focus on the benefits of the results of the study for the educators in order to improve their teaching practices. The informed consent form highlighted this, where the benefits of the study were discussed in terms of aiding the successful teaching of STEM subjects in third level education.

2.1 Instruments

For this study, two concept, one cognitive and two affective factor tests were used to gather the data. The FMCE was chosen as the measure for physics conceptual understanding, as this test is widely used in the literature, and includes a wide range of topics in mechanics [18]. This test consists of 47 multiple choice questions. For each question, a scenario is presented, with 7-9 possible choices and one correct answer per question. The PSVT:R was chosen to measure spatial ability, specifically mental rotation, as it is widely used within third level STEM student studies [19]. In each question, and 3D object is presented, and then shown with a particular rotation applied to this object. Then a second 3D object is presented, where the exact same rotation must be applied to the second object, in an identical manner to the first. The correct orientation of the second object must then be chosen. This test consists of 30 multiple choice questions, with each question having five possible answers to choose from.

The Van Hiele test [20] was chosen to measure the level of geometric thought, based on the Van Hiele Theory [21]. Many other studies have used this test in conjunction with the PSVT:R, to investigate relationships in various contexts. Mathematics and spatial ability are known to be closely linked [22], and geometry is particularly spatial in nature, thus the reason for choosing this measure. The test consists of 25 multiple choice questions, with five possible choices. The questions are grouped in five sets of five, where each set of five questions represents the geometric thought required to reach each Van Hiele Level, i.e. the first five questions represents Van Hiele Level 1, and so on. No numerical mathematics is required to answer the questions.

The sMARS (Shortened Mathematics Anxiety Rating Scale) was chosen as the measure of math anxiety, as there is a wide range of scenarios presented that are relevant for this cohort of students [23]. This test consists of 25 multiple choice questions, with five possible answers. In each question, a mathematically related scenario is presented. The answer selected is based on the test-takers' level of anxiety they would feel, if they were in the same scenario presented. The answers are on a five point scale, were A represents "*Not at all*" anxious, and E represents "*Very much*" anxious. The newly developed Spatial Anxiety Questionnaire was chosen as the measure of spatial anxiety [11]. This test was chosen, as there is quite a limited number of spatial anxiety measures to choose from, and this test is more comprehensive and similar in nature to the mathematics anxiety test selected. This test consists of 24 multiple choice questions, with five possible answers. In a similar manner to the sMARS test, the test-taker is presented with a spatially related scenario. The answer selected is based on the test-takers' level of anxiety they would experience if they were in the same scenario. Again, this is on a five point scale, with A representing "*Not at all*" anxious, and E representing "*Very much*" anxious.

The nature of the concept and cognitive tests are inherently different to the affective factor tests. The data obtained for the affective measures are self-proclaimed, and therefore the results must be interpreted accordingly. In contrast, the concept and cognitive tests assumes the data obtained is valid and reliable as there is a correct response for each question. This holds if each student endeavoured to answer correctly, and did not resort to randomly guessing. This is different from the affective tests, as there is no correct answer for each question. Even if two students select the same responses, this does not mean that they have equivalent anxiety levels.

3 RESULTS AND DISCUSSION

For this study, the variables were examined to investigate if gender differences existed for the five different measures. *Table 1* shows the mean values in percentages (except for Van Hiele Level results) of the variables, separated by gender.

Table 1: Comparisons of means for FMCE, Van Hiele, PSVT:R, sMARS and Spatial Anxiety by gender.

Test	Male			Female					
	n	Mean	SD	n	Mean	SD	t-test	Sig (2-tailed)	Cohen's d
FMCE	19	28.11	17.19	10	20.00	3.779	1.967	0.062	0.65 (large)
Van Hiele	19	2.79	0.976	10	1.80	1.32	2.299	0.029	0.85 (large)
PSVT:R	19	75.61	20.00	10	47.33	22.65	3.460	0.002	1.32 (large)
sMARS	19	19.28	11.90	10	30.08	11.04	-2.378	0.025	-0.94 (large)
SAQ	19	25.27	14.60	10	39.38	16.64	-2.358	0.026	-0.90 (large)

Table 1 shows that the male students for this first year cohort on average have higher physics conceptual understanding, Van Hiele levels, and spatial ability scores. Where the female students on average have higher math anxiety, and particularly, higher spatial anxiety within this cohort of students.

An independent sample t-test was then performed to determine if these gender differences were significant. In terms of the concept and cognitive factors, the results for physics conceptual understanding showed that there was no significant difference, although the results were approaching significance at the 0.05 percentile. For both the Van Hiele levels of geometric thought and for spatial ability, there was significant gender differences. These findings highlight that the female students are lagging behind the male students when entering a third level degree programme in physics, in terms of these abilities that are crucial for success in their field of study. Now turning to the affective factor measures, the results showed that there were significant gender differences for both the math and spatial anxiety. These findings suggest that the female students in this study have significantly higher anxiety levels when presented with situations and tasks regarding maths, and particularly, with situations and tasks regarding spatial reasoning. These are interesting preliminary findings for educators, as we must ensure that the female students are being exposed to math and spatial tasks in such a way that they can build confidence in tackling these type of problems encountered in physics and engineering disciplines. However, this sample is very small and therefore not representative of first year physics students in general. It is also not possible to verify that the affective factor measures are measuring anxiety levels affectively, as these tests are based on self-proclaimed data.

These results indicate that the female students are entering third level at a disadvantage in terms of the concept and cognitive skills required, and this, paired with the high anxiety levels surrounding math and spatial tasks could lead to a lack of confidence in ability to complete their physics programme. These preliminary findings are pointing to possible barriers for women in physics, as if the aim is to help improve the way we teach for this group of students, the high anxiety–low spatial ability cohort, we need to recognise this is potentially a current issue in our classroom, particularly for the female students. Further research is required to reach any substantial conclusions, as the sample is too small in this study. However, these preliminary results are similar to findings from previous studies, and therefore support a rationale for further research in this area. A correlation matrix was then produced for all five concept, cognitive and affective measures. *Table 2* below shows the correlational relationships between the variables.

Table 2: Correlations for FMCE, Van Hiele, PSVT:R, sMARS, and Spatial Anxiety.

	n	Van Hiele	PSVT:R	sMARS	SAQ
FMCE	29	.228	.106	-.340	.134
Van Hiele	29		.478**	-.560**	-.263
PSVT:R	29			-.340	-.425*
sMARS	29				.519**
SAQ	29				

The results show a moderate positive statistically significant correlation between Van Hiele level and spatial ability, and a negative correlation between Van Hiele level and math anxiety. There is a positive correlation between spatial anxiety and math anxiety. There is a negative correlation with spatial anxiety and spatial ability. There is a low negative correlation between math anxiety with physics conceptual understanding and spatial ability, approaching significance. There is very little to no correlation with physics conceptual understanding and spatial ability. *Fig. 1.* Below shows the relationship with a scatter plot.

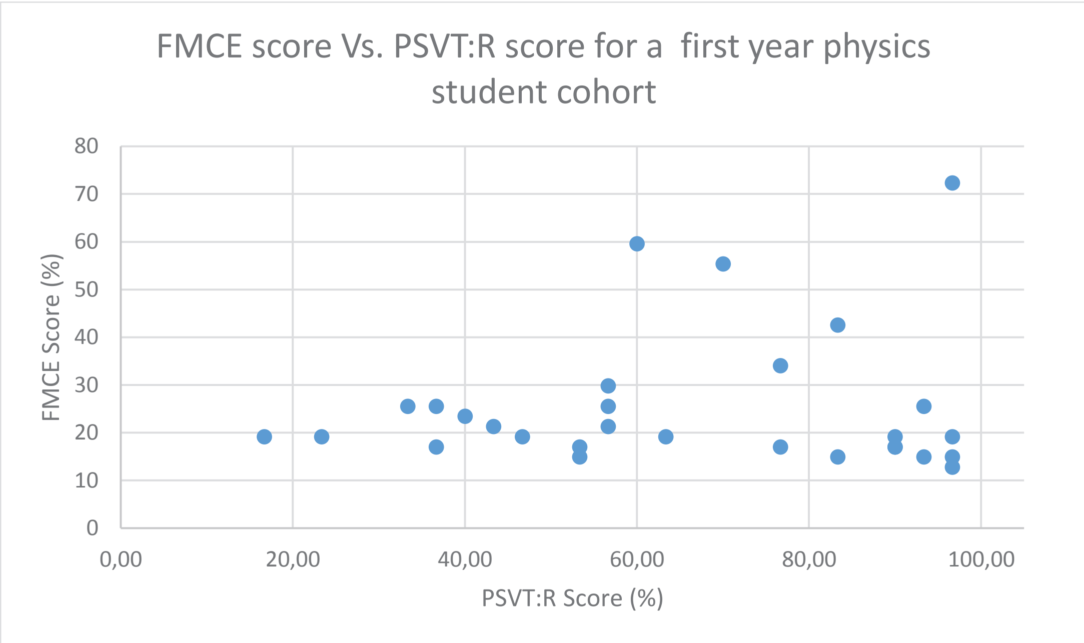

Fig. 1. Scatter plot showing the relationship between FMCE and PSVT:R Scores.

It can be seen in *Fig. 1.* that most of the FMCE scores are below the 25% mark. Where for the PSVT:R scores, there are many more scores at the middle and higher end of the spectrum. However, there are no students that scored highly on the FMCE with a poor score on the PSVT:R. The students that performed well on the FMCE also scored relatively well on the PSVT:R, with these data points shown in the top right quadrant in *Fig. 1.* There are no data points in the top left quadrant of the graph. In other words, there are no students that possess a high level of conceptual knowledge of physics, while having low spatial ability scores. This finding does align with a previous study which found similar results [24]

4 CONCLUSION

The findings from this preliminary study show gender differences favouring male students were found for spatial reasoning and geometric thought. In terms of the physics conceptual understanding measure, no significant gender differences were observed. However, the results were approaching significance at the 0.05 percentile. These findings could indicate that male students entering a first year physics degree programme have an advantage over the female students. Further research is needed to determine whether these findings hold for a larger sample. Gender differences were also found for both of the affective factor measures. The female students were found to have higher anxiety levels in both math and spatial related situations and tasks. This could imply that female students lack confidence in approaching these types of problems, compared to the male students, and thus, are at another disadvantage within this first year physics cohort. As physics and engineering disciplines require complex problem solving, often requiring spatial representation of various parameters and phenomenon, this would appear that the male students have an advantage over the females participating on the course. Although, the preliminary findings are only indicative at this stage, and further research is needed to determine whether these trends still hold for a larger sample of the first year physics cohort.

The correlational analysis showed preliminary relationships between the variables measured. The findings indicate that one's ability in spatial reasoning is related to one's ability in geometric thought, to some extent. The findings also indicate that if one has higher levels of anxiety in situations related to mathematics, or performing mathematical tasks, one is more likely to perform worse on the geometric thought test. This was also found for anxiety related to spatial situations, where one with higher spatial anxiety levels would be more likely to perform worse on a test of spatial reasoning. Furthermore, if one has a higher level of mathematics anxiety, one is more likely to also have a higher level of spatial anxiety.

As the gender balance in physics and engineering disciplines is a topic of concern, with many more male students than female students in these disciplines, this is particularly relevant as an area that needs further research in order to address these apparent deficits in female students' spatial ability and confidence within the disciplines. Further research would be beneficial in order to make the study much more representative for first year physics students by increasing the sample size substantially. It is not possible to draw substantial conclusions from this study, as it is limited by the sample size and the types of test instruments employed. However, a refinement of the methods used, and a substantial increase in the sample size will be a beneficial addition to these preliminary findings. In order for our teaching practice to improve and facilitate inclusivity, we need to recognise the barriers that are facing our female students, so that we can assist this student cohort to overcome any obstacles and flourish within the physics and engineering fields.

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Progression in PBL competences

Jette Egelund Holgaard
Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Aalborg University
Aalborg, Denmark
jeh@plan.aau.dk

Anette Kolmos
Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Aalborg University
Aalborg, Denmark
ak@plan.aau.dk

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ABSTRACT

In engineering education, qualification frameworks as well as curriculum standards, like the CDIO standards, have offered overall guidelines for progression in curriculum design. However, although the development has moved towards more student-centred and active learning environments, the attention towards learning progression specifically focusing on “learning to learn” has been limited.

The scope of this paper is to explore the challenges of creating progression in (problem based learning) PBL competences with a specific focus on the development of meta-cognitive competences. Whereas the conceptual framework builds on the experiential learning theory, the empirical material draws on a study of learning progression at the problem and project organized learning (PBL) institution, Aalborg University. The empirical material includes insights from three engineering domains (Energy, Software and Architecture & Design), and nine focus group interviews with students in their first and third years of the bachelor’s programme and during their master’s study.

The study showed that students develop a more comprehensive understanding of PBL throughout their study as their experience base expands. However, the case also raises attention to the risk of letting PBL competences become embedded into practice to an extent where it becomes tacit. If students do not have a language and a conceptual platform for PBL, it is difficult for them to identify their PBL competences, and it is also hard to transfer their understandings, concepts and methodological framework and apply their PBL competences to new learning situations as well as to new professional contexts.

1 INTRODUCTION

According to Graham [1:39] and based on a study of leaders in engineering education, the future engineering curricula will "*emphasise student choice, multi-disciplinary learning and societal impact, as well as expose students to a breadth of experiences outside the classroom, outside the traditional engineering discipline and across the world"*. Taking this prospect seriously, not many will question the importance of generic competences as an integrated part of the engineering curricula. The question is more related to *how* students should learn and develop these generic competences.

Different educational models have offered frameworks to foster generic competences such as teamwork and communication as well as the ability to cope with real life problems and work across disciplinary boundaries. Most of these models argue for an integrative approach, which means that the progression of generic competences occurs alongside the progression in domain specific competences. This, however, leaves educational designers with the challenge of balancing the concern for both types of competences.

Graham [1:37] points to disciplinary and educational silos as a current barrier for innovation and excellence in engineering education. Furthermore, based on a comprehensive literature review of generic engineering competencies, Male [2:40] concludes *"that academics have difficulties in teaching generic competencies, partly because of the low status assigned to generic competencies in comparison to technical competencies in engineering*". This paper works under the assumption that a more explicit and conceptual insight on the progression of generic competences is needed in order to understand what is eventually left out due to the aforementioned barriers.

Systemic problem based learning (PBL) models have shown to be effective to foster generic competences [3]. In fact, PBL is developed to co-facilitate generic and domain specific competences by letting students identify, analyse, formulate and solve real life problems, and make a comprehensive assessment of the proposed solutions. In a PBL environment, generic competences are framed and conceptualised as PBL competences.

PBL competences can be characterised by four types of competences: problem-oriented, interpersonal, structural and meta-cognitive [4]. As illustrated in figure 1, the meta-cognitive competences are a cross-cutting competence. As such, meta-competences raise the other competences above the level of application in Bloom's taxonomy [5], making students able to analyse, evaluate and synthesise their approach to learning to address new modes of applications. As such, without this cross-cutting competence, the other competences are reduced to skills.

Fig. 1. The cross-cutting metacognitive competence together with examples of different competences areas.

With this outset, we initiated a study with the following research question:

What are the challenges of creating progression in PBL competences that includes the cross-cutting meta-cognitive dimension?

2 RESEARCH DESIGN

The research design combines an empirical study of how students relate their study practices to PBL principles with a theoretical perspective on progression based on experiential learning. In the following section, we elaborate on the theoretical framework as well as the methodology of the empirical study.

2.1 Theoretical framework

Whereas taxonomies, like Bloom's taxonomy [5], help to clarify learning levels within the cognitive domain and the corresponding intended learning outcomes, such taxonomies say little about the learning process. Based on a constructivist learning perspective aligned with the roots of PBL, Kolb [6] has offered a model of the learning process (see figure 2).

Kolb (1984) stresses the importance of active learning by stressing active experimentation and concrete experiences as fundamental aspects of learning, but he also stresses the importance of meta-cognitive learning through reflective observation and abstract conceptualization in order to move from the concrete situation to the general and vice versa.

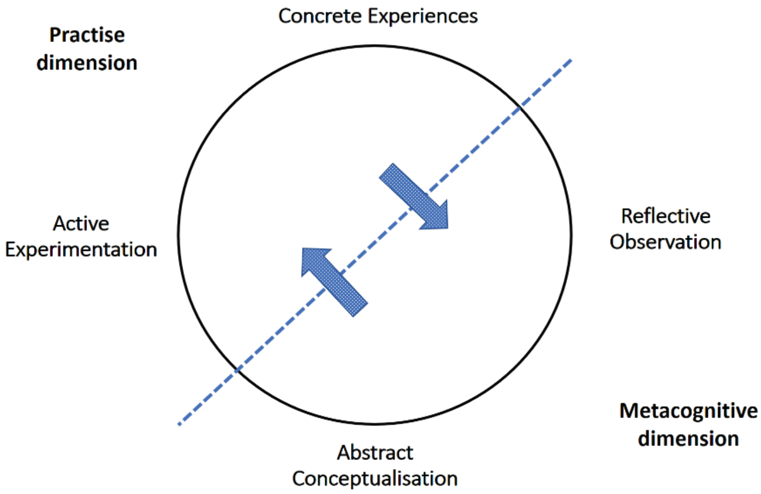

Fig. 2. Illustration of the interaction between the practice dimension and the meta-cognitive dimension of learning based on Kolb's cycle [6].

Like a wheel that needs a shape of a circle to function optimally, the active/situational and the reflective/theoretical sides of the experiential learning circle have to be complete and combined, as indicated in figure 2.

In a progression perspective, Dewey's [7] concepts of continuity and interaction is important in order to transfer the Kolb circle to a continuum of circles. Continuity refers to the way past experiences will influence current experiences. Therefore, learning occurs in a continuum of circles where past experiences will interfere with the way the current experiences are perceived and interpreted. Progression then appears when students build on past experiences in addressing new situations. The concept of interaction nevertheless adds another perspective to the understanding of progression, as interaction refers to situational influence and, thereby, the context of learning. Progression also becomes a matter of the diversity of situations that students face in their education, and in combination with the concept of continuity, their ability to transfer learnings from one context to another.

In terms of curriculum design, continuity stresses the importance of students' ability to build on previous experience (learning depth by addressing similar contexts), whereas interaction stresses the importance of variation (learning width by moving across different contexts).

2.2 Empirical research design

The empirical study has been carried out with the problem based and project organised learning environment at Aalborg University. Since its foundation in 1974, Aalborg University has had a systemic approach to PBL and can therefore, with reference to the case typology by Flyvbjerg [8], be characterized as an extreme case. The intention is not to generalize the findings, but to highlight that if this challenge is identified even in this case, it is worthwhile to consider in other contexts as well.

The study at Aalborg University was limited to the two engineering faculties: Faculty of Engineering and Science and the Technical Faculty of IT and Design. At these faculties, all students have a 5 ECTS course at the first semester in “Problem-based Learning in Science, Technology and Society”. Apart from the PBL practice during project work supported by facilitators from the disciplines, PBL consultants from PBL research environments scaffold the students to ensure that the students develop meta-cognitive competences. The output of this is that students are to document their meta-cognitive competences through a process-analysis, three times the first year and with increased depth. The process-analysis concept was developed in the late 1990s based on the experiential learning theory, see [9]. However, the systematic development of meta-cognitive PBL competences only takes place during the first year of study.

The data collection was carried out in 2018. The respondent groups were delimited to three engineering domains (Energy, Software and Architecture & Design), and included nine focus group interviews with four to six students each, who were working together on a team project in the first and third year of the bachelor’s programme and during their master’s study.. Aligned with the intention to use an extreme case, coordinating staff from the studies at different levels were contacted to select groups that were considered to have a high level of PBL competence. Focus group interviews with project groups were chosen for students to mutually support each other in their story of the problem based and project organized group work and to get as rich of a picture as possible.

The data-collection instrument was developed from the Aalborg University PBL principles [10]; students at different levels of education were asked to relate their study experiences to these principles, and in the final stage of the interview, students in later semesters were asked to reflect on the progression of PBL competences. The themes of the interview included students’ perspectives on problem-orientation, group collaboration and project management as well as more general perspectives on their learning processes, including aspects of exemplarity, self-directed learning and progression.

In the data-collection phase, young researchers, having experience with qualitative research but limited research experience with PBL, were selected to conduct the interviews with students. It was a deliberate choice to detach the PBL researcher from the discussion in the focus group interviews, and thereby limit PBL concepts and potential assumptions from previous research interfering with the results.

The interviews were recorded and coded in NVivo with respect to the developed understanding of the PBL principles and the sub-categories that unfolded in the empirical material. For this paper, the empirical material was synthesized in order to find material that would inform the specific focus on continuity, interaction and meta-cognitive competences.

3 FINDINGS

In the following, the findings from our study are presented together with a condensed discussion of the potential implications.

3.1 The challenge of combining different types of progression

In the analysis of student responses it becomes clear that some student groups express an understanding of progression which is aligned with the continuity perspective — e.g. going more in depth and developing one's own competences to work with a system (Focus group interview, Energy, Master, 2018):

"*In the beginning it (ed: the problem) is more about what we can actually calculate, and then later on it is about whether we can actually improve it — so the problem changes…but it is always a system that we are working on, and the first thing is to understand the system and how we can work with the system. These aspects of how to model a system — we can do that now. So now it is about, how we can improve it.*"

In terms of the more structural PBL competences, there are clear indicators of progression based on experiences, as expressed by this student from Software engineering, in his last semester of the bachelor's study:

"*Project management is definitely something that gets better the more projects you have experienced, as you experience something that is not functioning on one project and then you know that you have to focus more on that earlier in the next project.*"

The students also indicate that continuity can result in an understanding of PBL as a team autonomy. For example, a student in the final year of his bachelor's study in Energy used the metaphor of well-functioning machinery to describe the PBL model:

"*As the model is now, it is kind of working on its own because you get together in groups, you form your groups yourselves you are working in the groups and you are having a supervisor — and all the machinery is just functioning really well.*"

However, there are also several clear indications of variation in terms of problem design related to different problem types, from more narrow to more open problems, and as always problems relate to different contexts, e.g. systems or user groups. Across programmes, students also highlight company projects as a way of differentiating the problem based project. Below, you find an example of how a student at the end of their bachelor education in Industrial design experienced variation in problem design:

"*The way we identify a problem differs. For example, this semester we have to work together with a company. Some go into a company and observe what is happening and based on these observations they define problems. We have instead worked* *together with a company who had identified a problem that they wanted us to work with and based on that and the users we have identified our own problem.*"

There are less signs of continuity and variation considering the meta-cognitive PBL competences, when we move beyond the first semester. However, a student at the Energy Master level pointed to the part of the PBL experience in the first year that initiated reflection on current practices:

"*The primary thing I got out of the PBL course was the part where we reflected on what went well, and what did not go so well….so the reflection part… I could imagine that a similar course could be beneficial after the bachelor level, when we have had more experience with how the projects work…especially if you are not, as we have done, working together with the same people each semester."*

This reflection initiated a discussion in the group in which it became evident that not all students have an interest in PBL subjects, and this was corroborated in other focus group interviews. Therefore, it should be taken into consideration that there can be a motivational barrier to consider when introducing PBL theory to students.

In sum, there is a potential challenge in securing the progression of PBL competences related to the progression of meta-cognitive competences. This raises attention to the integration and continuity of PBL practice and theory.

3.2 The challenge of balancing PBL theory and practice

One student from Industrial design, a first year master's student, exemplified the challenge of combining PBL theory and practice in the following way:

To be honest, I did not get much out of the PBL course we had the first year… it quickly got too general for many of us."

A peer-student commented:

"It was a little too humanistic and super-academic."

There appears to be a wish from these students to move PBL away from the abstract and closer to the context of study, but at the same time the very same students also seem to find the different practices within the same PBL institution rather mysterious:

"*It is not my impression that what they do in the other programmes is similar to what we do, but it is still PBL*".

The interesting thing is that the students in the first year in the same programme call for more PBL theory in the PBL course in the first semester, pointing towards a potential shift in course-design to be less super-academic. Furthermore, the students pointed to the importance of the course to be taught in a semester where the students can work more freely within their field of study.

The above example demonstrates that even though the students have a PBL course and intensive problem based project work, they do not naturally combine the more abstract with the concrete, although they acknowledge that there is a more generic nature to PBL. This is a dilemma in learning practice competences that are based on experience combined with theoretical reflection.

There is a need to make PBL more explicit, as so nicely put by one student from Industrial design, a first year master's student:

"*I think, more generally, we have just talked about how PBL is deeply rooted in our understanding, but in reality, what is needed is to be more explicit about things. I do not know how…*

It is also the case in other programmes that as PBL theory and the methods presented to optimize PBL practice become known and are partly implemented in practice, they become tacit. A student in the final year of bachelor's study in the Energy programme expresses this in the following way:

"*In the first semester, we got a lot of tools, and I do not know how much of it I actually remember, but I think in one way or the other that we use them without really being aware of it."*

This perspective is supported by the following quote from a Software master's student, stating that:

"*I cannot remember the different elements of the PBL course... but I can remember what is was about, more generally, and I am also quite certain that I have used some of the things I got from that course even though I cannot explicit remember the specifics.*"

Therefore, it is not that the learnings from the more theoretical side of the Kolb cycle are not brought into practise. The question is, however, how the loop can be closed if the students lack a language to reflect on the experiences and whether a tacit reflection without a subsequent abstract generalisation will be enough when the learning environment changes considerably.

4 CONCLUSION

In this paper, we have focused on the challenges of creating a progression in PBL competences that includes the cross-cutting meta-cognitive dimension. We have chosen the specific focus on meta-cognitive competences to emphasize the process where students explicate, analyse, evaluate, synthesise and optimise their own learning competences. This is seen as a precondition for students to professionally appropriate their ways of learning to new learning contexts, as in future professions.

In the theoretical framework, we underlined the importance of meta-cognitive competences with reference to experiential learning, and the concepts of continuity and interaction were used to distinguish two perspectives on progression. Whereas continuity stresses the importance of students' ability to build on previous experience (learning depth by addressing similar contexts), interaction stresses the importance of variation in the curricula (learning width by moving across different contexts).

Not surprisingly, the empirical study of the extreme case in terms of PBL indicated clear signs of progression in PBL competences. Challenges were, however, detected to create continuity and variation in meta-cognitive competences. As PBL theory, in this specific case, is related to the introductory stages of education, this detachment left students with a tacit understanding of their PBL competences in their later studies. Furthermore, when PBL theory was in play, the alignment of PBL theory with practice and vice versa became crucial, together with an emphasis on motivating students to engage in PBL. The point on motivation indicate that the statement made in the introduction that generic competences is sometimes considered “low status” compared to technical competence also seem to live in pockets of even an extreme case of a PBL institution.

In cases where PBL competences have become tacit and there is a sliding focus on meta-cognitive PBL competences throughout the study, there is a risk that generic PBL competences become a blind spot (not visible within the domain), and even in some cases a black spot (unwanted within the domain). In such situations, strong institutional leadership is needed to unlock potential silo thinking — the kind of thinking which is said to be a remarkable threat to future advances in engineering education.

5 ACKNOWLEDGMENTS

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Preferred competences by the labour market in the opinion of higher education students

A. Kálmán
kalman.a@eik.bme.hu
Associate Professor
Budapest University of Technology and Economics
Department of Technical Education
Budapest, Hungary

E. Nyéki
nyeki.e@eik.bme.hu
PhD student
Budapest University of Technology and Economics
Faculty of Economic and Social Sciences
Budapest, Hungary

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ABSTRACT

A large-scale development of science and technology began in the twentieth century, which has further intensified in the 21st century, reinforcing the role of innovation and technological development both at the individual and organizational level. In the 21st century, not only the ability to develop is a requirement but technological advancement in different areas simultaneously creates competition and the need for co-operation between various actors. Creativity, complexity and innovation can result in novel methods, innovative or different ways of thinking, but at the same time, players in different industries are now forced to cooperate in certain areas of development as it is in their well-recognised state-of-the-art high-tech solution quickly and cost-effectively.

We were curious to find out what the Hungarian university students thought about what competencies they needed as career starters and what competencies they wanted to develop. We wanted to assess the proportion of students' expectations in the labour market. We started a research at the Budapest University of Technology and Economics (BME) Faculty of Economic and Social Sciences (GTK) and we received students' answers from 21 universities out of 28 state universities in Hungary. The goal was to get the views of students in as many higher education institutions as possible. The online questionnaire was popularized at conferences, professional events and in the social media. University professors and students

shared the questionnaire with potential respondents. The response was anonymous and voluntary, in this way, random sampling was performed.

Our hypothesis was that students do not know what the labour market expects of them, and therefore they don't develop their skills in the most appropriate direction, either in their choice of elective subjects or in their choice of tasks when fulfilling the subject requirements.

As a control question, we asked the students to answer whether the institution of higher education they were attending could meet their prior expectations and whether they trust that their schools would prepare them to face the challenges of the labour market.

1. THEORETICAL PERSPECTIVES

Nowadays higher education faces a big issue: universities have to train future employees to meet the expectations of the labour market in a rapidly changing technical and economic environment. The client of higher education is the labour market. Universities must pass on the knowledge of the labour market to students and develop competencies that meet expectations. Universities are in direct contact with employers, there is an ongoing cooperation and dialogue between the parties. Employers invest time, energy and money in teaching their prospective employees. At the same time, employers are confronted during the integration process of young graduates with the fact that fresh graduates have little usable knowledge compared to their expectations. This leads to the customers' dissatisfaction as well as the decrease of the entrants' confidence. It seems that the three actors in the education process - employers, universities and students - need more effective and efficient communication and cooperation. Universities need to understand even better what knowledge and skills they are expected to provide to future employees. The students should be aware of what they learn and how and why this knowledge will be useful to them in their work. This knowledge can help the students to engage in committed and motivated learning, in the conscious acquisition of knowledge. Students do not learn in the hope of passing an exam successfully but in order to be successful in the future. The employer should be aware of what can be taught at universities and what newcomers need to master challenges in the world of work. Information can be the link among the three actors in the training process that would result in the participants' knowing exactly what they do, teach and learn. Information functioning as a bridge is not just about today's expectations, but also about the development of employees how to face future changes. At the same time the role and the immense importance cannot be emphasized enough for employers "Skills and jobs remain in focus and the importance of exposure to the workplace and career guidance: internships, mentoring and site visits." (A. Kálmán 2017)1

[1] Anikó Kálmán: Lifelong Peer Learning – New Environments and Scenarios to Build Responsive Systems for Societies - IN REPORTS, APPLIED RESEARCH & DEVELOPMENT · VOCATIONAL EDUCATION — 12 Apr, 2017

As it was published by OECD in 2002 successful learning, was likely to mean that the learner has a high degree of self-confidence and self-esteem, is highly motivated to learn and its learning environment is "a great challenge" and "low threat ”. Based on the experiences, the OECD study emphasizes motivation, self-confidence and success as key factors for success in education. 2 Higher education must support the students' self-confidence and self-esteem in a way that the learning environment is at the same time a great challenge and low threat. The learning environment should inspire students to learn while providing the security that learners are able to acquire adequacy to the labour market. Students will trust the institution of higher education if they are confident that as a result of their studies they are sure to become a useful and sought-after labour force in the labour market. Students will trust the educational institution if they experience the essential characteristics of reliability, such as integrity, competence and benevolence.3 (Mayer 1995). These features include integrity as keeping the promise, competence, as knowledge, and skills that enable a student to act effectively in a job or situation, benevolence that involves a supportive learning environment. In a supportive learning environment, the student's self-confidence and self-esteem is strengthened as a resource for learning new knowledge.

We started a survey in February 2019 at the Budapest University of Technology and Economics (BME) Faculty of Economic and Social Sciences (GTK) and we received students’ answers from several universities in Hungary. Responding students had completed at least 1 semester in their higher education studies and had not yet graduated, all of them were active in higher education. The valid responses of 177 respondents to the online questionnaire were evaluated. We were curious to know which students among the 21 different higher education institutions considered labour market competencies important in their profession. These 21 universities are 75% of the 28 state universities in Hungary that are not church or private institutions4. The responses were compared to labour market expectations.

2. METHODOLOGY

Our first hypothesis was that students do not know what the labour market expects of them, and therefore they don’t develop their skills in the most appropriate direction, either in their choice of elective subjects or in their choice of tasks that can be chosen when fulfilling the subject requirements. In the online survey, the respondents had to select the 5 most important ones according to their perception of the competencies preferred by the labour market. We examined which labour market competencies were considered to be the most important by the students and whether the preferences of the university students coincided with the preferences of their

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prospective employers. In the following, we examined whether students were given feedback on their skills and trust in their higher education institution, in addition to their grades, in order to prepare them for the labour market expectations. We were looking for a significant relationship between feedback on skills and trust in the institution. Our second hypothesis was that if the student was studying in a supportive environment, one of the manifestations of which was to receive feedback on his / her existing ability, it not only had a positive effect on successful learning, but the student also trusted in the educational institution more. The correlation analysis was performed by SPSS analysis.

3. ANALYSIS OF RESPONSES

The online questionnaire on the question What skills and competencies are most needed in your home country for a graduate in your profession? listed in addition to the 13 competencies expected by Hungarian employers, further 8 competencies that have been defined by non-Hungarian organizations (UK, USA, EU, UNESCO). The 21 competencies listed are thus those defined by Hungarian and international employers. The respondents had to choose the 5 competencies which they judged the most important in their own profession.

As the Figure 1 shows students preferred 8 competencies out of 21 competences preferred by the labour market. The competence that students considered the 5 most important were communication skill, problem recognition, solving skill, self-determination and cooperation skill. Respondents were less favouring important competencies such as proactivity and accountability as competencies of a starter employee – 1.98% and 0.89% of the marked competencies were marked as the most important.

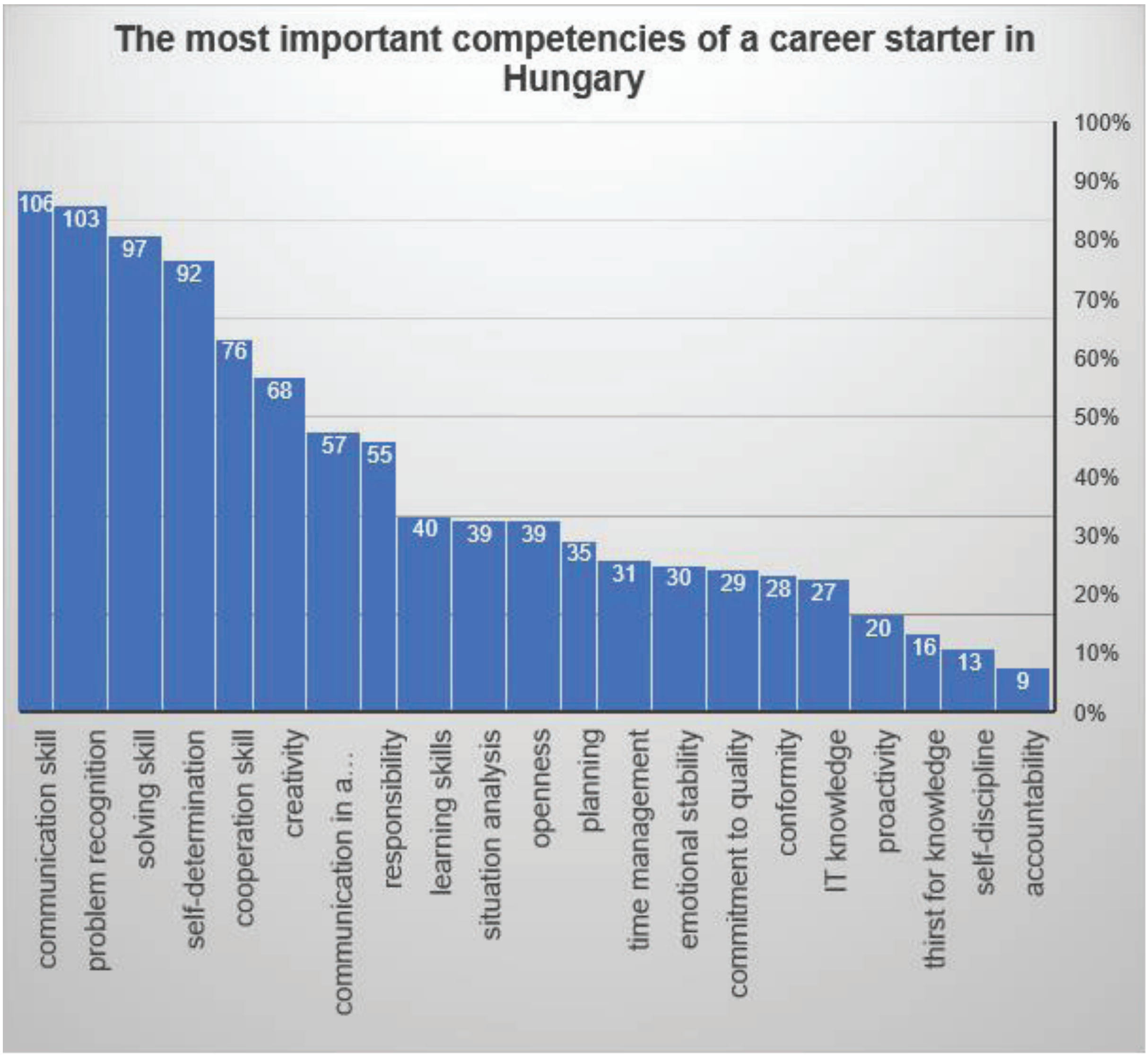

Figure 1
The most important competencies of a career starter in Hungary, according to the opinion of the respondent university students

The next question examined was, *Besides my grades, have I ever received oral or written feedback (even informally) on my existing skills from my teachers?* 59.9% of respondents answered yes to the question but 40,1% answered no. Based on the responses, 2 out of 5 students did not receive feedback on their abilities during their studies. Mayer, previously referred to, says that students will trust the educational institution if they experience the essential characteristics of reliability, such as integrity, competence and benevolence. One of the manifestations of benevolence is attention and feedback, which, if experienced by the student, not only increases confidence in the institution, but the feedback received may be inspiring in his or her development.

Besides my grades, have I ever received oral or written feedback (even informally) on my existing skills from my teachers?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	71	40,1	40,1	40,1
	Yes	106	59,9	59,9	100,0
	Total	177	100,0	100,0	

Figure 2
Received feedback about existing skills - frequency table

The last examined question in the survey was *Do you trust that the educational institution where you are studying prepares you to work in the labour market?* The importance of the question is justified by the fact that the OECD's 2002 study, cited above, states that one of the key factors in learning success is the high motivation of the learner to learn. The motivation of the learner is greatly influenced by the fact if he can trust the future usefulness of the acquired knowledge. 71,8% of the respondents answered yes.

Do you trust that the educational institution where you are studying prepares you to work in the labour market?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	50	28,2	28,2	28,2
	Yes	127	71,8	71,8	100,0
	Total	177	100,0	100,0	

Figure 3
Trust in the educational institution

In the following, during the significance study we examined whether there is a connection between the variables of the second hypothesis. Our second hypothesis was that if the student is studying in a supportive environment, one of the manifestations of which is to receive feedback on his / her existing ability, it not only has a positive effect on successful learning, but he also trusts the educational institution more. As you can see in the cross table, 77% of students who received feedback on their skills from their teachers said they trusted the educational institution to prepare them for the labour market. *(Figure 4)*

Do you trust that the educational institution where you are studying prepares you to work in the labour market?
* Besides my grades, have I ever received oral or written feedback (even informally) on my existing skills from my teachers?

			Besides my grades, have I ever received oral or written feedback (even informally) on my existing skills from my teachers?		
			no	yes	Total
Do you trust that the educational institution where you are studying prepares you to work in the labour market?	no	Count	26	24	50
		% within Besides my grades, have I ever received oral or written feedback (even informally) on my existing skills from my teachers?	36,6%	22,6%	28,2%
	yes	Count	45	82	127
		% within Besides my grades, have I ever received oral or written feedback (even informally) on my existing skills from my teachers?	63,4%	77,4%	71,8%
Total		Count	71	106	177
		% within Besides my grades, have I ever received oral or written feedback (even informally) on my existing skills from my teachers?	100,0%	100,0%	100,0%

Figure 4
Cross tabulation

Using the Chi-Square test, we examined whether there is a significant relationship between the variables. We examined whether there is a link between feedback on skills and trust in the educational institution where the university student pursues higher education. *(Figure 5)* Since the significance value is 0,043 <p, - where p = 0,05 - we reject the null hypothesis that there is no relationship between the two variables, i.e. there is a relationship between feedback on skills and trust in the institution.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4,099[a]	1	,043		
Continuity Correction[b]	3,438	1	,064		
Likelihood Ratio	4,051	1	,044		
Fisher's Exact Test				,060	,032
Linear-by-Linear Association	4,076	1	,044		
N of Valid Cases	177				

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 20,06.
b. Computed only for a 2x2 table

Figure 5
Chi-Square Tests

4. CONCLUSION

Examining the responses to the questionnaire survey, it can be stated that students in higher education are aware of the competencies preferred by employers. Although our first hypothesis has not been proven based on the results of the survey, this statement is relevant to learning motivation as a key factor for successful learning (OECD 2002). All of the preferred competences named by employers are considered important, but if they are to be prioritized, there are some that are prioritized more often by responders. The most important competency chosen by students is communication skill.

Based on the responses of students who receive feedback on their skills from their instructors, either formally or informally, it is more likely for the educational institution to prepare for work in the labour market. Our second hypothesis was confirmed, there is a relationship between feedback on skills and trust in the institution but it cannot be ruled out that other factors also affect students' confidence in the institution. According to Mayers study, students will trust the educational institution if they experience the essential characteristics of reliability, such as integrity, competence and benevolence. (Mayer 1995). Further investigations may be needed to explore the details of the relationship, including additional factors. It may be relevant to examine the impact of the feedback received on the evaluation of the educational institution, with particular regard to the degree of integrity, competence and benevolence.

As a final conclusion, it is worth highlighting the importance of feedback in the light of the preference of communication skills by employers and prospective employees. On the one hand, to receive feedback and, based on your own experience, to give feedback with constructive intention, is a very valuable skill in the world of work. On the other hand as to the trust in the institution, resulting from the study, feedback also contributes to creating a supportive learning environment that directly influences the success of learning. The success of learning is the common goal in which the purpose of the learner, the educational institution, and the employers, as customers, meet.

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The Future of Engineering Education: Where Are We Heading?

L. Gumaelius
KTH, Royal Institute of Technology
Stockholm, Sweden

Anette Kolmos
Aalborg University
Aalborg, Denmark

Conference Key Areas: New Complexity quest in engineering sciences, 4th Industrial revolution

Keywords: future, engineering education 2030, sustainability, digitalisation, employability

ABSTRACT

The Nordic Engineering Hub has conducted a study on what engineering education will consist of in 2030. The study, conducted by universities in five different countries, focuses on the educational content and the pedagogical methods. Three major challenges have been identified as being crucial for the development of future engineering education: 1) sustainability, 2) digitalisation and 3) employability.

The first challenge is related to climate change and the 17 Sustainable Development Goals (SDGs) formulated by the United Nations (UN) that are vital for the future of the globe. The second challenge is derived from technology and science. With an expected increase in the use of new technologies, such as the Internet of Things and artificial intelligence, digitalisation will saturate all corners of society; it will also affect the engineering disciplines. The third challenge is about future conditions for employability, including the need for innovation and entrepreneurship.

For this study, professors from various engineering disciplines were interviewed with the aim of understanding their perspectives on how their discipline will be developed in the future, and what trends will dominate engineering education in 2030. The study adopted a phenomenographic approach, and, in this paper presents the initial analyses of the first five interviews. The initial analyses identify two categories: the importance of change and the role of the university. The discipline each interviewee belonged to is hypothesised to be an important factor for variations, an indication that will be followed up in future quantitative measurements. While the study is exploratory, the theory about tensions between the academic, market-driven and community-oriented modes within universities is used as a theoretical framework. The methodological approach is discussed, and it will be further emphasised during the presentation.

1 INTRODUCTION

Engineering education faces a variety of contemporary challenges that impact its future [1]. Society demands that engineers be capable of co-creating sustainable development. The importance of integrating sustainable development as a thread throughout all levels of education has been relevant for a long time, and, with the formation of the 17 Sustainability Development Goals (SDGs) [2] in combination with the contemporary climate debate, this is even more relevant to engineering education in 2030.

In addition to the challenge of sustainability, another challenge is posed by the industry demand for engineers who are experienced in project management and who have the ability to learn and adapt quickly, given that career paths will change more rapidly in the near future [1], [3], [4]. Therefore, future requirements for employability, including innovativeness and entrepreneurialism, constitute a second challenge addressed in this study. A third challenge is digitalisation, which requires engineers to have an increased understanding of systems and process skills that are integral parts of the Fourth Industrial Revolution [5], which has just arrived, in order to handle the forthcoming industrial challenges. The list describing the challenges that need to be considered in order for tomorrow's engineers to meet the needs of society can be long.

To meet those needs and achieve these goals, both content and pedagogical methods must be reviewed. However, combining the demands from all different directions might make it difficult to decide what to include in the future curricula in order to fulfil all the requirements an engineer will need to succeed in the future. Especially, it is expected that tensions will arise when employability and professional competences are as important as the ability to handle the SDGs and the new wave of digitalisation (www.nae.edu/File.aspx?id=43359) [4].

2 BACKGROUND

Jamison et al. [6] identified three university modes associated with tensions in the development of engineering education: the academic mode, with its emphasis on theoretical knowledge; the market-driven mode, with its focus on employability; and the community-driven mode, with its focus on civic society and sustainability [6]. These three modes are found in existing engineering institutions, and all three are needed to develop a future curriculum. However, the academic and the market-driven modes are the most dominant today, and, currently, tension exists between them. For example, with the development of artificial intelligence and the Internet of Things, which is essential in the market-driven (employability) mode, it is important to also develop the academic mode with new subdisciplines and interdisciplinary programmes to create a new hybrid academic mode [5].

Additionally, it is acknowledged that it is important for engineering students to acquire and learn to apply theoretical knowledge to realistic problems. Authentic problems also help students understand the range of industrial and societal practices they will encounter. Especially, the issue of employability has shifted the focus from the academic mode to a more market-oriented mode. In addition to the challenges previously mentioned, the industry requires engineers who have acquired employability competences, such as project management and the ability to learn and adapt quickly, given that career paths will change more rapidly in the near future. Therefore, these future requirements for employability, including innovativeness and entrepreneurialism, constitute relevant areas of development in engineering education.

The third important mode, sustainability, is a major issue in engineering education; it addresses the need to find solutions to climate change, the north/south relationship and the United Nation (UN) SDGs. This calls for new types of universities, such as ecological universities, with embedded social and civic values [7].

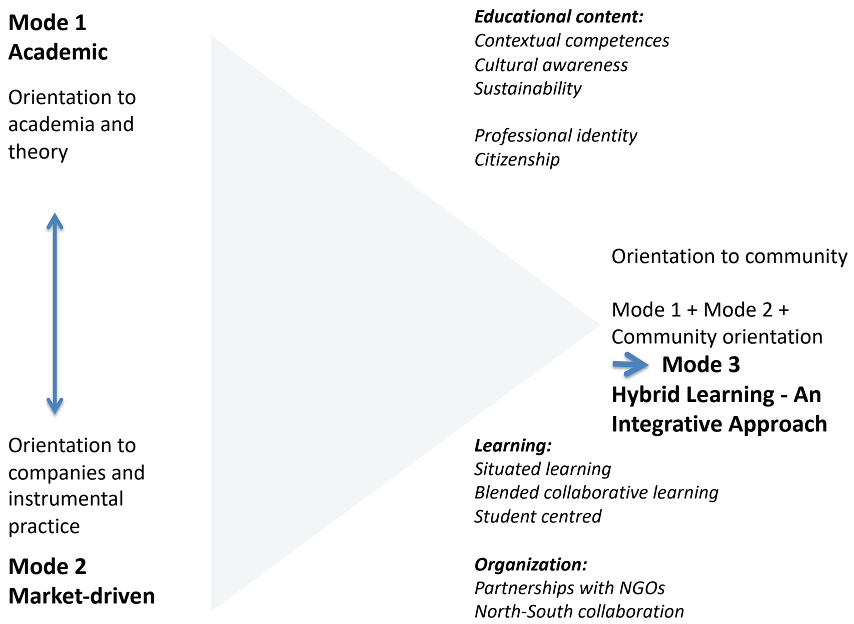

Fig. 1. Visual representation of the three university modes [6].

In the development of a three-mode education programme, based on an integrated, hybrid learning approach, the curriculum has to integrate or combine the various challenges with already existing development trends, such as: 1) student-centred learning, 2) contextual and practice experiences and 3) digital tools.

Student-centred learning methods encompass learning approaches in which students regulate their own learning processes. These methods include active learning, collaborative learning, team-based learning, design-based learning, inquiry-based learning, challenge-based learning and problem- and project-based learning (PBL). The general global trend indicates that accreditation is shifting away from content criteria towards learning-outcomes criteria. Thus, the focus is on both declarative content as well as competencies, including knowledge, skills attitudes and beliefs. The overarching trend is that education has shifted away from academic staff lecturing the students towards providing a more engaging and inclusive curriculum where students influence their direction of learning within a given academic framework. From a research point of view, there is clear evidence that student-centred learning activities have a positive effect on learning outcomes. In particular, PBL is a well-researched area; results indicate increased motivation for learning, decreasing drop-out rates and increased competence development. Increasing knowledge retention is another area in which PBL seems to have had a positive impact [8], [9]. Furthermore, PBL has been seen as a way to bridge the gap between engineering education and engineering work, thereby developing professional competences.

Conceptual and practice experiences represent an increasing educational trend that supports collaboration between private and public stakeholders. Collaboration with companies can occur in a variety of ways, ranging from being consultants or providing opportunities for students to observe practices to offering real-world collaboration and partnership experiences, where students work on solving identified problems. These collaborative projects give students a sense of the complex domain in which solutions emerge by engaging with the problem in all its real-world complexity. This trend also encompasses internships, where students are placed in companies while completing their studies to develop an understanding of the complex-problem situations in which they will be engaged after graduation. Normally, internships are regulated at a political level. In many countries, this has shifted from being a dominant part of the academic curriculum, with fewer internships and collaboration with external stakeholders, to a more practice-related curriculum, with more collaboration (also known as academic and employability drifts). The subject of internships is not a well-researched area in terms of documenting the students' learning outcomes. Positive outcomes have been reported regarding an increased understanding of future work, the application of academic knowledge and motivation for academic learning, but negative outcomes have also been reported, such as the lack of relating academic and practice, which is most often caused by the lack of facilitating the learning process in the workplace.

Learning with the help of digital tools (including the flipped classroom) is a relatively new trend that is still in its early phase. Massive Open Online Courses (MOOCs) and the flipped classroom are two of the icebreaking digital methods that aim at increasing the nature and quality of learning. MOOCs are unique in that they offer educational resources in a nearly 100% distance and virtual mode. The flipped classroom has influenced the development and quality of education by applying active learning and digital methods as alternative ways to present the learning content. Typically, the online part consists of a structured preparation, including videos, quizzes, reading or a collaborative activity, before the students and teacher meet in the classroom. The class is dominated by learning activities that prepare students for their assignments.

3 RESEARCH QUESTIONS

Each of above-mentioned educational trends has been applied in engineering education all over the world with various levels of success and various degrees of integration into the curriculum. Most often, the trends can be seen as “pockets” in the curriculum; they are rarely implemented at a systemic level.

In this study, we investigate the following research questions: How will these trends influence engineering education in the future? How will the trends influence academic research? Will there be a parallel development of research and education? What possible directions can be identified for engineering education in 2030?

4 RESEARCH PARTICIPANTS

Four professors at each of the five partner universities were selected to participate in a semi-structured interview [10]. The professors represent the following four engineering disciplines.

1. Biotechnology engineering
2. Mechanical (or industrial economy or production) engineering
3. Energy engineering
4. Civil engineering

The interviews were conducted by two people: one main interviewer and one representative from the university. On average, each interview lasted about one hour.

5 METHODOLOGY

A phenomenographic approach was chosen for this study because it provides an unconditional starting point for analysing the phenomenon, engineering education in 2030, based on the criteria presented by Ashworth and Lucas [11]. The study is exploratory; the interviewees were asked to give their personal perceptions of how they see the phenomenon and to also share how and why they developed those viewpoints.

One week before the interview, the interviewees were provided with the interview protocol, including the questions and short texts presenting the three contemporary challenges the informants were asked to reflect upon. The following questions formed the basis of the interviews.

1. How do you think the challenges (sustainable development, digitalisation and employability) affect the development of your discipline and the educational programme(s) you are involved in?
2. What do you expect the situation to be 10 years from now?
3. How do you prepare your students for the future using today’s educational resources?
4. How will students learn engineering in the future?
5. Are there other challenges ahead that we have not mentioned?

It should be noted that these questions were provided only as a guide for discussion; probing questions were used in each of the interviews to further elicit the interviewees' perspectives on the observed phenomeon.

The interviews were transcribed verbatim. In addition to analysing the transcripts, attempts were made to capture the moods and interpretations inherent in them, which can strengthen our interpretations. Analysis of the transcripts included identifying categories and addressing variations within the cohort of 20 participants representing the various disciplines and countries. This number of participants is considered sufficient to reach an acceptable level of trustworthiness.

6 RESULTS

The interviews with the faculty members were conducted in late spring 2019. For this first presentation of the preliminary results, five interviews were analysed, representing two of the five participating universities. In the initial analyses conducted to date, two more general categories were detected with two dimensions of variation in the respondents' perceptions.

Category 1: The importance of change. A large variation of perceptions was found regarding the importance of change in order to meet contemporary challenges. Some of the interviewees even expressed a reluctance towards change; they felt that ongoing trends might have a negative impact on the competence of future engineers.

For example, a chemical engineering professor said*: "...but I see the risk of actually the lack of competences in the future, because everyone is trying to be very generalist and broad. And that comes in some way in contradiction to being in-depth."*

This professor reflected on the need for deep content-knowledge in chemistry that is required to understand contemporary sustainability issues. At the other end of this variation dimension, we found professors that see the need for change in engineering education as being vital.

A mechatronics professor said: *"The future needs T-shaped engineers instead of I-shaped engineers; they need to have basic knowledge, but also knowledge in other areas, like safety, ethics ... there is enormous pressure on new technology of today– software can be hacked, which may be lethal … safety is very important."*

This professor claimed that engineers have to acquire better competence in some areas that have not been prioritised until now in order to contribute in future technology development. Both professors viewed the technical evolution as being extremely fast, and they noted that education needs to be adapted to the Fourth Industrial Revolution in the very near future. In this category, there is a trend in that the disciplines seem to be important factors in the variations that are noted. In the more science-dominated engineering disciplines, including biotechnology and energy, subject-specific core knowledge is highly valued. But, for disciplines that are closer to production, professors anticipate significant changes due to digitalisation and the Fourth Industrial Revolution.

Category 2: The role of future engineering institutions. As the interviewees discussed engineering education, they also reflected on the overall, future role of universities. This became the second category. Clear variations were seen in this category. At one end of this variation dimension, the interviewees thought that universities would adapt to societal change to as large extent as possible.

A civil engineering professor said: "*Yes, I hope it will evolve regarding the format. We are noticing that there is a clear demand for flexible learning…."*

This professor thought that engineering programmes, and the need for graduation, might disappear. Instead students/people will bring a file with them that provides information about the courses they have taken, and the file will be updated throughout their professional life.

However, some professors expressed a more passive role for universities in the future.

A biotechnology professor said: *"...the role may be more of quality control, in order to avoid faked facts etc.…"*

This professor saw the possibility that private actors would become educators, and because universities are slow to change, they will be left with more administrative tasks, such as quality control.

Several other trends deserve to be mentioned at this stage in the research. Sustainability is often seen as a challenge that has been on the agenda for a long time; thus, it is already rather well implemented. Professors in several disciplines expected education to take an even more holistic approach so students can address the sustainability challenge. Professors in other disciplines claimed that the trend of education being more holistic and broader for a single engineer may result in knowledge drainage within the discipline and in society; therefore, they did not regard it as the only solution.

One professor said: *"We see now an evolution where students become more and more generalists and less and less specialists. And I think that's also something that sustainable development has been striving for".*

The interviewees also had various thoughts about employability and the need for more innovative and entrepreneurial skills.

A civil engineering professor said: *"Innovation is our weakest point, meaning that the 'old' culture was, and still is, that the students want a job in a big company, where they do not need to care much about being an entrepreneur and establishing new companies. However, a change is seen, and this will definitely be important 20 years from now".*

Digitalisation is an area where the interviewees in all the engineering disciplines seem to agree that a change was needed. Some professors said that they do not yet have the ability to foresee the changes that will come, while others noted that their discipline is in the middle of this change and they already see a significant need for more digitalisation and programming in the educational curriculum.

7 DISCUSSION

The mode that is described as being the most important for engineering education in 2030 is the employability, market-driven mode. Many of the interviewees noted that reality-based problem solving will be used even more in engineering education in the future. The link with stakeholders is expected to grow, even though, as explained above, professors also see the risk of graduates not having the detailed knowledge they will need to succeed in their future career. In our analysis, the tensions between the three university modes that were described are clearly visible; the five interviewees expressed very different views on the priority of future academic quality and the need for market-driven education. It could be said that those tensions need to be emphasised when developing engineering education programmes. No perspectives should be neglected in an effort to arrive at a common vision of the development that all faculty can agree on. The hypothesis made after this initial analysis, which will be further investigated, is that those tensions are discipline-dependent rather than person/university-dependent.

The analysis did not find strong evidence for any anticipated development towards the community-driven mode at a university, although there were some indications of this as the interviewees remarked about society's influence on education.

In the Results section, it was mentioned that the interviewees identified different roles for the future of education at a university. Some of the professors expected to play a more active role than others. An idea for future analysis is to also include a question regarding engineering and its relationship to the future of society in order to identify a clearer picture of how the faculty views that relationship.

Although some preliminary results are addressed, this is a work in progress and the conference presentation will focus on the preliminary results as well as the methodology used. The advantage of using a phenomenographic approach is that it enables researchers to see variations and correlations. A disadvantage is that this methodological approach is rather complex; for example, many rules must be adhered to when using it, which can be difficult to follow.

By discussing these preliminary results and methodological approaches, we hope to increase the possibility that others will conduct similar investigations in other countries and/or at other universities. These studies would contribute by providing a comprehensive vision of how the engineering disciplines should evolve in the future to address the educational needs of engineers.

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Industry Advisory Board Members' Contributions to Engineering Education Program Development
A Case Study

S. Kullberg
Chalmers University of Technology
Department of Technology Management and Economics
Gothenburg, Sweden

D. Paulin[1]
Chalmers University of Technology
Department of Technology Management and Economics
Gothenburg, Sweden

Conference Topics: Another topic relevant to the conference but not listed above; Strong demand for democratic involvement in educational processes

Keywords: Advisory Board, Engineering Education, Curriculum Development, Program Design

ABSTRACT

Engineering education programs should be developed in line with society's needs. This becomes more challenging with an increased speed of technical development. In order to create this alignment input from society and industry is vital for program management as well as for higher education governance. One common way to gather input is through industry advisory boards on different organisational levels. Currently there are few studies that focus on contributions by industry representatives in industry advisory boards on individual education program level. These studies have primarily been performed through quantitative approaches (surveys) and findings are inconclusive.

In this original study we aim to answer how industry representatives contribute to program development of engineering education programs, and what their motives are. In order to gain increased understanding, we have performed 18 semi-structured interviews with industry representatives in program advisory boards at one Swedish university.

Results indicate that industry representatives provide different types of contributions, which are affected by preconditions set by heads of programme, and meeting formats. Several representatives mention that they are unclear of their actual contribution. They also highlight (1) personal motives such as supporting the head of programme and (2) their employers' motives to actively influence program content, as motives for contributions.

[1] Corresponding Author
D Paulin
dan.paulin@chalmers.se

This study adds new insights, through its qualitative approach, to the understanding of industry representatives' motives and contributions to program development. It provides additional perspectives to current contributions to this field, to program management, and for development of governance structures in higher education institutions.

1 INTRODUCTION

1.1 Background

In higher education in general, and for engineering programmes specifically, it is important that the content of education meets the current and future needs of the industry, and that the study programme is attractive to potential and current students. In developing programmes and courses, it is important from a strategic as well as from an operational perspective that teachers and programme gain understanding of the needs of the labour market.

Industry needs can be captured through contacts between universities and representatives from the industry. One way of doing so is to involve industry representatives in various forums and decision-making bodies linked to study programmes. In program advisory boards, industry representatives from program-relevant companies and organisations can share experience and industry perspectives with other members of the board; students, teachers and program management. At Chalmers University of Technology, a project has been under way since 2017 aimed at creating effective program advisory boards.

The number of previous studies of industry representatives in the development of educational programs in higher education are few. Genheimer and Shahab (2007, 2009) have published results from survey-based studies where school directors and advisory board members of 90 American engineering programmes were asked about the advisory boards work and efficiency. The advisory boards in the studies (Genheimer and Shahab, 2007; 2009) were all in higher education institutions or on department level and the studies had focus on financing of schools and programs. Viswanathan (2012) performed an interdisciplinary study at the National University of Singapore, where he argues for the importance of advisory boards for program development. Emmer and Ghanem (2013) present the results of an American survey-based study where programme managers and program advisory board members answered questions about the program advisory boards impact on the development of construction management program curriculum. El Refae, Askari and Alnaji (2016) question whether program advisory boards affect quality of education and report the results of a small survey at a university in the United Arab Emirates. All of these studies are based on questionnaires with a quantitative research approach.

In this study, we explore the field of program advisory boards (PAB) for individual engineering study programs (BEng and MEng) through interviews with industry representatives (IR) that are members of program advisory boards at Chalmers University of Technology in Sweden, in order to better understand their contributions to programme development, as well as their motives.

1.2 Aim

This study aims to address the issues: How do industry representatives in programme advisory boards contribute to programme development, and what are their motives?

2 RESEARCH DESIGN AND METHODS

In order to gain increased understanding of how industry representatives contribute to programme development and what their motives are, we have performed an original study applying a qualitative research design.

The main method used is interviews with industry representatives in advisory boards for individual engineering programmes.

Programmes studied are sampled from all four educational areas at Chalmers University of Technology in Gothenburg, Sweden. The areas are: Architecture and Urban Design (ASAM), Mechanical engineering, Mechatronics and Automation, Design as well as Shipping and Marine Engineering (MATS), Electrical Engineering, Computer Technology, IT and Industrial Engineering and Management (EDIT-I), and Physics, Chemistry and Bioengineering, as well as Mathematics and Engineering Preparatory Year (KFM).

Interview respondents were identified and selected through sampling (Descombe, 2010). Sample criteria used were Master of Science in Engineering (8 respondents)/ Bachelor of Science in Engineering programmes (8 and 10 respondents), male/female board member (12 and 6 respondents), and first term in advisory board / more than one term in advisory board (13 and 5 respondents). 14 respondents represent large organisations (>1000 employees), in manufacturing, telecom, construction, and consulting industries. Four respondents represent small organisations (<100 employees), mainly from technical consultancy firms, but also from one industry association. Most respondents (14) have 5-12 years relevant work experience, and four have more than 15 years experience.

In all 18 semi-structured interviews lasting 45-75 minutes each were performed. Interview questions (see Appendix A) are primarily based on a survey performed by Genheimer and Shahab (2007; 2009), and adjusted and expanded to better fit an interview format. Interviews were recorded if the respondent did not decline when asked, and were written down and summarised before the data was jointly analysed using thematic analysis (Sullivan and Forrester, 2019) by both authors. For the first part of the aim (how industry representatives contribute) the following themes were inductively identified: Time perspective (either strategic long-term, or detail-oriented, short term). Self-image (either performance management oriented, or advisory oriented / mentorship). Degree of abstraction (either concrete contributions, or more abstract reasoning). For the second part of the aim (what are the industry representatives' motives for contributing), these themes were inductively identified: Focus (for themselves, for their organisation, or for society). Contributions (to the program, or to the university). Reason (future impact, or reciprocation).

3 RESULTS

Industry representatives' (IR) contributions to the programme advisory board's (PAB) work are mainly in connection with meetings, which is why meetings, including preparation and post-work, are focused in this study.

3.1 Motives

Industry representatives express various reasons for participation in the PAB work. One reason mentioned by many is to bring "reality-perspective", in addition to the academic perspective held by teachers and programme management, into PAB and in development of study programmes. IR point out the importance of having influence on the programmes development to ensure it is aligned with industry's needs.

Several IR who previously have been students at the university express that they are part of the PAB because it gives them a chance to pay back to the programme or the university. They say that through their participation in the PAB, they want to make imprints and benefits for programme development. Several IR also state that they have a recruitment perspective on their participation; students met in PAB can be a potential future employee, IR get an understanding of today's students' and education's content and that they have the opportunity to influence the programme development for future recruitment needs.

Most IR express the importance of having the feeling of contributing, both in the moment at the meetings but also longterm through knowledge of making a difference in program development.

Several IR see that PAB meetings are opportunities for networking and providing opportunities to meet different people (students, teachers and industry colleagues). They also express an aim to receive information that can be of use in their home-organisation.

Another motive expressed for IR to participate and contribute to PAB work is that it adds to personal development, it is interesting, fun and it caters to the personal curiosity about what is happening in the programme and at the university. Several IR adds that it feels rewarding to give back to the HEI (Higher Education Institute).

The reasons that IR express for participating in the board can be divided into two main categories: Personal interest, and as a representative of the organisation in which they are employed.The two categories coincide to some extent.

3.2 How to contribute to programme development?

There are different preconditions for IR possibilities to contribute to programme development in PAB.

Recruitment of IR is one of these preconditions. The majority of IR in PAB are recruited via the heads' of programme personal networks. IR mention that they have been approached in different ways; after coincidental meetings, via an e-mail "from their previous thesis tutor", or as an old personal friend to the head of programme. However, a few of the IR have been involved since their home organisation (company or industry association) have approached the university or the head of programme directly and asked to be a part of the board.

Most of the IR are alumni from the programme or the HEI. They bring previous understanding of programme designs as well as from the specific university. Some of the IR have no previous experience from the programme or the university.

Differences in meeting structure have a big impact on PAB work, according to IR. Frequency of board meetings differs, from one meeting a year to six meetings. Low frequency of meetings (one-two meetings a year) IR experience that it is hard to feel engaged in the process of programme development.

How time is distributed between heads of programme and other board members during meetings is also mentioned as a structural matter of importance. Many of the IR express that large parts of the meetings are occupied with programme information (statistics of student performance, course evaluations etcetera) presented by the head of programme. Several IR point out that time for discussion amongst amongst board members is essential. Some PAB are smaller than others and depending on the number of board members, IR claim that discussion works well when the group is small (eight people or less) but when the board has more members, IR experience it is more effective when the group is divided into smaller units. It gives everyone time to talk and share their experience. There is a concistency amongs IR, that their contribution, industry experience, is critical for programme development.

In addition to requirements of time, frequency and group size, most IR also request more material to prepare prior to meetings. That would increase the quality of discussions during meetings. IR suggest that preparations can include involvement from the company/organisation where they are employed, through getting questions or topics to discuss, in order to get more and diverse information from industry. Meeting agendas are in most cases sent out prior to PAB meetings but rarely other material for preparations.

Several IR call for more and better feedback on PAB work and their own contributions. Many IR express that they are uncertain of their impact on the programmes development and call for better feedback on that. A suggestion from one IR is that each PAB meeting connects to the previous meeting and what has happened since then. IR also point out that they feel more involved in PAB work when meeting notes are distributed after board meetings.

During interviews IR express different views of their role and on PAB aim. Some IR focus on details and operational work, others focus on longterm goals and strategic objectives.

3.3 Contributions to programme development

When asked about current contributions to program development all interviewees mention that they add worklife reality, what is needed when the students graduate and gets employed. Most IR also mention that they add business perspective to discussions on program development, either from a current perspective (what is needed today), or from a future perspective (what will be needed in the future).

Other aspects that a few IR mention that they contribute with today, and that many IR see that they may do in the future, are by being involved in thesis work (as tutors, project initiators, or as entry points to thesis coordinators within their home organisation), by participating in courses as guest lecturers or alumni witnesses, as organisers of field trips and study visits, and by participating in different program marketing events (both directed towards potential students, as well as towards current students).

Several of the interviewees mention that in they experience that their contributions to board discussions are given high importance by the heads of programme.

4 DISCUSSION

IR are willing to contribute to programme development in different ways. However, certain criteria need to be fulfilled in order strengthen the work done by PAB. In this chapter results from interviews with IR are discussed.

4.1 Expectations, contribution and reward

Coe (2008) propose that the initial activity when designing an advisory board system is to decide and to be clear on what you (the HEI) want the board to do, and to communicate this clearly to the board members. Within the group of IR interviewed it is noticeable that they are of different opinion regarding their role in PAB; some see themselves as advisors to programme management, while others have a mindset of being part of a board of directors. This difference in mindset affects their expectation on PAB discussions – is input from the board a direct basis for decision making, or is it ideas and viewpoints to programme management to be considered, amongst other perspectives, when heads of programme make decisions?

The IR point out how important it is to be heard and to feel involved in making a difference in programme development. If feeling involved and being heard is an essential reward for contributing (in line with common motivation theories such as Hackman and Oldham, 1976) and PAB is the forum where industry experience is captured, structure of meetings etc., should support IR's request. Otherwise PAB aim will be jeopardised and study programme development will risk being onesided with only the academic perpective represented.

HEI have long decision processes, the organisations are hierarchic surrounded by a considerable amount of rules and regulations, therefore are longterm cooperation with industry representatives is vital for programme development. Some IR mention that they have been board members for a shorter period of time (less than two years) and that changes are not visible in such a short timeframe.

To avoid the risk of disjointed processes and decisions and risk of loosing engagement of IR, it is important to have balance between IR contributions and perceived rewards (in line with Hackman and Oldham, 1976). Rewards can be immediate through feedback during and between meetings, or long-term thorough implemented changes in programme design, programme content, or course content. One of the most strongly pronounced motives for contributing is “making a difference”. Rewards through feedback and programme development is however delusive; how can a single IR see his or her contribution when decisions and changes include the work of many different people and perspectives often adjusted do fit into an existing organisation with high sets of rules, regulations and culture?

4.2 Obstacles

Most of the IRs are recruited from the heads of programme personal network. This creates a certain homogeneity among board members, as well as a certain loyalty from IRs towards the heads of programme. Previous studies (Genheimer and Shehab, 2009) have concluded that when IR are alumni, they display a strong loyalty towards the university. If ambition is to increase experience and different points of views in discussions heterogeneous group compositions are preferred.

Coe (2008) stresses the importance of having a chair with strong leadership skills in order to creating a positive experience of advisory boards. Observations in this study show that heads of programme have a decisive impact on how IR experience the role the PAB. If discussions in board meetings are aimed to have an effect on the results/education, then the character of information presented should be aligned with the type of influences/effects desired, and with the purpose of the board. For example, if information related to course evaluation is sent to IRs, and this is pointed out as a problem, then it is likely that the board will focus on supporting the head of programme to some that specific problem, instead of discussing program issues on the strategic level as originally intented. If this type of misalignment is continued, there is a risk that the PABs’ purpose change permanently.

Coe (2008) also mention the importance of having as prepared a constitution including a clear statement of goals and mission. Several of the IRs mention a desire to receive material, preferably with a clear assignment or questions to reflect upon, sufficiently in advance in order to prepare themselves as well as having time to discuss within their home organisations prior to PAB meetings. They claim it will help them to feel useful and important, having well prepared thoughts and ideas into the meetings. On the other hand, during the interviews several IRs expressed that they felt unsure of how their contributions has short-term effects in terms of what is discussed, or what is decided during meetings. A study of heads of programmes and their experiences from advisory board interaction (Kullberg and Paulin, 2019a; 2019b) indicate that heads of programme are reluctant to burden IR with too much material and preparations, again pointing at the importance of managing expectations.

There were also comments made by IRs that reports regarding, for example student throughput, presented by heads of programme can be hard to relate to discussions in previous meetings.There are also expressions of frustration from not seeing how they (IRs) can affect key performance indicators, such as student throughput.

Another aspect of programme development brought up by IRs during interviews is that they have problems in seeing concrete changes in programme design, improvements in course evaluation results, or student throughput, as a result of board activities.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main conclusions related to how IR contribute to programme development are:
IR bring the reality perspective into programme development which is important to better align education to society's needs.
IR contribute to programme development during board meetings, and the type of contributions made are influenced by signals conveyed by the heads of programme via the types of information presented during meetings.
IR contributions are affected by feedback with different time frames, immediate during meetings regarding personal contributions, short-term from one meeting to another highlighting actions taken after the previous meeting, and long-term from one academic year to another regarding programme development.

The main motives for IR to contribute are:
To pay back to the programme or university for the education and experiences that they have received.
To make an imprint on programme content and thereby knowledge of the future workforce.

5.2 Recommendations

If heads of programme, and other decision makers, want to include important industry perspectives in programme development via program advisory boards, we propose that:

IR are recruited from a broader base than in the studied case (mainly personal networks of heads of programme) in order to bring heterogeneity and thereby additional perspectives into strategic discussions.

When designing meeting formats, several aspects should be considered. Before meetings, sufficient time and material for preparations is desired by IRs. The type of information send out should be aligned with the desired purpose of the board whether that is the board as a "strategic council" or an "operational control function". Allocation of meeting time should include significant time for recurring small group discussions, and/or workshops, in order for the IRs to experience that they can contribute, time for specific follow-up from previous meetings of strategic level development primarily, and operational level development occasionally.

We also recommend that universities as well as heads of programme clarify the purpose of the PAB to each member in the board, and expectations on board members' contributions. We also want to highlight the importance to listen to the expectations of IRs and take these into consideration when possible. We stress that heads of programme inform each board member of the conditions under which the board operates as well as the conditions under which the heads of programme operate, for example in terms of decision making processes with the university. Finally, we recommend that IRs provide feedback of how they perceive decision making processes relevant for the purpose of the board.

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APPENDIX A

Interview Questions – Program Advisory Board

Aim: How do industry representatives in programme advisory boards contribute to programme development, and what are their motives?

Background information

What is your name?

What organization do you currently work for?

What is your job position?

Describe your work experience?

Are you an alumnus?

For how long have you been a member of the advisory board?

How were you recruited into the board?

Which study program, and educational area, is your advisory board connected to?

Questions

How were you approached and asked to be part of the advisory board?

Why did you want to be part of the advisory board, when asked?

Why do you want to be part of the advisory board, today?

What do you want to get out of your participation in the advisory board? What is “in it” for you?
Do you get that? Please, elaborate.

What development phase would you say that your program is in? Development, or more of a steady-state phase?

What do you normally discuss during the board meetings? What type of questions?

How do you contribute to the board? Content wise? Speaking space?

How often do you have board meetings?

Do you have other meetings within the board?

How often do you participate?

Are the head of programme, and board members in contact with each other in between board meetings?
If yes, what type of contacts (phone, e-mail, meetings)? How often? For what reasons?

Please, describe a typical board meeting.

What is the purpose and aim of the board?

How important is that purpose?

How effective would you say that your board is (with regards to fulfilling the purpose)?

What is the overall effectiveness/efficiency of your board?

How do you perceive that input provided by the board is received by the head of programme and the university?

Additional comments?

Understanding how students learn in project-based courses
A review of literature

S. B. Larsen[1]
Center for Bachelor of Engineering Studies
Technical University of Denmark
Ballerup, Denmark

N. C. Kjærsgaard
Center for Bachelor of Engineering Studies
Technical University of Denmark
Ballerup, Denmark

P. V. Bigum
Center for Bachelor of Engineering Studies
Technical University of Denmark
Ballerup, Denmark

P. Jacobsen
Department of Management Engineering
Technical University of Denmark
Lyngby, Denmark

Conference Key Areas: New notions of interdisciplinarity in engineering education, New Complexity quest in engineering sciences (these are the best fit from the list)

Keywords: Project-based learning, Problem-based learning, Learning facilitation, Literature review

ABSTRACT

Project-based learning is a key ingredient in most engineering education programs. Trained instructors that use traditional classroom teaching methods can often easily spot when students grasp key learning outcomes simply by observing students' face and body language. However, in project-based courses instructors only interact occasionally with students (e.g. in supervision meetings, milestone meetings, and lab exercises). At exams, students demonstrate that they have indeed grasped the course's key learning outcomes. But how? And why? That project-based courses

[1] Corresponding Author
S. B. Larsen
sbla@dtu.dk

result in deep learning with long retention is well documented in literature. However, under-researched is the question of which particular circumstances induce or facilitate the learning. The purpose of this study is to gain a better understanding of the causes for learning in project-based courses. To identify the learning-inducing causes in project-based courses, this study reviews extant literature. Three distinct categories of learning-inducing causes appear in the literature: instructor-directed learning, team-directed learning, and individual self-directed learning. The study presents results within each category. One distinct finding is how the team's application of the project methodology facilitates several important means for learning. Examples are (a) breaking down a project into its components parts and (b) summarizing and presenting progress in status reports and pitches. Literature focuses (perhaps not surprisingly) on how instructors can facilitate learning. Missing in literature are learning-inducing causes related to the individual student and, in particular, the students relations to outsiders on and off campus.

1 INTRODUCTION

Project-based learning is a key ingredient in most engineering education programs. Often, engineering education programs begin with math and natural science disciplines; continue with disciplines about methods, tools, and techniques; and end with courses concerned with the application of these methods, tools, and techniques. These latter course type often take the shape of a project-based course, where students work in teams to develop a solution using the discipline's tool box [8]. Depending on the engineering discipline, a solution could be an engine, a building, a production system, or a chemical process.

For second or third semester projects, student teams might receive project descriptions that include a detailed set of project requirements. Later in the education, student teams often cooperate with an external partner, who supplies the problem to be solved [2]. Such a problem usually takes the shape of either a defined solution need or that something existing is unsatisfactory or simply has an improvement potential. Examples of solution needs are a need for new building with sixty stories or an app with a fast launch speed. Examples of something existing that needs improvement could be a production system's high scrap rate or a machine's short longevity [9].

While the end result of a project differs widely, students must often learn certain, pre-specified learning outcomes these project-based courses. Examples of learning outcomes are (1) how to apply a technique introduced in an earlier course or (2) how two element from two separate prior courses relate to one-another, and (3) how to sequence the activities in a project that designs a solution to a problem, (4) how one element fits into a greater structure. Students often conduct their work in project-based courses using methods, tools, and techniques learned in earlier courses [7].

These earlier courses are often taught through traditional classroom teaching methods. In these courses, trained instructors can often easily spot when students grasp key learning outcomes because instructors have continuous interactions with the students. Instructors can measure learning simply by observing their students' face and body language or through classroom assessment techniques. In project-based courses, instructors and supervisors only have occasional interactions with students (e.g. in supervision meetings, milestone meetings, and lab exercises). At the exam of the project-based course, students demonstrate that they have indeed grasped the course's key learning outcomes. One could ask "how?" or "why?". And so does this study.

That students learn well and with long retention through project-based learning is well documented in educational literature (e.g. [1] and [11]). However, under-researched are the questions of when during a course the learning occurs, how the learning occurs, and (perhaps most important) which particular circumstances induce the learning. The purpose of this study is to gain a better understanding of the latter question. The study seeks to contribute to a better understanding of the causes for learning in project-based courses.

That students grasp key learning outcomes when their supervisor explains issues is well-known. However, other causes that induce learning are only vaguely known or assumed. Do students learn by discussing subjects with one-another, do they learn when explaining subjects to friends and family, when biking to school, when conducting individual project tasks, or perhaps in the shower? This study will reveal what extant literature holds of answers and suggest avenues for future research into unknown territory.

2 METHODOLOGY

To identify the learning-inducing causes in project-based courses, the study applies the literature review methodology that is adapted from the tradition in the medical sciences (see [10] for an example). The study will apply the research protocol illustrated in Figure 1. First, the study locates papers; second, the study screens papers for relevance; third, data is extracted and, fourth, the study conducts a descriptive analysis of the selected papers and provides a thematic analysis following the particular purpose of the study, which is to identify and categorize the causes for learning in project-based engineering education courses.

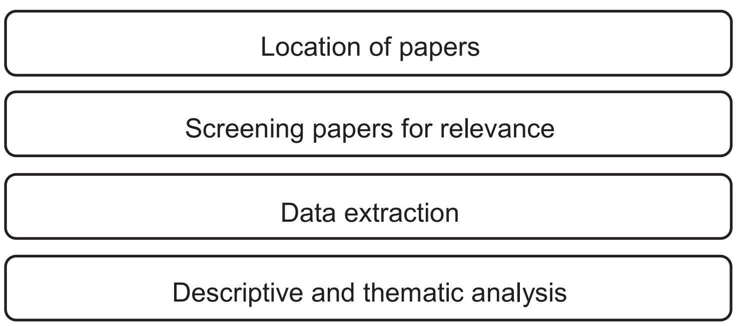

Fig. 1. Research protocol

To locate the right set of papers, the study applies the search engine from the Technical University of Denmark, called *DTU FindIt*. This search engine provides results from most major scientific databases, including Web of Science and SCOPUS. The authors of the study are all instructors within industrial and manufacturing engineering, so to ensure a thorough understanding of the selected papers, the study limits the search results to papers about engineering education within these subjects. The study applies the following search string:

> "engineering education" AND project AND learning AND ("industrial engineering" OR "manufacturing engineering" OR "production engineering")

The search engine provides the option of selecting journal articles only, and this selection results in 410 hits. These 410 hits were screened for relevance by reading title, abstract and keywords. The screening resulted in 73 hits. The screening criteria was whether the paper contains descriptions of the learning-inducing causes in project-based courses. Included were also papers where the abstract leads to believe than the paper itself will provide relevant content. These 73 papers serve as the data for the study and the study will therefore extract descriptions of learning-inducing causes from the dataset. Some causes will be well-described in a paper, while others may just be mentioned and some even just assumed.

As mentioned, the study will conduct both a descriptive analysis of the selected papers and a thematic analysis that will categorize the learning causes. The descriptive analysis will analyze the dataset by examining publication years and journal outlets. The thematic analysis will inductively develop a set of categories of learning-inducing causes and within these categories provide cause-descriptions.

3 RESULTS

This section presents the results of the study findings. First, section presents the descriptive analyses and, second, the thematic analysis.

3.1 Descriptive analysis

Table 1 shows how the selected set of paper are distributed over time ranging from 1999 to the present, and across journals.

The table shows an increasing trend in researching learning through project-based courses. The most prevalent journal in the study is the *International Journal of Engineering Education*, while the *ASEE conference* is the largest outlet on the conference scene. Other than these two outlets, the topic appears to be relevant across a large range of journals. 28 of the 73 papers are published as the only publication on the subject within the outlet. Perhaps s bit surprising is the difference between the *International Journal of Engineering Education* (17 publications in the study) and the *Journal of Engineering Education* (two publications in the study).

Table 1. Descriptive analysis

Distribution across time and journals		Number of papers
Year	Before 2001	7
	2001-2005	2
	2006-2010	13
	2011-2015	25
	After 2015	25
Journal	International Journal of Engineering Education	17
	ASEE Annual Conference and Exposition Proceedings	10
	Proceedings - Frontiers in Education Conference	4
	Advances in Engineering Education	3
	AIEDAM	3
	European Journal of Engineering Education	2
	Journal of Cleaner Production	2
	Journal of Engineering Education	2
	Producao	2
	Other journals with one selected paper	28

3.2 Thematic analysis

In this analysis, the study will seek the answers contained in literature about what induces learning in project-based courses, in which instructors have only occasional student interactions. This section will examine the factors that make students acquire knowledge. To exemplify, one of the basic processes of acquiring knowledge is deduction. A student deduces a logical connection, e.g. between two variables or how a theory or method is properly applied. The study will seek what induces deduction.

Some of the selected papers apply the term instructor-directed learning, which in project-based courses refers to elements of the course that are pre-determined by the instructors (e.g. [1]). Examples are (a) project scoping, (b) description of particular project tasks, (c) mandatory methods or frameworks, (d) a particular sequence of project activities, or weekly assignments [11]. The opposite of instructor-directed learning is student-directed learning. This concept ban be divided into learning directed by the *student team* as the actor and self-learning where the individual student is the actor. The following three sections divide the study's results into the three categories of (1) instructor-directed learning, (2) team-directed learning, and (3) self-directed learning. Each of these category-sections will examine how direction from the instructor, the student team and the individual student, respectively, induce learning.

Instructor-directed learning

Instructors can take several different roles in a project-based course based among others on the degrees of freedom for the student teams. An instructor can take the role as a mentor rather than an instructor or as facilitators or guides [2].

Instructors have a pivotal role in the beginning. One particular task is formulating the project descriptions, which may include a set of specific tasks to be solved. The description will motivate students to seek information (papers, construction codes, industrial practice instructions, textbooks, etc). The task of evaluating theory, methods, models, tool an techniques induces students to think critically and learn about applicability and the context of their application. In addition, instructors often introduce the basic concepts of project planning, team dynamics, reporting, etc. [13]. Applying these concepts induce learning through learning by doing.

Later in the project, instructor-conversations induce learning. Examples of instructor-team interactions are laboratory solution tests and design reviews [15]. These conversations around tests and reviews induce learning about what works and what does not.

Team-directed learning

Team directed learning is the most described means of learning in project-based courses. The following section will go through a number of themes contained in the selected papers.

Problems are often the initial stimulus for learning in project-based courses. Based on the problem, the team develops a structural knowledge frame in which specialist knowledge is embedded [5]. The project plan itself functions as a structural and methodological frame (see a later section).

Brainstorms for solutions are as an explicit stimulus for surfacing potentially useful ideas and concepts [13], and the process of qualifying ideas enables a deductive thought process of “If the objective is X, then criteria for selection is X1 and X2. The current idea works because X1 and X2 critiera are met”. This thought process is often implicit and vague.

Targeted input from non-engineering disciplines “enable new and varied perspectives on a problem” and integrating multiple disciplines help students “weave a tapestry” from seemingly unrelated facts [14].

When visiting the external partner, who provides the problem, and discuss issues with external partner contacts, the team is prompted to think about how potential solutions can fit into the context of the external partner. For example, a student team identifies a feasibility criterion for a solution [4] and needs to satisfy the criterion in the solution design.

Several papers apply writing task as part of their project requirements. When writing solution documentation [11], student teams must formulate their knowledge in writing, which forces students to embed their learning in the logic that is the structure of the documentation. Communicating progress is a learning inducing cause. The team must summarize their work in writing. This could be on a written “one-pager”, as notes for a five-minute pitch or graphically in three PowerPoint slides.

Decision-making activities are key to learning. [3] describe knowledge acquisition in engineering design as being “strictly linked with the progression from the initial need (the design problem) to the final product that is made in increments punctuated by design decisions”. Decisions of potential solutions facilitate discussions of not only pro’s and con’s of one or more alternatives, but also which set of factors to include in a decision [5]. Even simple decisions about how to stack a deck of cards foster discussion [12]. Such a task is relevant in e.g. construction engineering. Other examples are when prioritizing among analytical routes to examine further og among possible elements of a solution to a problem.

Project planning functions as a learning-inducing cause. The team must disaggregate the project’s overall complex task into a set of simpler tasks. When conducting and discussing the disaggregation, the team will learn the logical build-up of the project including the problem and later the solution. A work breakdown structure [2] is often one of the explicit activities in a project-based course that helps with disaggregating a project into a set of logical and solvable component parts.

Self-directed learning by the individual
When conducting individual tasks, each students learn. When applying tools and hands-on experience or when combining methods learned in earlier semesters with the particular problem to be solved in the project ([5] and [6]). An example could be formulating an algorithm using a textbook filled with potential functions.

4 DISCUSSION AND SUGGESTIONS FOR FUTURE RESEARCH

Project-based learning is distinct in the way that it is organized as a sequence of activities. The project’s technical content is embedded in these activities, but the project also includes activities that stem from the project methodology itself. Some of these activities induce learning. The team naturally needs to break down the project into specific activities that can be part of the project plan. In problem-based learning (PBL) breaking down the project enables learning of (a) the natural or logical make-up of the problem to be solved, (b) the activities in a causal analysis of the problem, and (c) the activities in the identification of design requirements for the solution. In addition, the team must often report progress. Developing the message in an often predefined format enables learning by having to formulate messages, hone their argumentation skills, and develop graphical displays.

The study reveals that team-related themes are much more researched than issues related to the individual students or the individual student's larger context. Future studies could focus on learning through students' individual tasks, and how ideas often appear to the student seemingly like a bolt from the blue. In addition, how much learning happens when students discuss their work with outsiders (friends or family)? This has yet to be examined.

Team processes can be frustrating. Students learn from their own emotional reactions to situations and also from the reactions from other team members. They learn what makes themselves and their team perform well and which pitfalls to avoid. Future studies could examine how students learn from being present, having emotions, and react to project situations.

Several papers discuss design processes and the concept of problem-based learning (PBL). A project-based course is an effective method for facilitating PBL and learning design thinking and design processes.

Results show a number of papers discussing the motivation for running project-based courses. Teamwork, communication, critical thinking and other professional skills are key to early career success. Project-based courses are pivotal for developing these "soft skills".

Many of the selected papers evaluate how a particular approach to project-based learning impacts learning (often measured in GPA-increases). Perhaps the prevalence on these studies is explained by the popularity of the Scholarship of Teaching and Learning concept where practitioners are encouraged, measured, and often promoted based on their ability to reflect and research the effectiveness of their own teaching methods.

Finally, the study did not find much information about the relationship between the project-based course and the earlier courses that form the theoretical foundation for the project-based course. Perhaps future research could examine this relationship as it related to the team's and individual's learning.

5 CONCLUSIONS

The study has found three distinct categories of learning-inducing causes: (a) instructor-directed learning, (b) team-directed learning, and (c) individual self-directed learning. The paper presents sets of learning inducing causes in each of these categories.

One distinct finding is how the team's application of the project methodology facilitates several important means for learning. Examples are (a) breaking down a project into its components parts for the purpose of planning the project, (b) summarizing and presenting progress and key facts in status reports and pitches, and (c) discussing designs and ideas with faculty during milestone meetings.

Literature focuses, perhaps not surprisingly, on how instructors can facilitate learning and on the learing processes of the student *team*. Missing in literature are learning-inducing causes related to the individual student and, in particular, the student's educational context (e.g. relations to others on and off campus).

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A Systematic Literature Review of China New Engineering Education

Li Tuoyu
（College of Public Affairs, Zhejiang University, Zhejiang Hangzhou, 310058）
Wang Yujie
（Corresponding Author, College of Public Affairs, Zhejiang University, Zhejiang Hangzhou, 310058, happypp@zju.edu.cn）
Li Chen
（Institute of China’s Science, Technology and Education Policy, Zhejiang University, Zhejiang Hangzhou, 310058）
Wu Wei
（Institute of China’s Science, Technology and Education Policy, Zhejiang University, Zhejiang Hangzhou, 310058）

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ABSTRACT

With the advent of a new round of industrial revolution, China has put forward its New Engineering Education initiative at the right time. A literature review is an important way to understand the current state and future directions of New Engineering Education. The Systematic Literature Review is an internationally emerging and widely applicable research method that adopts standardized data coding technology, integrating systematic and qualitative evaluations to examine the literature on specific issues and formulate new problems and theories. This study provides an overview of research and practice in New Engineering Education in China by systematically analyzing articles containing the keyword “New Engineering Education.” These articles were published in the main journals of the CNKI database from January2017, when the concept of “New Engineering” was first proposed. Two hundred and sixty studies were analyzed with 6 first-level codes and more than 20 second-level codes. After presenting the results of the analysis, three cases are described in detail in terms of the specific paths in practice from technical universities, comprehensive universities, and regional universities. The results showed that New Engineering Education resulted from the joint promotion of multiple levels and subjects and that its construction logic could be classified into policy logic, industrial logic, disciplinary logic, and the logic of knowledge. By integrating these different types of logic, this study constructed a systematic analysis framework for research and practice in New Engineering Education. As a result, this study helps to explain how engineering education has evolved in the face of the Fourth Industrial Revolution and market demand and facilitates efforts to find a possible breakthrough to promote a paradigm shift in engineering education.

Keywords

New Engineering Education; Content Analysis; Logic Exploration; Systematic Review

Introduction

With the progressive of cutting-edge technologies such as artificial intelligence, big data, and cloud computing, a new round of scientific and technological revolution and industrial revolution led by intelligent industry has emerged. The manufacturing industry has once again become a key point of global economic competition. Countries have formulated manufacturing development strategies to revitalize their manufacturing industry. It can be predicted that in the next 20 years, the “new format” of engineering in the context of technological and industrial change will offer new opportunities and new challenges for the reform and development of engineering education around the world. Universities around the world have launched corresponding reform plans, such as the NEET Plan (2017-2020) proposed by MIT; the second phase of the Excellence Initiative proposed by RWTH Aachen University in 2012; RWTH 2020: Meeting Global Challenges—The Integrated Interdisciplinary University of Technology; and the Comprehensive Engineering Plan launched by University College London in September 2014. At the right time, the Ministry of Education of China has put forward the “New Engineering Education” plan, setting the direction of China’s engineering education reform in light of the new situation of international competition, the new demand for national strategic development, and the new requirement to cultivate talent. This plan offers a positive response to major national strategies, such as Internet Plus, Made in China 2025, and The Belt and Road Initiative.

Since the Ministry of Education proposed New Engineering Education (NEE) in February 2017, research and practice in New Engineering Education have become focuses of attention from all walks of life. As a result, a large number of theoretical and empirical studies on this topic have sprung up like mushrooms in the recent two years. Through bibliometric analysis, we found that the number of relevant studies in New Engineering Education has increased significantly since 2017 and that the number of research papers on New Engineering Education in each quarter has almost increased significantly compared with the previous quarter (see Figure 1). In terms of research methods, most studies have followed the tradition of research in engineering education, discussing the construction status and corresponding connotation characteristics of New Engineering Education based on typical cases using case study methods(Lu & Shang Guan, 2018; Qin &Wang, 2018; Yang &Yu, 2019). A small number of studies have explored the factors influencing the participation of engineering students in science and technology competitions based on large-scale questionnaire surveys (Mao &Dai, 2019), the quality of professional construction in New Engineering Education based on the process factor model(Liu,Xiong,&Zhang, 2019), and the development of engineering education in China over the last 40 years (see Figure 2). In terms of academic journals, *Education Modernization, Education and Teaching Forum, and Research in Higher Education of Engineering* have become the leading academic publishing platforms in New Engineering Education.

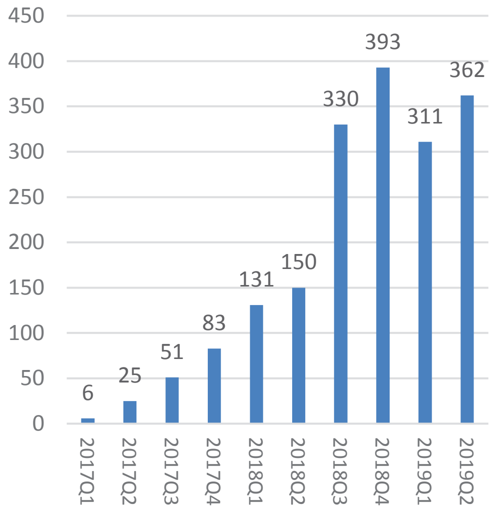

Figure1: Quarterly Changes in NEE

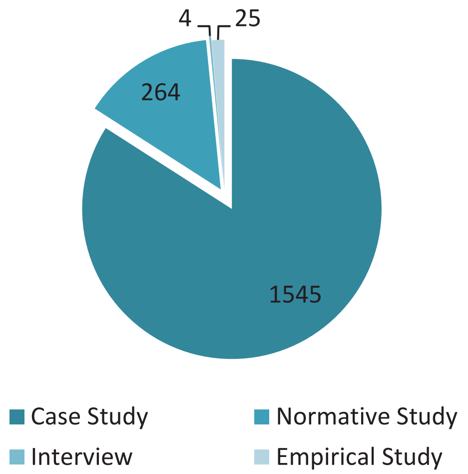

Figure2: Distribution by Category of NEE

The current literature on research and practice in New Engineering Education has focused on explaining the integration and externality of engineering education but ignored the logicality of disciplinary evolution and knowledge derivation, which has led to great limitations in explaining the evolution of New Engineering Education. It is therefore necessary to carry out systematic coding and structural analysis of previous studies. Based on a detailed discussion of specific paths for the development of New Engineering Education in different types of colleges and universities, this study attempts to construct a systematic analysis framework for research and practice in New Engineering Education to explain how engineering education has evolved in the face of the Fourth Industrial Revolution and market demand and to find a possible breakthrough to promote the paradigm shift in engineering education. To this end, this study carries out a systematic coded and structured review of 260documents published in the main CNKI journals with the keyword "New Engineering Education," since the emergence of the concept in January 2017. Starting by exploring the motivations behind the development of New Engineering Education based on the context of this development, it then refines subject characteristics, talent training objectives, construction situations, and other elements and explores its underlying logic.

Methodology

This study used a Systematic Literature Review(Jesson, Matheson, &Lacey, 2011; Borrego, Foster,& Froyd, 2014) method to systematically review and analyze the New Engineering Education literature from January 2017 to June2019. The systematic review included a content analysis, which was conducive to the critical evaluation and synthesis of previous findings, and provided useful information for future practice in research(Borregoet al., 2014). Borrego et al. (2014) proposed key steps to follow in a systematic literature review: (a) deciding to conduct a review, (b) identifying the scope of research and research questions, (c) defining the inclusion criteria, (d) identifying and cataloging the sources, (e) criticizing and evaluating these sources, and (f) synthesizing the results. Based on this method, this study adjusted and expanded these key steps as follows.

Defining: Research Questions and Sub-questions

This study systematically reviewed the literature on New Engineering Education, sorted and commented on the results of current research in New Engineering Education, and integrated logical relationships to construct a systematic analysis framework to analyze the development of New Engineering Education. What was the logic and path of its development? To answer this question, this study further defined the following key points: (1) Why was New Engineering Education developed? (2) Who developed it? (3) What kind of people should New Engineering Education cultivate? (4)At what level (and where) was New Engineering Education developed? (5) How can New Engineering Education be developed?

Scoping: Identify Where and How to Search the Literature

Using the keyword “New Engineering Education,” all documents from January 1, 2017 to June30, 2019 were searched in the China National Knowledge Infrastructure (CNKI). After eliminating duplicates, 1,932 articles were collected.

Coding: Collect the literature and develop a coding framework

First, after removing non-academic articles from newspapers and conference papers/abstracts, 1,838 valid documents were eliminated through preliminary screening, removing duplicates, and deleting erroneous messages. It is obvious that although New Engineering Education was proposed only two years ago, it has always been a popular topic. Therefore, to ensure the authority and effectiveness of the articles, only the journals from CSSCI and those of Peking University’s main journal catalogs were retained. The remaining articles were re-examined and all duplicates and errors were eliminated, resulting in a final sample of 260 valid articles. Each data entry included 9 elements of bibliographic information about the article: title, Chinese keywords, author, organization, affiliated funding, journal name, year, period, and abstract in Chinese (Table 1).

Table 1 Overview of the coding framework

Category	Item	Category	Item
Authors	The first author The second author	**Region of the first author**	Anhui Zhejiang ......
Journals	Research in Higher Education of Engineering China University Teaching Education Modernization	**Quarter**	First quarter Second quarter Third quarter ……
Research Methods	Case study Normative study Interview Empirical study	**Research Content**	Motivation Subject Objective Situation

Source: Compiled by the author

Checking: Inter-rater Reliability

Reliability in content analysis emphasizes the consistency, stability, and reliability of the measurement results of the analysis dimensions. Internal consistency results mainly from the degree of consistency of two authors coding the same content. To improve the reliability of content coding, the researchers adopted the basic process of coder training, double-blind evaluation, negotiation of differences, and mutual recognition. In the pretest, the researchers performed a preliminary reliability test on the coded content. First, the two content raters were invited and trained in coding. The training included understanding the coding table, mastering the coding procedures, and using coding tools skillfully. Next, the raters conducted a double-blind evaluation and discussed and resolved any inconsistencies.

Analysis

Motivations for the Development of New Engineering Education

Based on the literature review, this study classified these motivations into three categories: format change, national strategy, and paradigm shift in engineering education (see Table 2).

Table 2 Content of Research on Development Motivations for NEE

Motivation	Typical Description
Format change	With new advanced technologies such as artificial intelligence, big data, and cloud computing, to make breakthroughs in technology, the "new format" will introduce new subversive features in the future: Humanity, Technology, Scale, Polity, or Industry.
National strategy	With the rapid development of the new scientific and technological revolution and the new industrial revolution, competition in comprehensive national power has become increasingly fierce. We must find solutions through innovation. Major strategies include Innovation-driven Development, Made in China 2025, Internet Plus, Cyber Power, and The Belt and Road Initiative.
Paradigm shift in engineering education	Slogans such as "Return to Engineering", "Paradigm Shift in Engineering Education" and "Reengineering Education" were proposed.

Source: Based on studies by Ye et al. (2018), Xu et al. (2017), and Wang (2013), among others.

First, the global industrial transformation has led to the development of New Engineering Education. Engineering education and industrial development are closely linked and mutually supportive. Indeed, the development of new formats relies on engineering education to provide new talent. Therefore, efficiently developing the active layout and deepening the reform of engineering education can promote the vigorous development of a new economy characterized by new technologies, new formats, new industries, and new modes, and can foster economic transformation and upgrading. Only when New Engineering Education is able to break through key technologies will China be able to gain first-mover advantage and occupy the strategic commanding heights of future global innovation ecosystems (Hu et al., 2017). From this perspective, the talent knowledge structure of the "new format" posed new challenges, forcing engineering talent to take into account both sound professional technology and compound knowledge. Therefore, the development of New Engineering Education was necessary for the transformation of global formats. Second, the development of national strategies led to the development of New Engineering Education. With the rapid development of the new scientific and technological revolution and the new industrial revolution, competition in comprehensive national power has become increasingly fierce (Xu et al., 2017).It was therefore necessary to find a solution through innovation. The historical experience of developed countries has shown that the active adjustment of the structure of higher education and the development of new frontier disciplines are the central elements to promote the structural transformation of national and regional human capital and achieve the transformation from a traditional economy to a new economy. China has implemented a number of major strategies, such as Innovation-driven Development, Made in China 2025, Internet Plus, Cyber Power, and The Belt and Road Initiative. To respond to the country's strategic needs, support the vigorous development of a new economy characterized by new formats, break through key technologies, gain first-mover advantage, and occupy the strategic commanding heights of global innovation ecosystems in the future, it was necessary to rapidly cultivate a large number of emerging talents in engineering and science with increased capacity for innovation, change, and adaptability(Xu et al., 2017; Zhong, 2017). Therefore, the New Engineering Education initiative was a positive response to China's major strategies. It also illustrated the concept of "China's experience" and "China's model" in engineering education(Wu et al., 2017).Its purpose was to cultivate talent that could adapt and even drive future engineering needs(Li, 2017), meet the main needs of the country, industry, and science and technology(Hu et al., 2017), improve the country's future competitiveness, and win competitions in the global market(Lu& Li, 2017). Third, the paradigm shift in engineering education has led to the development of New Engineering Education. From the perspective of global engineering education paradigm reform, engineering education is represented on the axis of science and technology, namely the period of the technological paradigm, that of the scientific paradigm, and that of the engineering paradigm. At the end of the 20th century, international engineering education reform was developing. The slogans "Return to Engineering" (Wang, 2013), "Paradigm shift in Engineering Education" and "Reengineering Education" were proposed, reflecting the trend of international development of innovative engineering education (see Figure 3). The engineering paradigm belongs to the paradigm of integrating science and technology(Wall, 2010), and its practical tasks include project organization and communication. This paradigm highlights the role of students as professional consultants, their innovative design capabilities and empirical requirements, and ethical issues related to how science can be applied in society(Li, 2010).

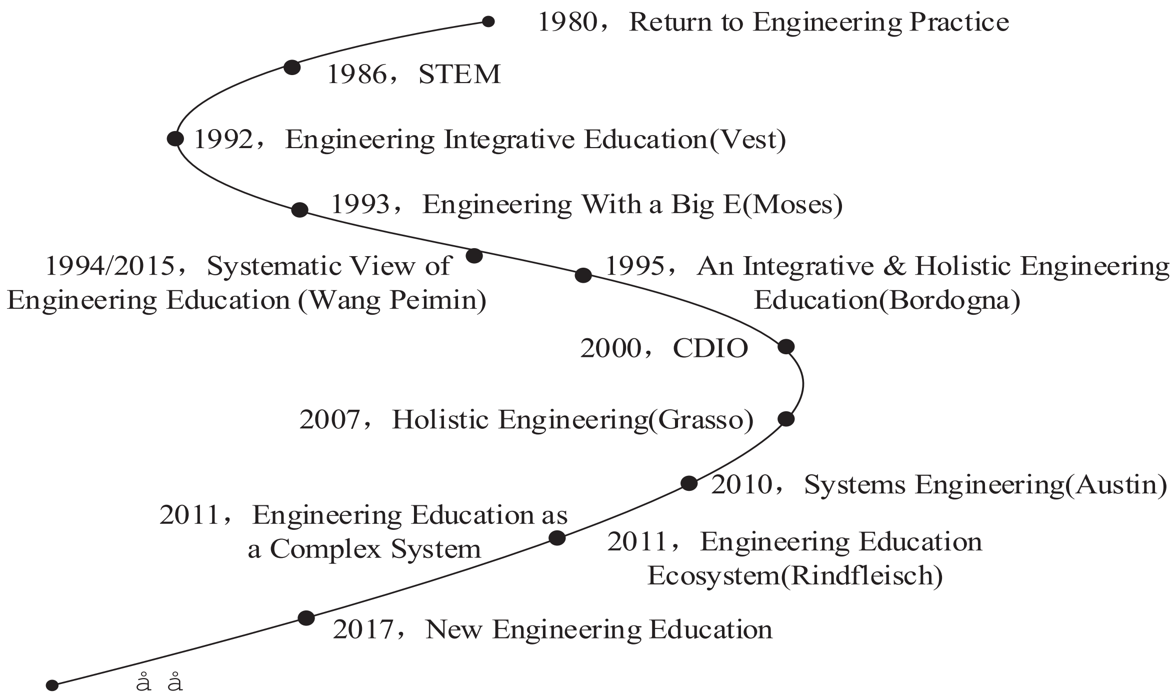

Figure 3: Theoretical Basis of the Engineering Education System. Source: Drawn by the author.

In summary, the New Engineering Education initiative was a Chinese practice aimed at actively adapting to the global trend of engineering education. Based on the perspective of the dynamic development of engineering(Reynolds & Seely, 1993), scholars have proposed that engineering education has undergone continuous development(Lin, 2017; Wang, 2017; Wu et al., 2017; Xu& Ding, 2017).Indeed, New Engineering Education was based not only on the creation of new disciplines and new specialties in the process of knowledge discovery, but also on the upgrading and transformation of traditional industries and old specialties(Li, Hu & You, 2017; Wang, 2017; Wu et al., 2017). The proposal for New Engineering Education was essential to reform the paradigm of engineering education with Chinese characteristics, to regain the central position of the "Engineering Paradigm" in engineering education, to clarify the guiding role of the system paradigm in all engineering education practices, and to solve the problems of "training concept, talent structure, knowledge system, training mode" and other problems of maladaptation of talent training in engineering education in China (Zhong, 2017).

Subjects of the Development of New Engineering Education

To explore the Chinese path and mode of the development of New Engineering Education, we must understand the developmental characteristics of higher education in the new era based on the current situation of higher education in China, starting with the subject of the development of New Engineering Education: how to combine the characteristics and advantages of different types of universities to carry out the essential work of New Engineering Education. In the only case study of domestic colleges and universities, the research momentum of Regional Universities was rapid(74articles), surpassing the sum of articles based on Comprehensive Universities and Technical Universities(see Table 3). This result highlighted the enthusiasm of Regional Universities to participate in the development of New Engineering Education.

Table 3 Content of Research on the Development of New Engineering Education

Subject	Characteristics	Cases	Main content
Technical Universities	Overall strength in engineering, benefits of research and development in technology, and close relationships with industries	Zhejiang University, Xi'an Jiaotong University, Shanghai Jiaotong University	Actively optimized the layout of disciplines and specialties, broadened the connotation and focus of engineering specialties, and fully exploited the key benefits of engineering in response to the urgent needs of current and future industrial development
Comprehensive Universities	Multidisciplinary, strong basic discipline and scientific research, and diversity in resource allocation	Fudan University, Sun Yat-sen University, the University of Science and Technology of China	Promoted the extension of applied science to engineering, explored the development path of New Engineering Education, grasped the concept of overall school development, and appropriately adjusted their system
Regional Universities	Focused on the region, relied on local resources for support, fully exploited the benefits of integrating production and education	Shanghai University of Engineering Science, Wenzhou University	Focused on a regional mode of economic development and industrial transformation and upgrading, and deepened the creation of an interactive development between engineering education and the economic society

Source: Based on studies by Lu et al. (2017), Lin (2017), Bao et al. (2017), Xu et al. (2017), Chen et al. (2017) and Xu et al. (2017).

Based on current research, the three types of colleges and universities involved in New Engineering Education had different characteristics and advantages, and their main content and directions were also emphasized. This study performed a structural analysis of this result. It found that Technical Universities relied on the overall strength of engineering, the benefits of research and development in technology, and close relationships with the industry. They actively optimized the layout of disciplines and specialties, broadened the connotation and focus of engineering specialties, and fully exploited the key benefits of engineering in response to the urgent needs of current and future industrial development. In contrast, Comprehensive Universities had the following characteristics: multidisciplinary, sound basic disciplines and scientific research, and diversity in resource allocation. They actively promoted the extension of applied science to engineering, explored the development path of New Engineering Education, grasped the concept of overall school development, and appropriately adjusted their system. Finally, Regional Universities mainly focused on the region, relied on the support of local resources, fully exploited the benefits of integrating production and education, adopted a regional mode of economic development and industrial transformation and upgrading, and deepened the creation of an interactive development between engineering education and the economic society.

As the subjects of the development of New Engineering Education, the unique attributes of colleges and universities determined the objectives and paths of development. However, during the development of New Engineering Education, the traditional advantages of some colleges and universities were not fully exploited, the convergence of construction ideas and practices was obvious, and there was a lack of systematic construction layout. Clearly, it is not possible to fully stimulate internal motivations for the development of New Engineering Education simply by adding to the curriculum and developing professional joint training and industrial docking. Therefore, in the process of developing New Engineering Education, problems such as the unclear orientation of engineering talent training, the scientization of engineering teaching, and the gap between engineering education and industrial enterprises should be avoided (Xu,Wang,&Shi, 2017), while more systematic and overall methods and measures should be adopted. By combining the characteristics and attributes of colleges and universities, attention should be paid to the development of sub-regional distribution, the management and construction of classification, the reform of talent training mechanisms, and the optimization of engineering education evaluation systems (Chen&Chen, 2017).

Objectives of the Development of New Engineering Education

In accordance with the rules of interaction between global higher education and previous industrial revolutions, and new trends and new requirements for the future development of technology and industry(MOE, 2017), scholars have focused on two main objectives in the development of New Engineering Education based on the experience of the technological paradigm, the scientific paradigm, and the engineering paradigm: discipline development and capability structure.

Discipline Development

The new technological revolution and the new industrial revolution have created a new format for global development. In addition, the development of the global economy has generated new requirements for engineering education. Through classification, we found that the popular topics and keywords covered in the "new format" involved "sharing" (Lu, 2017; Zhu,Zhou,&Li, 2017), "inosculation" (Lin, 2017; Zhu,Zhou,&Li, 2017), "integration" (Zhu,Zhou,&Li, 2017), "innovation" (Zhong, 2017), and "intelligence" (Zhu,Zhou,&Li, 2017).Based on current research, the development of New Engineering Education was based on the law of dynamic evolution of the discipline itself against the backdrop of the new economy and new industries, offering a certain degree of autonomy and flexibility(Lin&Hu, 2018)to meet the new requirements for the development of disciplines under the "new format". This included three aspects. First, a number of emerging engineering disciplines were established (Wu et al., 2017). Second, promoting the reform and innovation of the current engineering specialty, a new discipline developed from the transformation and upgrading of traditional engineering (Huanget al., 2019). Third, this new discipline was generated by the cross-combination of different engineering disciplines or the cross-integration of engineering disciplines and other disciplines (Li et al., 2019; Lin, 2017b).

Capacity structure

The development of New Engineering Education focused on "leading-edge technology", "diversity of knowledge systems" and "innovation in talent cultivation" (Ye,Kong,&Zhang, 2018). It was necessary to cultivate engineering talent that could adapt and even meet future engineering needs(Li, 2017)in response to the new requirements of the new industrial revolution and the scientific and technological revolution (Wuet al., 2017). The key to cultivating such talent was to study the talent capacity structure of New Engineering Education. General Secretary Xi Jinping proposed at the National Education Conference in 2018 "to provide socialist builders and successors with all-round development in morality, intelligence, physique, art and labor."[1]As a result, current research has further

[1] http://edu.people.com.cn/n1/2018/0911/c1053-30286253.html

explored the talent capacity structure of New Engineering Education (see Table 4) in combination with the development characteristics of new technologies, new industries, and the new economy. In this study, it was systematically divided into five aspects. The first aspect, the spirit of engineering ethics, emphasized technical ethics, ethical interests, and the ethical responsibility of engineering. As engineering ethics problems often originated in engineering practice, it was necessary to explore them in the process of talent training (Lin, 2018). The second aspect, professional basic ability, emphasized having strong professional basic knowledge, skills, and abilities (Xu & Ding, 2017).The third aspect, sustainable competitiveness, emphasized that students should have the knowledge, quality, and ability to recognize changes in the process of social informatization, the role of science and engineering in promoting these changes, and their effects on globalization(Wall, 2010). The fourth aspect, innovative design capacity (Lu, 2017; Ye, Kong, & Zhang, 2018), focused on developing the capacity for innovation, reshaped the dimension of technological art in technological development, and helped technology evolve toward life itself. The fifth aspect, practical skills, emphasized the practical skills and application skills of engineering students to better apply engineering knowledge and tools to real engineering problems (Gu, 2017; Ye, Kong,&Zhang, 2018). As a result, the reform of the New Engineering Education development strategy included objective, targeted, and systematic training of engineering talent and clear direction.

Table 4 Talent Cultivation Ability of New Engineering Education

Dimension of Ability Required for Engineering Talent	Competency Category	Concrete Ability
De (Morality)	Spirit of engineering ethics	Professional ethics and social responsibility consciousness Humanistic and social accomplishments Spirit of engineering innovation
Zhi (Intelligence)	Professional basic ability	Basic theoretical capacity Professional and technical capacity Interdisciplinary thinking ability Inter-university integration capacity Systematic thinking ability
Ti (Physique)	Sustainable competitiveness	Adaptability to change Lifelong learning ability
Mei (Creativity)	Innovative design ability	Engineering design capability Computational thinking Critical thinking and analytical ability
Lao (Practice)	Practical ability	Engineering practice capability Ability to use tools Ability to learn and apply Engineering leadership

Source: Based on studies by Lin (2018), Xu et al. (2017), Lu et al. (2017), Ye et al. (2018), and Gu (2017).

Situation of the Development of New Engineering Education

According to the statistical analysis of the current literatures, the situation of the development of New Engineering Education mainly focused on two levels: one is teaching level and the other is education system level(as shown in Table 5).

Table 5 Scope of Research Content for New Engineering Education

Situation of the development of New Engineering Education	Number of articles
Education and teaching level	132
Education system level	71

Source: Compiled by the author.

Research at the Level of Teaching

The first aspect was to grasp the professional logic and reconstruct the curriculum content system. The development of New Engineering Education required the construction of a new knowledge system. The traditional knowledge system for engineering talent mainly consisted of public courses, professional basic courses, and professional courses, which could not meet the challenges of the new industrial revolution nor those of the national strategies of Made in China 2025 and Innovation-driven Development (Zhu & Li, 2018). Therefore, to promote the development of New Engineering Education, it was necessary to update the professional training program(Lin, 2017a; Ren et al., 2019), to reconstruct the curriculum system to meet new requirements in terms of knowledge content and skills, and to design a new curriculum and teaching content accordingly. **The second aspect was to integrate cutting-edge technologies and explore diverse teaching modes.** With the continuous integration of modern information technology and the Internet Plus environment, teaching methods for engineering talent training have undergone fundamental changes (Zhu&Li, 2018). Therefore, it was necessary to adjust teaching methods according to the interests of the students, to improve teaching efficiency and effectiveness, and to promote the reform of teaching methods. **The third aspect was to reform assessments and build an engineering innovation platform.** First, thanks to the reform of the evaluation system, engineering education could return to engineering (Ye et al., 2019; Zhong, 2017).Second, the creation of an engineering innovation platform integrating education, training, and research and development (Yang, Chen & Dong, 2019)should increase interdisciplinary professional cooperation in schools, expand out-of-school collaboration with Governments, Industries, Universities, Institutes, and stress the importance of international cooperation to train engineering talent, develop research and development in industrial technology, and serve regional economic development (Lin, 2017a).

Research at the Level of the Education System

In addition to achieving breakthroughs in the development of New Engineering Education at the level of education and teaching, current research has also focused on the education system, considering the introduction or design of the overall framework, to promote the development of New Engineering Education, as shown in Table 6.

Table 6 Research at the Level of the Education System in New Engineering Education

Education system level	Concrete development in New Engineering Education
CDIO conversion platform	Based on the analysis of the construction elements of the CDIO conversion platform used as a practice path, the platform embodied systematic thinking, educational environment, training modes, and innovative practices in engineering education
Excellent Program 2.0	According to the general idea of the Excellent Program 2.0, industry enterprises are deeply involved in the training process, universities cultivate engineering talent based on general standards and industry standards, and strengthen the engineering and innovation capabilities of students

Source: Compiled by the author.

The first aspect was to build the CDIO conversion platform at the system level. CDIO, an innovative educational model, aims to train the next generation of leaders in the field of engineering. It focuses on engineering theory and engineering practice in real-world systems and the product process of Conceive, Design, Implement, and Operate. This includes systematic thinking, educational environment, training modes, and innovative practice in engineering education, which are of great importance to the practice path of New Engineering Education. Ye et al. (2018) believed that the CDIO model based on the system life cycle embodied the essential characteristics of engineering, different from those of science. For New Engineering Education, the knowledge and lessons learned from its practice path could be discussed by analyzing the construction and environmental elements of the CDIO conversion platform (Ye, Kong, & Zhang, 2018). Based on grounded theory, Ye Min et al. (2018) summarized the relevant elements of the CDIO conversion platform into five platform components, “curriculum setting, teacher policy, academic evaluation, teaching methods, and university culture,” and three environmental support elements, “national strategy, financial support, and industry participation.” **The second aspect was to promote the Excellence Program 2.0 at the system level.** To improve the quality of engineering education and accelerate China’s progress toward becoming a strong country in engineering education, China launched the “Excellent Engineer Training Program” (hereinafter the “Excellent Program”) in 2010. In June 2017, Lin Huiqing, Vice Minister of Education, pointed out that “colleges and universities should take the initiative to serve the needs of national strategy and industrial enterprises, accelerate the construction and development of New Engineering Education, and create an upgraded version of the ‘Excellence Program.’” From a design perspective, the Excellent Program focused on three main characteristics that could be used to develop New Engineering Education: industry enterprises are deeply involved in the training process; universities cultivate engineering talent based on general standards and industry standards; and universities strengthen students’ engineering and innovation capabilities. Lin Jian (2017a) proposed that as an improved version of the Excellent Program, the development of New

Engineering Education should include research and practice related to aspects of education and teaching, discipline and professional structures, discipline and professional development, talent training modes, multi-party cooperation, practice and innovation platform, teaching staff construction, and talent training quality, by adjusting the ideas of discipline and professional development and reinforcing the importance of the reform of engineering education. Zhu et al. (2018) believed that the main ideas of the Excellent Program 2.0 included support for the development strategy of engineering education in China in the new era. As a result, it was necessary to actively explore and implement the paradigm of "integration and innovation," the construction of a new knowledge system, the management methods of the professional environment, the modes of talent training, and the diversification of teaching methods (Zhu & Li, 2018).

Discussion

Based on the current literature and considering the characteristics, limitations, and weaknesses of traditional engineering education research, this study proposed a systematic logical framework for the development of New Engineering Education, including policy logic, the logic of industrial demand, the logic of disciplinary evolution and the logic of knowledge derivation. This helped to explain how engineering education had evolved in the face of the Fourth Industrial Revolution and market demand and to find a possible breakthrough to promote the paradigm shift in engineering education.

Policy Logic in the Development of New Engineering Education—Chinese Characteristics

Most of the major reforms in higher education in China were driven by national policies based on economic and social needs, while the development of New Engineering Education had clear characteristics of economic, technological, and industrial development. General Secretary Xi Jinping pointed out, "our need for higher education is more urgent than ever, and our thirst for scientific knowledge and outstanding talent is more intense than ever."[2] Following the proposal of New Engineering Education, industrial policies at the national level included the content of the development of New Engineering Education and new engineering talent training (as shown in Table 7), which became an important policy logic to promote the development of engineering education and the creation and training of engineering talent in New Engineering Education.

[2] http://www.gov.cn/xinwen/2016-12/08/content_5145253.htm?allContent#1

Table 7 Summary of Talent Policy Documents in New Engineering Education

Date	Issue agency	Policy name	Core content
Feb 18, 2017	MOE	Symposium on the Strategy of Developing Higher Engineering Education (Fudan Consensus)	The path choice for the construction and development of New Engineering Education was that universities play a leading and supporting role, with strong support from the government and social forces
Feb 24, 2017	MOE MOHRSS	Guidelines for the Development Planning of Manufacturing Talent	Five key talent projects were proposed, and the innovative talent development system and mechanism should be improved to further improve the quality of the manufacturing talent team
Apr 8, 2017	MOE	Symposium on New Engineering Education Construction(Tianjin University Action Plan)	The specific modes and methods of talent cultivation in New Engineering Education were discussed in depth, and 9 main tasks, 10 key areas, and 5 major projects were proposed
Jun 9, 2017	MOE	Guidelines for New Engineering Education Construction (Beijing Guidelines)	Continue to deepen the reform of engineering education, train high-quality engineering talent, and explore the possibility of creating an engineering education system with Chinese characteristics and global standards
Jul 20, 2017	General Office of the State Council, PRC	Next Generation Artificial Intelligence Development Plan	Support and train leading talent in artificial intelligence with development potential, promote compound talent training , and focus on vertical compound talent training and horizontal compound talent training
Dec 19, 2017	General Office of the State Council, PRC	Deepening the Integration of Industry and Education	Emphasize the development pattern of the integration of education and industry as a whole, deepen the integration of industry and education, and promote the organic connection of the education chain, the talent chain, the industrial chain, and the innovation chain
Mar 21,2018	MOE	Announcement of the First Batch of "New Engineering "Research and Practice Projects	The first batch of 612 national "new engineering" research and practice projects was identified, covering 19 project groups, including popular "New Engineering" topics such as artificial intelligence, big data, and intelligent manufacturing
Apr 11,2018	MOE	AI Innovation Action Plan for Colleges and Universities	Promote the cross-integration of discipline and specialty education and create a new model of composite specialty education: "artificial intelligence + X". By 2020, 100 "AI +X" composite specialties will be built and 50 AI institutes, research institutes or cross-disciplinary research centers will be established
Oct 08,2018	MOE MOI CAE	Opinions on Accelerating the Construction and Development of New Engineering and Implementing the Excellent Engineer Education and Training Plan 2.0	Focus on building a series of new high-level universities in science and engineering and multi-agent institutes to develop the industry and meet the future needs of emerging engineering institutes of technology, industry professionals, and the new curriculum; Cultivate the engineering practice skills of high-level professional teachers, representing more than 20% of the engineering professionals, through international equivalent professional certifications
Dec 08,2018	NDRC MOST MOE	The Initiative to Strengthen Collaborative Innovation Between Education and the Science and Technology Innovation Platform and Promote the Integration of Science and Education	Emphasize the deep integration of artificial intelligence, big data, virtual reality, and other technologies with education, promote the integration of science and education, and explore new avenues for collaborative innovation and the development of industry and education and scientific research
Apr 03,2019	NDRC MOE	Implementation Measures for the Construction of Enterprises Integrating Production and Education (Trial)	Promote a deep fusion between the demand side and the supply side; Teach integrated production enterprise construction as an important direction for the construction of a modern enterprise system; Promote "policy mix"; Motivate companies to participate in the reform of the integration of production and education through the talent cultivation system, the science and technology innovation chain of supply and demand, and the tens of thousands of fusion companies supporting the development of high quality "learning factories" created to accelerate talent acquisition for structural reforms
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Source: Compiled by the author.

Therefore, this study showed that in the current situation in China, national policies have strongly dominated and supported the reform and development of engineering education in China, providing a clear vision of the planning and construction logic of New Engineering Education and high-level design and guiding ideas for theoretical innovation, system innovation, and practical innovation in engineering education with Chinese characteristics.

The Logic of Industrial Demand for the Development of New Engineering Education—Engineering Essence

Practice is an essential attribute of engineering(Wang, 2015), and its goal is to cultivate talent for industrial development to meet the needs of the industry(Zhu,Zhou,&Li, 2017). Given the historical process of paradigm shift in engineering education, it has been found that the essential attribute of engineering and the complex changes in the environment of the engineering system and their interactions have determined the evolution of the engineering education paradigm. Therefore, the emergence and development of the industrial revolution can also be seen as a process in which the development values and modes of engineering and engineering education have evolved(Qiu,Li,&Wu, 2014). As a result, some scholars have begun to reflect on the construction logic of New Engineering Education in terms of talent demand in the global industrial reform, suggesting that the novelty of New Engineering Education was based on the industry's new demand for engineering talent and the understanding and responding to the new modes of future formats. It emphasized the guiding role of new talent demand formats to promote the revolution of traditional concepts in engineering education, the curriculum system, and the education system(Ye&Qian, 2017).

Table 8 Analysis of the Trend of Industrial Change and Paradigm Shift in Engineering Education

Industrial revolution	First industrial revolution	Second industrial revolution	Third industrial revolution	Fourth industrial revolution
Characteristics of the industrial reform	Represented by steam engine technology The era of steam technology Mechanization Simple production in factories	Represented by internal combustion engine and electric power technology The era of electrical technology Mechanization Technological scale production	Represented by computers and information technology The era of information technology Informatization Integration of science and technology	Represented by artificial intelligence, quantum technology, etc. The era of new technologies Intelligentization Integration of politics, economics, science and technology, etc.
Engineering education paradigm	Technological paradigm	Scientific paradigm	Engineering paradigm	New Engineering Education paradigm
Characteristics of engineering education	Education mode: apprenticeship Training direction: craftsmen (field engineers) Learning content: discipline and curriculum system of handicraft technology, academic engineering education gradually developed at a later stage	Education mode: scientific training mode Training direction: engineering scientists Learning content: theory of engineering science, laboratory development and research, and discussion of theoretical issues	Education mode: open, practice-oriented, and comprehensive engineering education mode Training direction: engineers Learning content: engineering practices, technology and scientific theory, returning to engineering practices and starting from practical problems	……

Source: Compiled by the authors.

Therefore, this study showed that the logic of industrial demand was important in the development of New Engineering Education. In addition, it emphasized that the development of New Engineering Education should further explore the characteristics of industrial demand with Chinese characteristics and the attributes of engineering education and continuously optimize the knowledge system, level types, and capability structure of engineering talent, to comply with the ever-changing global technological reform and the sustainable development of the industry in China (as shown in Table 8).

The Logic of Disciplinary Evolution in the Development of New Engineering Education—Discipline Development

When the knowledge system is completely inherited, taught, and innovated, a discipline is represented as an academic system, a knowledge organization, a teaching subject, or a form of activity (Zhou&Wu, 2016). Therefore, we believe that the construction and development of disciplines have their own unique evolutionary logic. Metzger (1987) proposed four paradigms of disciplinary evolution in the United States based on the early history of disciplinary evolution in higher education in the United States, namely Subject Parturition, Subject Dignification, Subject Dispersion, and Program Affiliation. From the perspective of the global paradigm shift in engineering education, the entanglement of science and technology was a unique attribute of the construction and development of engineering disciplines in the period of the technological paradigm, the scientific paradigm, and the engineering paradigm. Recently, some scholars have also begun to explore the construction and development of New Engineering Education from the evolution of the discipline itself. This study summarized the approach in two logics: the logic of disciplinary evolution and the logic of disciplinary derivation.

The first logic is the logic of disciplinary evolution. Compared with traditional engineering, New Engineering Education is a more dynamic concept (Wu et al., 2017). Its development cannot be completely separated from traditional engineering, but is the product of transformation and upgrading based on traditional engineering. Liu et al. (2019) believed that New Engineering Education did not mean completely breaking away from traditional engineering. On the contrary, New Engineering Education was closely related to traditional engineering. There should be no absolute boundary between "old engineering" and New Engineering Education. Indeed, the "new" and the "old" are always relative, dynamic, and developing. The construction of New Engineering Education should keep pace with the times and beat the forefront of progress. Similarly, Li et al. (2017) proposed that New Engineering Education should not abandon traditional engineering because of its "novelty", but should create a new form of engineering integrity through "traditional engineering+."

The second logic is the logic of disciplinary derivation. Consistent with the connotation of Subject Parturition, New Engineering Education is a new discipline created by the cross-combination of different engineering disciplines or the cross-integration of engineering disciplines and other disciplines. On the other hand, disciplines and specialties for the development of new technologies and industries in the future will be nurtured, expanded, and developed from other non-engineering disciplines, especially basic disciplines such as applied science (Lin, 2017a).

The Logic of Knowledge Derivation in the Development of New Engineering Education—Education Essence

Starting from the evolution process of engineering education and research and practice in New Engineering Education, we examined three types of logic in the construction of New Engineering Education, policy logic, industrial logic, and the logic of discipline, highlighting the importance of New Engineering Education from different perspectives and pointing out the directions for the development of New Engineering Education. At the same time, it was worth noting that the rapid growth and evolution of the current industry and the constant change and innovation of knowledge forced us to think about the unique derivative logic of the production, specialization, systematization, dissemination, and absorption of current and future knowledge.

Based on the continuous analysis of disciplines in the development of New Engineering Education and industrial logic, we found that the development of New Engineering Education was based on the reform of education and that the main logic of education was “the logic of knowledge.” With the arrival of the fourth revolution of science and technology and the continuous progress of human society, the degree of integration of various situations and factors, such as crowds, social economy, technology, and culture, is deepening, and the way of producing knowledge is also evolving (Wang,Li,&Xiang, 2018). As knowledge creation evolves to meet the new demand for industrial development, the traditional knowledge system can no longer cope with current development and innovation, and reform is urgently needed. In the development of New Engineering Education, we should pay attention to the most essential logic of knowledge, answer the questions of knowledge production, specialization, systematization, dissemination, and absorption, and discuss and analyze the general laws of knowledge evolution and development to achieve the lowest logical construction of New Engineering Education.

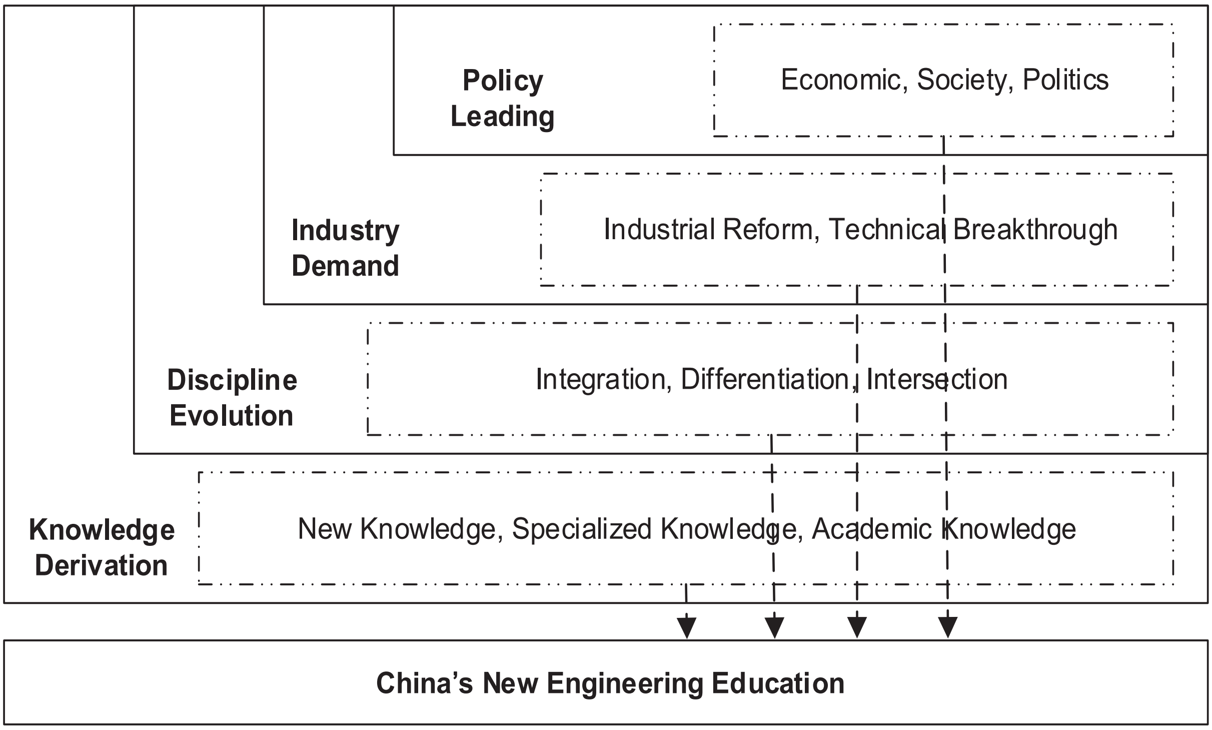

Figure 4: Logical Architecture of the New Engineering Education Development System

Source: Drawn by the author.

Based on the above logical analysis of the development of New Engineering Education, **we found that “policy logic, industrial logic, the logic of discipline, and the logic of knowledge” have the unity of systematic logic and answer the eternal question of the process of education: the matching of “supply and demand” in talent cultivation.** Whether the engineering talent cultivated by universities can meet the needs of society has become the cornerstone of the development of New Engineering Education.

Conclusion

Based on 260academic papers on the theme "New Engineering Education" from January 2017 to June2019, this study proposed a preliminary analysis of the current state of research in New Engineering Education. First, this study used the systematic review method to provide a comprehensive and systematic summary of the results of current research in New Engineering Education based on the following five aspects: (motivation)Why, (subject)Who, (objective)What, (situation)Where, and (logic)How. Second, in terms of motivations for the development of New Engineering Education, the background section of the study proposed that the development of New Engineering Education was the result of multi-level and multi-factor promotion and that these motivations were further divided into the factors of policy level, industry level, and engineering education level. Third, with respect to the subjects of the development of New Engineering Education, based on current research, this study proposed to further specify the characteristics and regional attributes of the different subjects of the development of New Engineering Education to develop New Engineering Education in terms of layers and categories. Fourth, with regard to the objectives of developing New Engineering Education, this study systematically sorted out the development of disciplines and ability training and innovatively classified the remaining skills of talent training in New Engineering Education in the literature into professional basic ability, practical skills, systematic thinking ability, engineering innovation capacity, and active learning ability. Fifth, based on current research, this study proposed four main types of logic in the development of New Engineering Education, namely policy logic, the logic of industrial demand, the logic of disciplinary evolution, and the logic of knowledge derivation, which helped to explain how engineering education has evolved in the face of the industrial revolution and market demand and to find a possible breakthrough to promote the paradigm shift in engineering education. Sixth, this study not only sorted out and analyzed the above five aspects in isolation, but integrated their logical relationships to construct a research and analysis framework for the development of New Engineering Education, taking into account the integrity and micro-logicality of research. These five aspects presented some logical relationships: (1) the subjects of the development of New Engineering Education had different motivations, logic types, and target effects based on their own attributes; and (2) under different motivations, the results of using different types of logic were the objectives of the development of New Engineering Education. Finally, the whole process took place in a specific situation, which affected and restricted it. The New Engineering Education research framework based on these logical relationships is illustrated in Figure 5.

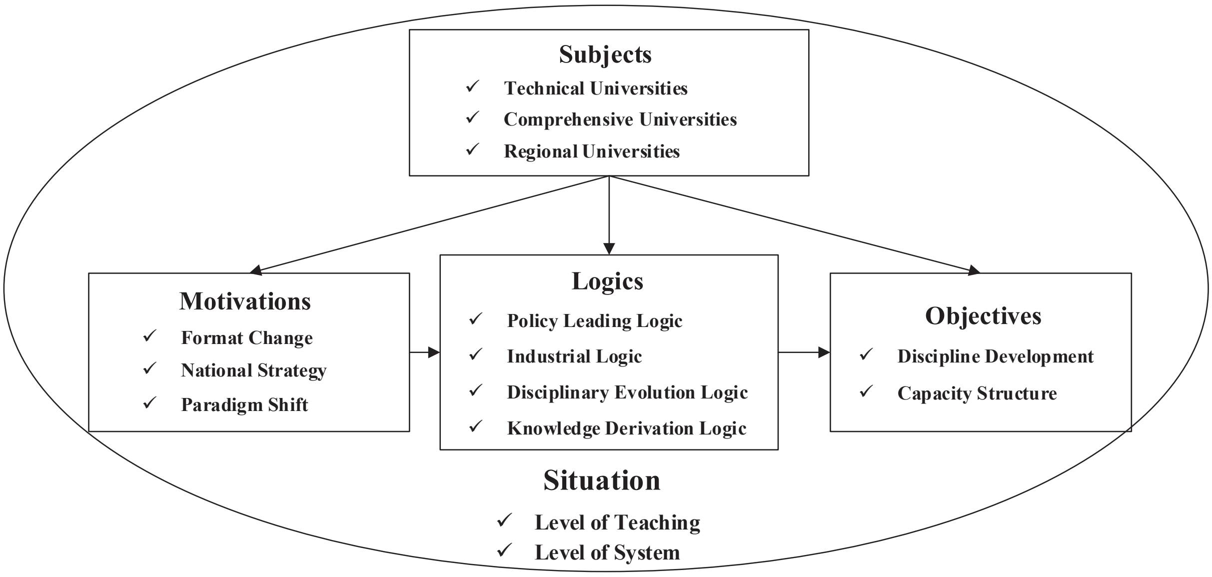

Figure 5: The New Engineering Education Research Framework

Source: Drawn by the author.

Limitations and Prospects

According to the research framework presented above, this study suggests that there is room for further in-depth research on the development of New Engineering Education, from the perspective of research, to deepen research content, or from the perspective of measurement and quantification results. **First, from the perspective of research,** current research has focused on macro-industrial logic and policy logic, preferring the analysis of education teaching and teaching systems, while few studies have discussed disciplinary evolution at the micro level and knowledge derivation. Future research should focus on these aspects to deepen and refine New Engineering Education’s research and practice from amore evolutionary perspective at the micro level, such as strengthening the identification of construction subject attributes for New Engineering Education, analyzing the characteristics of construction situations, and exploring how different types of subjects rely on the logic of disciplinary evolution and the logic of knowledge derivation to develop New Engineering Education. **Second, in terms of research content,** the development of New Engineering Education should be a systematic project of higher education and teaching reform. Current research and practice have focused on the combination of different types of motivations, subjects, logic, goals, and situations for the development of New Engineering Education. Few researches have comprehensively considered the systematism of these factors. Future research should classify and compare the development paths of New Engineering Education based on the logical framework of the construction system of New Engineering Education, conduct in-depth research on various types of construction processes in New Engineering Education, and provide information on how to better promote the construction and development of New

Engineering Education, create an engineering education paradigm with Chinese characteristics, and develop an engineering education theoretical system with Chinese characteristics. **Third, in terms of research methods,** current research has mainly focused on theoretical research, supplemented by case studies, with only a small number of empirical studies and a lack of interactive verification of different methods. Future research on New Engineering Education should pay more attention to the comprehensiveness and diversity of research methods. The research methods of vertical co-performance, grounded theory, or the fs/QCA software, for instance, can be used to compare various types of New Engineering Education construction paths, providing useful information. **Fourth, in terms of measurement and quantification results,** current research has been rather vague in judging the developmental effects of New Engineering Education, with almost no mature concepts, dimensions, and items, and even less quantitative indicators. How many and what types of construction subjects are needed for the development of a new engineering practice project? How long will it take to train engineering talent for a new project? How to evaluate the effectiveness of talent training? No current research has answered these questions. Therefore, it is suggested that research on these issues may provide detailed information on the breadth, depth, and duration of New Engineering Education.

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Military Veterans' Pathways from High School to Postsecondary Engineering Education

J. B. Main[1]
Purdue University
West Lafayette, IN, USA

C. Pantoja
Purdue University
West Lafayette, IN, USA

S. M. Lord
University of San Diego
San Diego, CA, USA

C. Mobley
Clemson University
Clemson, SC, USA

C. E. Brawner
Research Triangle Educational Consultants
Raleigh, NC, USA

M. Camacho
University of San Diego
San Diego, CA, USA

Conference Key Areas: Impacts of demographics in tertiary education; Diversity in Engineering Education

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[1] Corresponding Author
J. B. Main
jmain@purdue.edu

ABSTRACT

This study examines the pathways of U.S. military veterans from high school to postsecondary engineering education. In the U.S., there is a growing demand for engineering professionals from diverse backgrounds. Given that many military veterans come from diverse backgrounds and some receive technical training while in the military, their participation in engineering education has great potential to contribute to expanding and diversifying the engineering workforce. This is a mixed methods case study that utilizes survey data and semi-structured interviews with 20 military veterans pursuing engineering degrees across four academic institutions in the U.S. Our analysis of the survey data reveals that student veterans in engineering (SVEs) take various paths as they embark upon their engineering studies. Thematic analysis of the in-depth interviews shows that SVEs pursue engineering based on numerous factors, including: early and life-long engineering interest, encouragement from veterans' centers, and the positive job outlook. This article presents four cases of participant pathways into engineering education. Research findings provide context and information regarding student veterans' pathways into engineering, revealing overlooked areas for promoting student veterans' participation in engineering as well as encouraging the development of new strategies to support student veterans' interest and success in engineering.

1 INTRODUCTION

There are numerous calls to increase participation in postsecondary engineering education in the U.S., and the veteran population is considered to be a tremendous resource for expanding and diversifying the engineering workforce [1]. Many U.S. colleges are enrolling an increasing number of veterans with an expected growth of 30% per year due to the expanded benefits of the Post-9/11 GI Bill, which covers the full cost of in-state tuition at public colleges, and the Yellow Ribbon Program, which provides additional financial assistance to attend private colleges, making postsecondary education affordable and accessible [1]. Although the number of military veterans pursuing higher education is increasing, a relatively lower proportion of them are pursuing engineering degrees specifically, despite often receiving technical training while in the military that aligns with these fields of study. This study examines the academic and military pathways of a group of military veterans who are pursuing bachelor's degrees in engineering. Using a mixed-methods case study approach across four institutions, we conducted an online survey and individual interviews to gain insights on the following research questions:

1. What are the academic and military pathways of student veterans pursuing engineering education?
2. How do military experiences contribute to their pathways into engineering?

We analysed the survey data using descriptive analysis and the interview data using thematic analysis and identified four different pathways from high school to postsecondary engineering education including the military and often work and other higher education. Our findings provide context and information for various applications, such as: 1) identifying ways in which the military can help separating service members transition into engineering education; 2) developing new strategies to support student veterans as they plan and develop their academic and career trajectories; and 3) identifying potentially overlooked areas for promoting student veterans' participation in engineering in the U.S. Overall, we illustrate some of the paths that military veterans have taken to pursue engineering. We highlight their important stories to provide a guide for others to consider, as well as to identify areas that could be strengthened to facilitate transition into engineering specifically, and higher education, in general.

2 LITERATURE REVIEW

Since 2008, nearly 500,000 military veterans in the U.S. have used GI Bill Benefits to fund their education, and many college campuses across the nation are considering how best to serve the needs of this population [2]. Universities have increased their services for student veterans — constructing new centers to serve student veterans, augmenting campus advising services, offering early enrolment in courses to speed time to graduation, and strengthening other programming. To better inform the development of support programs for student veterans, particularly those interested in engineering, this study investigates the pathways of student veterans enrolled in engineering programs at four academic institutions.

The pathways of military veterans are complex because of several factors that distinguish their academic trajectory from traditional engineering students. There is often a gap between their high school studies and their pursuit of a Bachelor’s degree. Given the relatively large cultural transition into college from the military, which provides more structure than civilian undergraduate life [3], student veterans face unique challenges. For one, student veterans are typically older and have a wider breadth of experiences than traditional-aged college students. They are also more likely to be first-generation students; that is, students whose parents did not earn a college degree or attend college [4]. Some first-generation students struggle because their academic pathways do not share the same access to social capital as their peers who come from households with college experience. Research has suggested, for example, that they may be stymied by lower educational aspirations and/or lower academic preparation [4, 5]. However, previous studies show that military training can provide motivation for academic success and more defined career paths [6]. Military training can also provide important skills useful for engineering study and professional practice, such as technical preparation [7], teamwork, communication, and leadership [4, 8, 14].

Students choose to major in engineering for many reasons including interest in the subject matter, previous academic experiences, and the hands-on opportunities that engineering provides [10]. Individual-level characteristics, such as engineering-related attainment value (“being an engineer is consistent with sense of self”) have been shown to be associated with higher interest in pursuing an engineering degree [9, p.299]. Although these studies were not focused on student veterans, student veterans may share some of these same reasons for pursuing engineering. The present study examines the pathways of student veterans into engineering and extends our previous research using focus groups to identify military veterans’ pathways into engineering [11].

3 DATA AND METHODS

With Institutional Review Board approval, we conducted a mixed-methods case study to examine the academic and military pathways of student veterans pursuing Bachelor's degrees in engineering. Our sample for this paper is comprised of 20 student veterans across four academic institutions in the U.S, which we anonymize as Western University, Southern State, Midwest State, and Eastern University. The demographic characteristics of the student veterans we interviewed are presented in Table 1. Our sample is primarily composed of male, White Marine or Navy student veterans. Most are majoring in mechanical or electrical and computing engineering, which are also the largest enrolment engineering fields in the U.S. [15].

Interview participants completed an online survey that included questions regarding their demographic characteristics and academic and military trajectories between high school and postsecondary engineering education. We obtained data regarding our participants' trajectories using a "lifeline/life history" exercise, which asked survey respondents to identify at which age they engaged in or experienced the following activities: (1) graduated from high school, (2) joined the military, (3) served in the military, (4) attended classes, (5) left the military, (6) worked at a paid job outside of the military, and (7) attended college(s). The "lifeline/life history" exercise also included questions regarding time of marriage/divorce, birth/dependents, and service-related injury (if any were applicable), and provided open areas for respondents to add other major/significant life events. We generated an Excel chart to document the life history of each interview participant and conducted descriptive statistics on the relevant variables. We then created a visual display of qualitative information, which we coin as a "path diagram", for each participant, and subsequently compared these diagrams as a method for categorizing commonalities.

We complemented the survey data by conducting individual interviews with each of the student veterans in engineering (SVEs) using a semi-structured interview protocol. A professional transcriptionist transcribed the audio recording of the interviews, and we verified the accuracy of the transcripts through review. Our initial analysis of the data comprised re-reading the verified transcripts and writing an episode profile for each interview, which highlighted the key points and most compelling quotes in relation to the participants' military and academic pathways [12]. We also used the transcripts to verify the "life history" data provided in the survey. The interviews also provided elaboration on major life events, as well as reasons for the key transition events.

We then applied a three-step coding process comprised of open coding, axial coding, and selective coding [13] using NVivo 12, a qualitative data analysis program. For open coding, we identified the key themes related to academic and military pathways. For axial coding, we categorized these themes into the different categories of pathways. For selective coding, we connected the different pathways with one another. We compared the resulting themes and categories across and within participants, and connected the findings with the "life histories" as analysed from the survey data. We generated "case notes," which synthesized the "life history" and interview data focusing on how military experiences contribute to following the engineering path, using a representative participant from each identified pathway. The representative case for each pathway was selected in order to present a range of demographic backgrounds and engineering institutions.

Table 1. **Demographic Characteristics of Study Participants**

Demographic Characteristics		n	%
Sex	Male	20	100%
Race	White	14	70%
	Black	4	20%
	Asian	1	5%
	Other	1	5%
Military Branch	Navy	9	45%
	Marine Corp	8	40%
	Air Force	2	10%
	More than 1	1	5%
Engineering Major	Mechanical	11	55%
	Electrical & Computing	4	20%
	Civil	2	10%
	Aerospace	1	5%
	Agriculture	1	5%
	Industrial	1	5%
Total		20	100%

4 RESULTS

We identified four distinct pathways (A-D) among our 20 student veteran participants. Below we present each pathway using a representative case highlighting how the military contributed to the SVE's pursuit of a bachelor's degree in engineering.

4.1 Pathway A: Military, Work, and Higher Education before Engineering

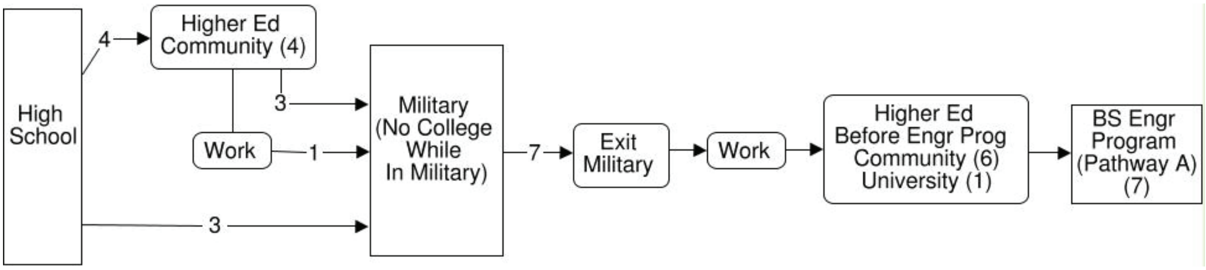

Fig. 1. Pathway A: Military, Work, and Higher Education Before Engineering

Seven respondents' pathways from high school to engineering followed that of Pathway A, where they began work soon after exiting the military and then attended a different higher education institution before pursuing their engineering degree. The representative case is Jonathan, a male, Asian American Marine studying mechanical engineering at Western University. Jonathan joined the military as soon as he graduated from high school. After serving for 4 years, he departed the military to work in his family's business. During the nine years he worked in his family business as a phone service technician, he also enrolled in a few classes at the local community college. During community college, he realized he wanted to become an engineer because of the support and encouragement he received from the campus Veterans' Success Center.

Jonathan shared,

> "What really helped me was…I was introduced to the Veterans' Center, … where you have friendly veterans willing to help… It was in the [community college] Veterans Center that… [a Marine] was openly talking about '[if] you're going to go to school, you might as well go into a degree plan that you are interested in because it doesn't matter how much the pay is if you don't like your job.' I took that into consideration. I changed my degree to mechanical engineering."

Whereas Jonathan previously thought of engineering as his hobby, his involvement with the Veterans' Center inspired him to pursue this program as a degree and to strive for higher grades in order to transfer into a four-year institution. His transition into the four-year Western University was facilitated by mentorship from another veteran who allayed his fears regarding the higher tuition. Although Jonathan did not feel that his transition to college was facilitated by the military or that his supervisors in the military actively encouraged him to pursue higher education, he received abundant mentorship from veteran peer mentors at the Veterans' Center at both higher education institutions he attended, which helped establish his pathway into engineering.

4.2 Pathway B: Military and Work before Engineering

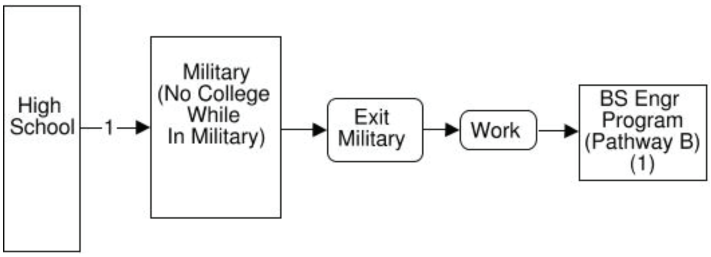

Fig. 2. Pathway B: Military and Work Before Engineering

Of our 20 interview participants, only one followed this particular pathway of entering the workforce immediately after the military and then enrolling directly into a bachelor's degree program in engineering. Jesse is White, male, and served in the Navy. He is majoring in computer engineering at Southern State. After Jesse graduated from high school, he served in the military for 3 years. He then worked for 5 years in the private sector primarily on engineering projects. His company "identified [him] as a high-value asset. They didn't want to risk losing [him] to another company so they paired [him] up with a mentor." His mentor encouraged him to pursue a degree in order to move up to management. Thus, Jesse decided to pursue a college degree, but he chose engineering because he has "always been along that engineering path" and "computers will always be [his] hobby and influence [his] life directly."

Jesse intended to go directly to college from high school and was attending college orientation programs when he overheard his parents talking about the financial challenges of paying college tuition. It was then that he decided to join the military instead because "it pays for college and you get a paycheck right away." In the Navy, Jesse was a nuclear electronics technician, and that experience solidified his interest in engineering. After exiting the military, he worked as a control engineer, and his supervisor assigned him entry-level engineering work activities. However, without an engineering degree, he had limited opportunities for a promotion to management, and that compelled him to consider pursuing a bachelor's degree. He said, "it was a fit. I was good in science and math in school, now I'm applying science and math in real life in my job, and I still like it." And as Jesse described, he appears to have always been on the engineering path, although with stops in the military and in work, both of which solidified his interest in pursuing an engineering degree.

4.3 Pathway C: Higher Ed, Military, and Higher Ed Before Engineering

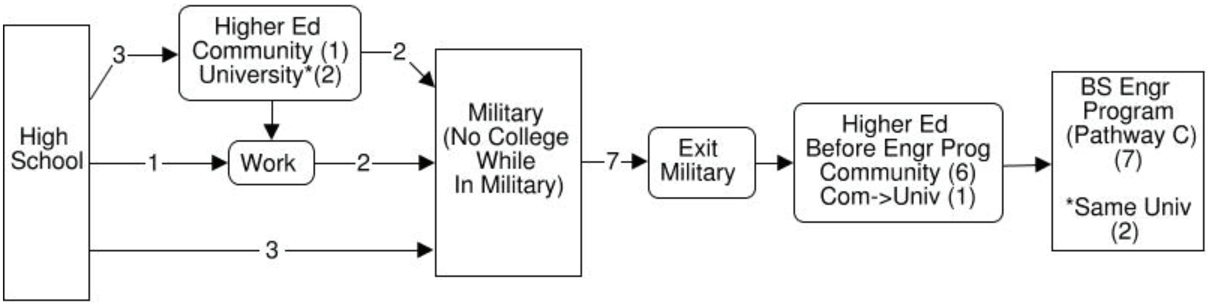

Fig. 3. Pathway C: Higher Ed, Military, and Higher Education Before Engineering

Seven of our respondents began higher education immediately after high school, but left college before graduating to join the military. Once exiting the military, they attended another higher education program before pursuing a Bachelor's degree in engineering. Our representative case for Pathway C is Brian, who was a jet engine mechanic in the Air Force, and is now pursuing mechanical engineering at Southern State. Brian is male, Black, and started engineering at a postsecondary institution immediately after high school. Even though he wanted to join the military right out of high school, he received scholarships that encouraged him to pursue higher education instead; "Joining the military… was something that I wanted to do…straight out of high school…I had scholarships to [go to college]. So, it was like everyone expected me to do that. So, I just thought, 'Well, I'll just go to [college].'" However, in his third year of undergraduate studies, Brian decided to join the military: "it finally got to the point where I was tired of school … and I wanted to be productive…Joining the military…helped me meet a lot of people… guided me while I wasn't in school and helped guide me back towards school."

For Brian, his military service drew him away from undergraduate studies, but also gave him the depth of experience and connections he was looking for, as well as the motivation, to continue to finish his engineering degree. After the military, he attended a community college and then returned to Southern State where he first started his higher education before the military. He imagines that engineering has always been on his path, "I have an uncle who's an engineer…And, I was like 'Ok, all these guys are successful.'…'Let me go try engineering...' People always told me, you like taking apart cars and all that stuff." His military service gave him the opportunity to explore the world and different applications of engineering that he needed to solidify his commitment to finishing the engineering degree. It also helped that when he returned to a bachelor's engineering degree program after the military, Brian had a sibling at the same institution and that they gave him additional support and another reason to complete his degree.

4.4 Pathway D: Higher Ed and Military Before Engineering

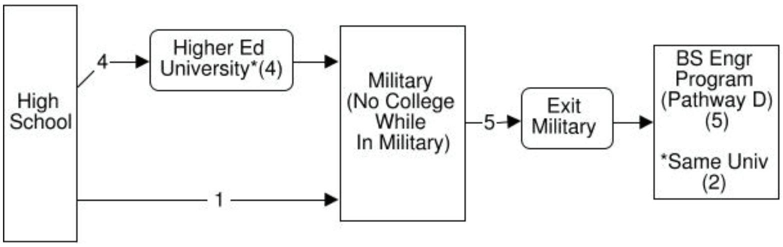

Fig. 4. Pathway D: Higher Ed and Military Before Engineering

The five respondents who followed Pathway D started pursuing engineering degrees right after exiting the military. For Harry, a white, Male Marine now pursuing agricultural engineering at Midwest State, the military was a 20-year break from college. Harry initially enrolled at Midwest State after high school as an electrical engineering student. He said, "I was only 17, and prone to 17-year-old tendencies, and I didn't do very well. I've always had the goal of coming back and becoming a [Midwest State] engineer." Looking back, he said he decided to join the military because of the "college benefits that you could earn after service."

> "There was a very rich military tradition in my family. I'm actually a third-generation Marine. There's lots of military in my family. I've always wanted to be a pilot. With doing all that, and a little bit of patriotic service, and getting college benefits, that made kind of a logical choice for me to go into the military."

After 20 years serving in the military, Harry shared, "I've finished my career. I've found more personal enlightenment in being an outside naturalist. Wildlife is more happiness than monetary…I'm a little bit older. I had the chance to do something in wildlife and ecology, environmental science, and still be an engineer." While in the military, Harry sought help in planning for returning to education, "There's a section in the headquarters that dealt with education…and they would help you out with college degrees, and then there's our separation class, where they help us transition from military to civilian life, and they connect us with the Department of Labour, Department of Defense, Veterans Affairs, entities that help you with your benefits and places that you can go to still get help." In particular, because he wanted to make a career change from aviation maintenance to wildlife range management, "that program actually sat you down and helped you with what kind of degree you want." Unlike Jonathan from Pathway A, Harry received a lot of support from the military in his transition into postsecondary engineering education. Military service helped him refine his career interests and identify an engineering path that would prepare him for a meaningful career. It also gave him the perspective and motivation he did not have at age 17 to pursue and complete an engineering degree, which was his life-long goal.

5 DISCUSSION AND CONCLUSION

Based on our interviews with 20 student veterans, we presented four pathway cases highlighting the stories of Jonathan, Jesse, Brian, and Harry. Those who travelled on pathways A and B worked after exiting the military before pursuing engineering degrees, whereas those on pathways C and D started some form of higher education after exiting the military. Our case studies reveal that military service contributed to our student veterans' pathways into engineering in a variety of ways, beyond the financial support provided by the GI Bill and Yellow Ribbon programs. Whereas Jonathan (Pathway A) did not find that his supervisors in the military actively encouraged him to pursue higher education after separation, he did find a lot of support from other veterans through two different campuses with Veterans' Centers. His engagement with the Veterans' Centers reminded him of his interest in engineering and helped him identify engineering as a viable pursuit. In contrast, Harry (Pathway D), who served in the military for 20 years, found that his time in the military helped him gain the maturity, perspective, and skills to re-try obtaining his engineering degree, albeit in a different engineering discipline, from the same academic institution he started at when he was 17 years old. Becoming an engineer was his life-long goal and his military service helped make it a possibility, including through their provision of support services during the separation and transition period. Likewise, Brian (Pathway C) found that his military service provided him a much-needed break from his initial engineering studies and instilled in him the connections and perspectives he needed to be appropriately motivated to be successful in his second attempt at an engineering degree. Jesse (Pathway B), who pursued work then engineering after military service, also indicated that engineering has always been one of his goals. Military service made college affordable and also provided him with technical skills that made him invaluable to his employer, who encouraged Jesse to pursue a degree to be considered for a management position.

Overall, as exemplified by the four case studies presented, military service has contributed positively to our participants' pathways into engineering in the U.S. For all of them, it made college affordable and provided them with the skills, perspectives, connections, and motivation to actively pursue engineering. However, all of our case studies represent student veterans who have shown some interest in science and engineering prior to entering the military. Military service helped to further and solidify these interests, both directly and indirectly. Future research should examine the experiences of military veterans who may not have as strong existing connection with engineering prior to military service and explore how technical jobs in the military may contribute to potential interest in professional engineering practice. Our research findings provide important contextual information for student services centers and other groups and organizations supporting military veterans' transition into civilian life and into postsecondary education. Research findings also illustrate important stories that could potentially inform other military veterans about the multitude of pathways travelled and how some student veterans have leveraged their military service. While our study focuses on SVEs in the U.S., our findings have implications for academic institutions with non-traditional students in other countries. Support provided by academic institutions and from student peers make a difference in the academic trajectories of non-traditional students.

6 ACKNOWLEDGMENTS

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The Early Career Outcomes of Engineering PhDs in the United States

J. B. Main[1]
Purdue University
West Lafayette, IN, USA

Y. Wang
Purdue University
West Lafayette, IN, USA

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Keywords: Engineering PhDs; Career Pathways; Industry; Faculty; Employment Outcomes

ABSTRACT

Examining the career paths of engineering PhDs in the United States has important implications for strengthening the engineering workforce. This study models the early career outcomes of engineering doctorates by sex, race/ethnicity, citizenship, and other observable characteristics, as well as identifies factors that influence these pathways using regression analyses on nationally representative data from the National Science Foundation Survey of Doctorate Recipients. Research findings show that early employment outcomes vary by PhD demographic factors, including sex and race/ethnicity. The logistic regression results show that primary source of funding, such as fellowships/grants and research assistantships, are associated with employment in tenure track faculty positions. Additionally, the employment outcomes of previous PhD cohorts from the same program and the relative ranking of the engineering program also contribute to early career outcomes.

[1] Corresponding Author
J. B. Main
jmain@purdue.edu

1 INTRODUCTION

Although initiatives and programs designed to broaden participation in academic institutions have generated many positive changes, the proportions of women, African American/Black, Hispanic/Latino, and Native Americans have not seen commensurate increases in engineering fields in the U.S. [1]. There is a strong connection between the demographic composition of faculty and the level of diversity and persistence among undergraduate and graduate students, such that it is critical to identify who pursues faculty careers and why they pursue this career path to further develop strategies to broaden participation in the engineering professoriate [2-4]. It is equally important to identify who pursues careers in industry, government, and other areas to better explain career decision making and how PhDs view different career paths, as well as to develop strategies to help prepare PhDs for the realities of the multitude of careers available beyond the professoriate. This study examines the early career outcomes of engineering doctorates by sex and race/ethnicity, and identifies the factors that influence attainment of the first post-PhD employment sector using logistic regression analyses. We leverage data from the National Science Foundation Survey of Doctorate Recipients, which is representative of all engineering PhDs in the U.S., to address the following research questions:

1. What are the employment patterns of early career engineering PhDs, and are there differences by sex and race/ethnicity?
2. Which factors at the individual and departmental levels influence the first post-PhD employment sector of engineering PhDs?

Research findings provide important context and information for various applications, such as policy formation, development of strategies and interventions to promote a competitive engineering workforce, increasing information flow and partnerships between academia and industry, and providing students with critical information on the multitude of career paths available to doctorates. Doctoral students, particularly women and underrepresented minorities (African American, Hispanic/Latino, and Native American), will be able to more accurately assess their early career prospects, which have implications for persistence and broadening participation in the engineering workforce. This study has the potential to inform the approaches and strategies to prepare doctoral engineering students for a rapidly changing, global work environment.

2 LITERATURE REVIEW

The major employer sectors for engineering PhDs in the U.S. include academia (tenure track, non-tenure track), industry (private or business sector), and non-academic public sectors, such as government and non-profit organizations [5]. Although doctoral programs are traditionally designed to train scholars for academic research, the majority of engineering PhDs find employment in non-academic sectors, especially in industry [6-8].

The individual-level factors that affect career choice among new engineering doctorates include individual characteristics/background, experiences during PhD program, and field of study [5-9]. In general, PhDs with higher levels of interest in basic research, desire for peer recognition, and preference for autonomy in choosing research topics are more likely to pursue basic research in academia, whereas PhDs with greater preference for applied research aimed at technological development, professional experience, and monetary returns are more likely to pursue careers outside of academia [5-7]. Individual preference for types of careers changes over time, and experience during PhD training also influences subsequent career choice [9]. The field of study, including the engineering discipline, also has an impact on PhDs' career choice [8].

Labour market conditions also play a role in new doctorates' career choices. For example, there is evidence that institutions are training more engineering PhDs than can be employed as tenure-track faculty [9, 10]. Subsequently, a number of PhD graduates need to find employment outside of academia [11] or to find temporary positions within academia, such as non-tenure track faculty or research positions [12-14]. While the number of PhD students aspiring to work as faculty members tend to exceed the number of available tenure-track faculty positions [10], there is also increasing evidence that declining job security and lack of opportunities to establish a research program may be diminishing the attractiveness of academic positions to engineering PhDs [9, 11].

3 DATA AND METHODS

3.1 Data

Our sample is comprised of engineering PhDs who responded to the 1993-2013 waves of the National Science Foundation Survey of Doctorate Recipients (SDR). The SDR is conducted approximately biennially on a nationally representative sample of PhDs in engineering (and science and health), who received a PhD degree from a U.S. academic institution. The SDR provides demographic, educational, and employment history information for each respondent. We match our sample of SDR respondents to data from the National Science Foundation Survey of Earned Doctorates (SED). The SED is a census of recipients of research doctorates from accredited U.S. institutions, which provides demographic information, educational history, and post-graduation plans of recent doctorates. We also include data from the National Research Council's ranking of the PhD program, which we categorized into three groupings: top-ranked, mid-ranked, and not ranked. Our resulting merged data therefore includes both educational and employment histories for engineering PhDs, as well as measures for relative engineering doctoral program ranking.

Our sample includes PhDs from Aerospace, Civil, Chemical, Electrical/Computer, Mechanical, and Other Engineering. Due to a change in the specific fields of study reported in the SDR in 2001, the "Other Engineering" category includes Industrial, Materials and Metallurgical, as well as other engineering fields not specified in the SDR. Table 1 presents the summary statistics of demographic characteristics and employment information for respondents who completed the SDR 1-2 years after their PhD completion (n = 6,192) during the 1993 through 2013 survey waves.

Consistent with reports regarding the underrepresentation of women in the engineering workforce, only 21% of the sample is comprised of women. Black and Hispanic engineering PhDs each comprise less than 6% of the engineering workforce. In terms of employment, during the period of 1-2 years after PhD completion, the largest proportion of engineering PhDs work in industry (57%), followed by non-tenure-track positions (19%), tenure-track positions (11%), and then government positions (8%).

Table 1: Description of the 1993-2013 Survey of Doctorate Recipients Sample

Variable	Initial career 1-2 years since PhD n (%)
Sex	
Female	1,309 (21.1)
Male	4,883 (78.9)
Race/Ethnicity	
Asian	2,557 (41.3)
Black	327 (5.3)
Hispanic	334 (5.4)
White	2,887 (46.6)
Other Ethnicity	87 (1.4)
Citizenship	
U.S. citizen	3,449 (55.7)
Perm. resident	1,056 (17.1)
Temp. resident	1,686 (27.2)
Disability	
No	5,470 (88.3)
Yes	722 (11.7)
Marital status	
Married	4,298 (69.4)
Not Married	1,894 (30.6)
Children under age 6	
0	4,305 (69.5)
1	1,292 (20.9)
2 or more	595 (9.6)
Work status/Employer sector	
Government	466 (7.5)
Industry	3,551 (57.3)
Non-profit	176 (2.8)
Non-tenure track	1,169 (18.9)
Tenure track	671 (10.8)
Unemployed	112 (1.8)
Not in labour force	47 (0.8)
Total	6,192 (100)

3.2 Methods

To examine the early career outcomes of engineering PhDs, we use descriptive statistics and logistic regression models.

Employment patterns. In addition to the descriptive statistics provided in Table 1, we generated Figure 1 to illustrate the employment patterns of early career engineering PhDs by sex, race/ethnicity, and employment sector.

Initial job placement by employment sector. Leveraging information from both the SED and the SDR, we use logistic regressions to identify individual- and departmental-level factors that influence engineering PhD initial job placement by employment sector (1-2 years after the PhD). Our analyses are based on the sample of engineering PhDs who responded to the SDR between 1993 and 2013 and were in the workforce during the survey reference week. We focus on the following employment sectors: tenure track, non-tenure track academic, industry, and government because these sectors are the most prevalent areas of employment based on the descriptive statistics (Table 1).

For each of the employment sector, we estimate the following model:

$$Ln\left(\frac{\mathrm{p_i}}{1-\mathrm{p_i}}\right)=X_{\mathrm{i}}\beta+u_{\mathrm{i}}, \qquad (1)$$

where p_i is the probability that individual *i* is initially employed in the given employment sector, X_i is a set of covariates for individual *i,* which includes sex, race/ethnicity, U.S. citizenship, disability status, marital status, number of dependents under 6 years old in the household, age at PhD completion, and primary financial support during the doctoral education, and u_{i} is the error term. For race/ethnicity, the model includes Asian, underrepresented minorities (URM), and White as the reference category. We also include in the model parents' education, time to PhD degree, PhD degree year, and engineering discipline, although the coefficients for these variables are not shown in the resulting table. Primary financial support includes fellowship/grant, research assistantship, teaching assistantship, and self-funded as the reference category. In terms of departmental characteristics, the model includes the categorized National Research Council ranking for the PhD department (top-ranked, mid-ranked, or not ranked), as well as the job placement/employment sector of the 5 previous cohorts graduating from the same engineering program as individual *i*.

4 RESULTS

Figure 1 provides a visual summary of the percentage of PhDs employed in different sectors (government, industry, non-profit, non-tenure track, tenure track, and unemployed) by sex and race/ethnicity. As also shown in Table 1, the majority of engineering PhDs work in industry. However, the percentage varies by demographic characteristics. Among Asian female and male engineering PhDs, those working in industry constitute the highest relative percentage, but those working in tenure-track faculty positions or are unemployed constitute relatively lower percentages. Relative to Asian women, Hispanic and Black women have higher percentages of engineering PhDs in tenure track faculty positions. This trend is consistent among men as well.

Our logistic regression results are presented in Table 2. The attainment of tenure track, non-tenure track, industry, and government positions are shown in separate columns. In terms of tenure track faculty positions, women are 4.5 percentage points more likely than men to start out in these positions 1-2 years after PhD completion. However, consistent with Fig. 1, Asian engineering PhDs are 6 percentage points less likely, and URM engineering PhDs 4 percentage points more likely, than White engineering PhDs to be in tenure-track faculty positions. The primary type of financial support during doctoral education matters—PhDs with fellowships/grants are 5 percentage points more likely, and those with teaching assistantships 8 percentage points more likely, than PhDs who are self-funded to obtain tenure track positions. Departmental characteristics also play a role in the likelihood of obtaining a tenure track position. PhDs who graduate from top ranked institutions are 2.1 percentage points more likely than those from mid-ranked institutions to be an early career tenure-track faculty member. Departmental norms regarding job placement also appear to contribute to career outcomes, as departments with higher proportions of previous

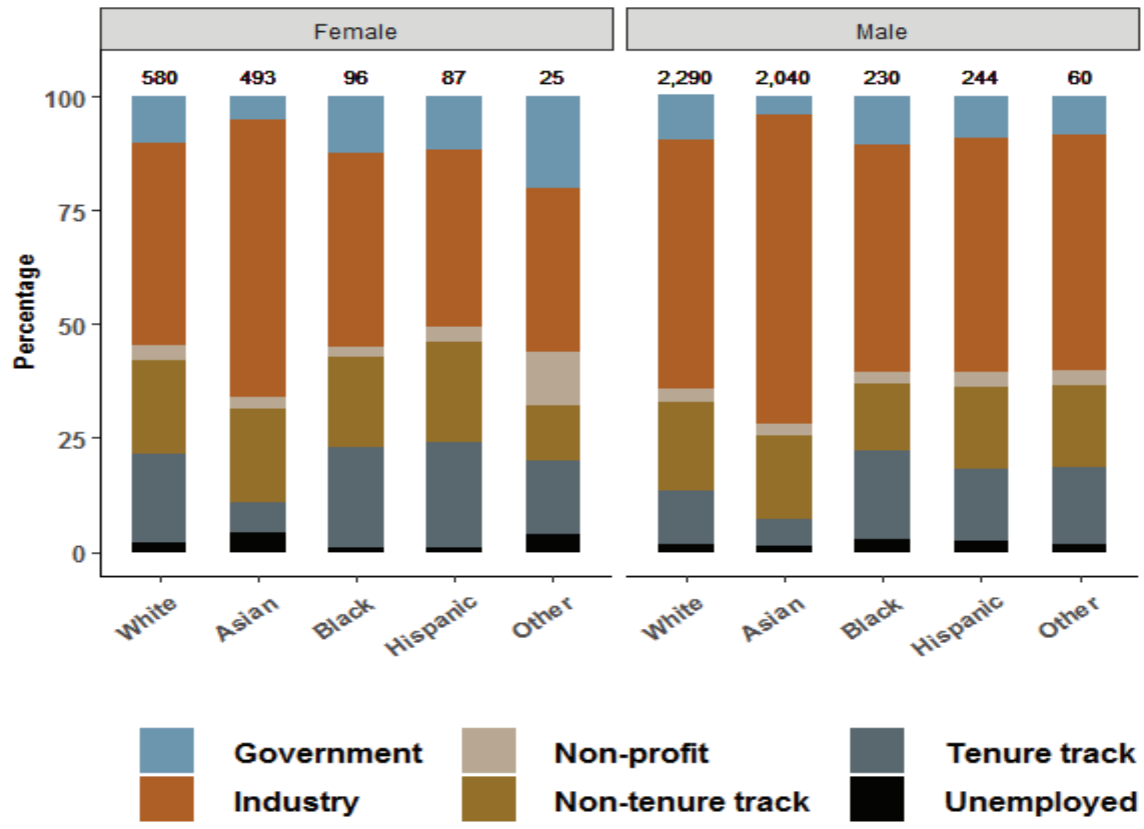

Fig. 1. Initial employment sector 1-2 years after the PhD by sex and race/ethnicity.

graduates obtaining academic positions are more likely to continue this pattern.

Consistent with our descriptive Figure 1, Asian engineering PhDs are more likely to work in industry, but less likely to work in non-tenure track academic positions, compared to their counterparts. URM engineering PhDs are also less likely to work in non-tenure track academic positions and in industry than White engineering PhDs. The primary financial support appears to only be significant for tenure track faculty positions, except that engineering PhDs who were self-funded are more likely to work in government sector compared to PhDs who were funded through research or teaching assistantships, by 1.3 and 2.4 percentage points, respectively.

In terms of department-level characteristics, PhDs graduating from programs that are not ranked are 4.5 percentage points more likely than those graduating from mid-ranked programs to obtain a non-tenure track academic position. Meanwhile, engineering PhDs who graduated from top-ranked programs, as measured by the NRC rankings, are less likely than PhDs graduating from mid-ranked programs to work in the industry and government sectors. The employment outcomes of previous PhD cohorts also appear to play a role. PhDs who earned their degrees from programs where a higher proportion of previous cohorts obtained jobs in government are also more likely to work in the government sector.

Table 2: Estimated marginal effects of factors associated with initial job placement by employer sector

	Tenure track	Non-tenure track	Industry	Government
Individual Characteristics				
Female	0.045**	−0.016	−0.051*	0.009
	(0.017)	(0.019)	(0.027)	(0.011)
Asian	−0.061***	−0.046***	0.113***	−0.001
	(0.009)	(0.012)	(0.017)	(0.007)
URM	0.039***	−0.036**	−0.036*	0.009
	(0.012)	(0.014)	(0.022)	(0.008)
Perm. resident	−0.013	0.053***	0.055***	−0.045***
	(0.011)	(0.018)	(0.021)	(0.006)
Temp. resident	−0.018*	0.102***	−0.003	−0.054***
	(0.01)	(0.017)	(0.019)	(0.006)
Disability	0.012	0.008	−0.03	0.005
	(0.011)	(0.016)	(0.021)	(0.008)
Child<6	0.017*	0.011	−0.025	−0.002
	(0.01)	(0.014)	(0.018)	(0.007)
Married	0.02**	−0.06***	0.055***	−0.004
	(0.01)	(0.015)	(0.019)	(0.008)
Child<6*Female	−0.006	0.009	−0.079*	0.017
	(0.019)	(0.031)	(0.043)	(0.019)
Married*Female	0.003	0.053*	−0.059	0.001
	(0.019)	(0.031)	(0.037)	(0.014)

31-40	−0.003	0.045***	−0.07***	0.014**
	(0.008)	(0.011)	(0.015)	(0.006)
40 or older	0.022	0.04*	−0.085***	−0.002
	(0.015)	(0.023)	(0.027)	(0.009)
PhD Financial Support				
Fellowship/Grant	0.048***	0.017	−0.031	−0.009
	(0.017)	(0.02)	(0.025)	(0.008)
Research Assistantship	0.009	0.009	0.022	−0.013*
	(0.011)	(0.014)	(0.019)	(0.008)
Teaching Assistantship	0.077***	0.002	−0.019	−0.024***
	(0.023)	(0.022)	(0.03)	(0.009)
Institutional Characteristics				
PhD Program NRC Ranking				
Not Ranked	−0.018	0.045**	−0.041	−0.01
	(0.012)	(0.02)	(0.025)	(0.008)
Top Ranked	0.021**	0.016	−0.028*	−0.015**
	(0.009)	(0.012)	(0.016)	(0.006)
Percent of Previous 5 Cohorts in				
Post-doc	0.017	0.052	−0.068	−0.022
	(0.034)	(0.045)	(0.064)	(0.024)
Academia	0.108***	0.028	−0.177**	−0.023
	(0.041)	(0.057)	(0.08)	(0.03)
Industry	0.008	−0.147***	0.229***	−0.056*
	(0.039)	(0.053)	(0.072)	(0.029)
Government	−0.04	0.0004	−0.32***	0.129***
	(0.062)	(0.076)	(0.107)	(0.03)
Observations	6,145	6,145	6,145	6,145

Estimated marginal effects of factors associated with initial job placement in tenure-track, non-tenure track, and industry, respectively. Parents' education, discipline, and degree year are included in the model, but not shown in the table. *p<0.1; **p<0.05; ***p<0.01.

5 DISCUSSION AND CONCLUSION

With the United States' call for a larger and more diverse engineering workforce, identifying the role of doctoral education in preparing engineering students for a multitude of careers is more important than ever. Our descriptive analysis showed that the first employment sector that engineering PhDs enter varies by sex and race/ethnicity. We also identified which individual- and departmental-level factors contribute to the different early career outcomes using logistic regression analyses. We found that demographic characteristics, primary financial support, program ranking, and the employment outcomes of previous cohorts matter.

These findings provide important context for developing strategies to increase diversity across the different employment sectors in the United States. Doctoral programs can use these findings to better inform their students about the different career outcomes of engineering PhDs. The findings also provide information for current and prospective doctoral students to develop post-graduation career plans given their own interests and the likely career outcomes of previous cohorts of engineering PhDs. While our study focuses on engineering PhDs in the U.S., our findings provide important comparative information for PhD programs in other countries. Prospective students from other countries considering attending an engineering program in the U.S. can also use these findings in their academic and career decision making. For example, we found that PhDs who are temporary residents are more likely than U.S. citizens to work in non-tenure track faculty positions, but less likely to work in tenure-track or government positions.

Future research will examine how early career employment outcomes contribute to the long-term career pathways of engineering PhDs in the U.S. 5 years and 15 years from degree completion. We will also investigate whether non-tenure track academic positions, such as postdoctoral research positions, lead to tenure track faculty positions. We plan to complement our quantitative analyses with interviews with engineering PhDs to provide more information regarding their doctoral education preparation and career transitions and paths.

6 ACKNOWLEDGEMENTS

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Engineering Education, Split Between Two Cultures: An Examination into Patterns of Implementation of Ethics Education

D. A Martin[1]
Technological University Dublin
Dublin, Ireland

E. Conlon
Technological University Dublin
Dublin, Ireland

B. Bowe
Technological University Dublin
Dublin, Ireland

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Keywords: engineering culture; ethics education; nontechnical skills; delivery methods; accreditation

ABSTRACT

International literature points to the unevenness of ethics education in countries where ethics is an accreditation criterion for engineering programmes ([3], [8], [21]), and a low presence in countries where ethics doesn't feature as an accreditation criteria [20].

Given that most research carried on the implementation of engineering ethics education is based in US, our contribution aims to fill a gap by providing insights into the implementation of ethics education in the European context. The study enquires how ethics is implemented in engineering programmes in Ireland, where ethics is an accreditation criterion since 2007 [10]. The research is supported by the national accreditation body and the sample consists of 23 engineering programmes in Ireland. The method employed is a simple statistical analysis based on a rubric present in the documentation submitted for accreditation, in which programmes are required to self-assess how each accreditation outcome is being met.

The findings reveal that nontechnical outcomes have the lowest weight in the curricula of engineering programmes, with ethics having the lowest presence of all accreditation outcomes according to the programmes' self-assessment. These findings show the prevalence of an engineering education model focused on the development of technical skills. There are also disciplinary differences in the provision of ethics education, with programmes of electric, electronic and computer engineering attributing a lower eight to ethics and other nontechnical outcomes compared with other engineering disciplines.

[1] Corresponding Author: DianaAdela.Martin@dit.ie

1 BACKGROUND

Ethical concerns are a recent addition to engineering programmes. Traditionally, disciplines of exact sciences such as engineering were regarded as morally neutral, and henceforth did not require ethical instruction [9]. Looking at the history of engineering education and current trends, three paradigms of engineering professional identity emerge [14]. These represent three competing visions about the nature of the engineering profession, as well as about the educational approaches to support them.

First, there is the academic vision of engineering as applied science, dominant in science universities. Second, a market-driven vision of engineering as technological innovation, present in an entrepreneurial university model. Thirdly, we have the integrative vision of engineering as public service, promoted by an ecological oriented university. Describing the later approach, ([14], p.264) notes that it mixes elements of both the academic and market driven models into a “socially oriented hybrid” that favours an educational approach which includes the scientific, technical, ethical, social and environmental dimensions of engineering. They also state that this mode of engineering education has played a less prominent role historically.

Currently, there is an increased presence of ethics education in national accreditation systems of engineering programmes worldwide, following the introduction of the Washington Accord [7]. The Washington Accord places a strong emphasis on the ethical and social responsibilities of engineers, stating that graduates are expected to “understand and commit to professional ethics and responsibilities and norms of engineering practice,” as well as to “understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts” and “apply reasoning informed by contextual knowledge to assess of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering practice and solutions to complex engineering problems” [13]. Nevertheless, the current state of engineering ethics education points to an uneven presence in countries where ethics is an accreditation criterion for engineering programmes ([3]; [8]; [21]). There is also a significant disparity between the perceived importance of ethical and societal related practices by engineering faculty and their actual presence in the curriculum of engineering programmes ([22], p.14).

In Portugal, where ethics education does not feature as an accreditation criterion for engineering degree programs, 60% of the courses did not provide any mandatory or optional ethics units in their curriculum [20]. [19] puts this situation down to the strong influence of the lecturer in shaping curriculum development, combined with a reduced ethical training of engineering lecturers. She notes that “almost all engineering teachers had made an academic career that didn't include any curricular explicit form of ethics education.” This finding is consistent with empirical research carried in US ([3]; [11]; [15]; [27]; [28]) and Australia ([24], p.136), which revealed that ethics had a low presence in the curriculum of engineering programmes prior to the introduction of an ethical criterion for accreditation. Accreditation bodies can thus have a positive influence on how programmes shape their curricula in this regard, given that an ethical criterion for accreditation has been shown to lead to an increased emphasis on engineering ethics education.

The main risk associated with a weak presence of ethics education in engineering programmes is that of perpetuating a traditional view of engineering as a solely technical discipline. With it, passing on to students the message that ethics is not as important for their education and future profession as other skills, such as technical abilities ([18], p.525). In our times marked by a rapid pace of technological development, the two cultures of science and humanities described by [25] can no longer exist separately and on different hierarchical levels.

[6] warns about the dangers of separating the “two cultures” in engineering education. She observed a correlation between the emphasis placed by a programme on ethical and social issues and students’ concern for their ethical and social responsibilities as engineers. Students from engineering programs that favour the development of technical skills to the detriment of ethics and social engagement tend to have declining beliefs about the importance of public welfare from their first to their last year of studies. ([1], p.58) also found that as engineering students advance in their study programme, they tend to develop strong and rigid views about the lower value of academic disciplines oriented towards people and society. A survey about the views on ethics held by students upon entering their engineering degrees show that almost a third of the 1136 first year engineering students interviewed did not believe that engineers act ethically and it was not realistic to expect engineers to have an ethical behaviour [26]. Engineering students are also found to express significantly lower commitment to social activism and concern for society than students from other disciplines ([2]; [23]). What is worse, [6] notes, engineering students’ engagement with public welfare issues does not rebound upon graduating and entering the workforce.

University education is the propitious period when engineering students start to develop their identities as future professionals [17]. The weight given to ethics in the engineering curricula is extremely important in sending students the message that ethics is not peripheral to engineering, but a substantial aspect of their profession [16]. As ([5], p.72) points out, teaching only the technical aspects of engineering will direct students to consider solely these once they go into the work field, without even noticing the ethical concerns embedded in their work. This further enforces [6]’s contention that "if engineering programs can overcome forces of isomorphism […] they could produce a new brand of engineer, one that thinks critically about the construction of public welfare and the technological systems on which he/she works." The stakes are thus high on the issue of a more important weight given to ethics in engineering programmes, on a same par with technical related learning outcomes.

Summing up, the main findings of the literature review show that the current state of engineering ethics education is characterized by a growing presence of ethics education in engineering educational systems where ethics features as an accreditation criteria, yet still a low priority given to ethics in the engineering curricula. Notable is also the correlation between the emphasis given to ethics in the curricula of engineering programmes and the formation of students’ professional identity as socially responsible engineers.

2 METHOD

The main research question of the paper is what are the patterns in regards to the weight given to ethics in Engineering Honours Programmes in Ireland? To answer this question, we use a quantitative simple statistical analysis of the documents submitted for accreditation by participant Engineering programmes. The method is employed to determine the presence of ethics related outcomes in the engineering curricula according to the programmes' own assessment of how they meet each of the seven accreditation outcomes.

The analysis is based on a rubric present in each document submitted by Engineering programmes in Ireland for accreditation. In this rubric, programmes are asked to self-assess how each of their modules meets the seven accreditation outcomes presented in Table 1.

Table 1. Programme outcomes for accreditation of Engineering programmes in Ireland

Programme outcome	Domain
a	Knowledge and understanding of the mathematics, sciences, engineering sciences and technologies underpinning their branch of engineering
b	The ability to identify, formulate, analyse and solve engineering problems
c	The ability to design a system
d	The ability to design and conduct experiments and to conduct guided research
e	An understanding of the need for high ethical standards in the practice of engineering, including the responsibilities towards people and the environment
f	The ability to work effectively as an individual, in teams and in multidisciplinary settings, together with the capacity to undertake lifelong learning
g	The ability to communicate effectively on specialised engineering activities with the engineering community and with society at large

The self-assessment scale recommended by the accreditation body contains 5 scores ranging from 0 to 4. These are known as POLO scores and their meaning is described in Table 2. The programmes have to assigning a scoring for each of their modules, based on the learning outcomes achieved by the module. Typically, this self-assessment process is carried by the module's coordinator(s), as specified in the documents submitted for accreditation by seven programmes.

Table 2. Five-point POLO scale for module contribution to programme outcomes

Score	Description
4	Module strongly contributes with a large component of assessment relating to the Programme Outcome.
3	Fairly strong contribution, with significant assessment relating to the Programme Outcome.
2	Some assessment relating to Programme Outcome, but the Programme Outcome is not a central theme of the module.
1	Only a small portion of assessment relates to the Programme Outcome.
0	Module does not contribute to the Programme Outcome.

Ireland has a two-tiered system of engineering education, divided into universities and institutes of technology. Programmes offered by both institutions types were included in the current study: 15 programmes offered by universities and 8 programmes offered by institutes of technology. In total, 7 institutions participated: 5 universities and 2 institutions of technology. One institution of university type whose programmes underwent accreditation in the period under analysis declined to participate. The programmes comprise a wide range of engineering disciplines, as seen in *Table 3.* This allows the researcher to analyse different disciplinary contexts of engineering ethics education.

*Table 3***.** Participant Engineering programmes disciplines

University programmes	**Institute of Technology programmes**
Electronic and Computer Engineering (2)	Electronic Engineering (1)
Electrical and Electronic Engineering (2)	Manufacturing and Design (1)
Electrical Engineering (1)	Building Services Engineering (1)
Electronic Engineering (1)	Structural Engineering (1)
Computer Science and Information Technology (1)	Civil Engineering (1)
Civil, Structural and Environmental (1)	Energy Systems Engineering (1)
Civil Engineering (2)	Mechanical Engineering (2)
Energy Engineering (1)	
Mechanical Engineering (2)	
Process and Chemical Engineering (1)	
Biomedical Engineering (1)	

The programme averages for each of the seven learning outcomes have been calculated based on the POLO scores provided by the programmes in the documentation submitted for accreditation Only 56% of the programmes (amounting to 13 programmes) used the scale of 0-4 recommended by the accreditation body, for the purpose of self-assessment. Although all 8 IOT used the 5 point scale recommended by Engineers Ireland, less than a quarter of the university programmes (amounting to 5 programmes) employed this scale.

The remaining 10 university programmes employed a diverse range of scales, besides the 0-4 POLO scale. Three programmes from the same university institution employed a self-assessment scale of 0-22, which the researcher uniformed as follows. The programme used a score of 1-5 to indicate “a small contribution”, which was translated into a 1. A score of 6-10 is described by the programme to indicate “some contribution”, which was translated into a 2. A score of 11-15 is described by the programme to indicate a “fairly strong contribution”, which was translated into a 1, while a score of 16-22 is described by the programme to indicate “a strong contribution’, which was then translated into a 4. The modules that received no score by the programme are understood to have no contribution to the learning outcome, a self-assessment which was translated into a 0.

Six programmes used a self-assessment scale that cannot be converted to the 0-4 scale. As such, three university programmes matched how their modules meet the seven learning outcomes by splitting the contribution of each module to the programme outcomes in terms of ECTS credits. One university programme opted for splitting the contribution of each module to the programme outcomes in terms of percentages. Finally, two university programmes used a 4 point coloured heat map to show how the modules contributed to the programme outcomes. Although the description of the four colours matched the description of the scores 1-4, no colour was assigned for modules with no contribution to the programmes outcomes, which would correspond to the score of 0 of the recommended POLO scale described in Table 2

By analyzing the average POLO scores for all seven accreditation outcomes and for all programmes, the study determines the weight given to ethics in engineering programmes according to the programmes own assessment and compare it with the average POLO scores for the other outcomes. Based on the POLO scores for the ethical outcome, the researcher calculated the percentage distribution of the five scores for the ethical outcome within each programme, in order to establish methods of delivery of ethics. It then compared the distribution of POLO scores across all programmes, in order to identify patterns in methods of delivery of ethics education. The method helped identify patterns and variations in the presence of ethics in engineering programme, according to the participant programmes' own assessment carried for the purpose of accreditation.

3 FINDINGS

According to this numerical analysis, the preliminary data reveals that the ethical outcome *e* is preponderently self-assessed the lowest of all learning outcomes by the programmes under investigation. *Table 4* shows that the average POLO scores given by the 17 programmes to outcome *e* falls between 0.81-2.41, with an overall average of 1.56.

When comparing the average of outcome to the average scores of the other six programme outcomes, the overall average for outcome *e* is the lowest. In fact, it is more than twice lower than the overall average for outcome *a* (mathematics and scientific knowledge) and outcome *b* (problem solving). For ten of the 17 programmes, accounting for 59% of the participant programmes that employed either the 0-4 self-assessment scale or a scale which can be converted to 0-4, the average for outcome *e* is more than twice lower than the average of programme outcome *a*. For one programme the average for outcome e is more than three times lower than the average for the highest outcome *a*.

The color gradient *Table 4* captures a striking image of the existing dichotomy between technical skills and nontechnical skills. The total average POLO scores for each outcome across the 17 programmes reveals a strong focus of engineering education on developing skills traditionally associated with the engineering profession, such as technical, mathematical and scientific knowledge, problem solving and design, which have the top average scores. On the other side, the average scores for non-technical learning outcomes e-g (ethics, teamwork, communication) are consistently self-assessed with the lowest averages.

Table 4. The weight given to the accreditation outcomes based on self assessment (n=17)

	Outcome a	Outcome b	Outcome c	Outcome d	Outcome e	Outcome f	Outcome g
IoT A Energy	3.47	3.16	2.82	2.85	2.41	2.58	2.56
IoT A Mechanical	3.69	3.67	3.22	3.33	2.37	3.11	2.9
IoT A Electronic	3.38	3.19	2.45	2.38	1.55	1.9	2.19
IoT B Build Services	3.13	3.3	2.34	1.91	1.99	1.85	2.23
IoT B Manufacturing	3.3	3.25	2.1	2	1.7	2.35	2.1
IoT B Mechanical	3.44	3.39	2.24	2.43	1.64	2.53	2.5
IoT B Structural	3.22	3.51	1.98	1.8	1.37	1.54	1.58
IoT B Civil	3.12	3.35	2.03	1.86	1.87	1.91	1.87
U C Electronic&C.S.	3.33	3.18	2.28	1.52	0.88	1.21	1.39
U D Chemical	2.36	2.19	2.05	1.15	1.05	1.51	1.34
U D Civil, Structural &Environmental	2.06	1.95	1.74	1.01	0.94	1.4	1.51
U D Energy	2.4	2.3	1.9	0.94	1	1.3	1.15
U D Electric&Electronic	2.21	2.25	1.89	0.95	0.81	1.18	1.24
U E Biomedical	3.73	3.53	2.57	2.39	1.68	2.23	2.13
U E Electronic	3.71	3.63	2.86	2.98	1.7	2.21	2.29
U E Electric	3.74	3.68	2.77	2.77	1.88	2	2.05
U E Mechanical	3.69	3.46	2.49	2.83	1.69	2.2	2.29
AVG	**3.18**	**3.12**	**2.33**	**2.07**	**1.56**	**1.94**	**1.96**

Analyzing disciplinary differences, *Table 4* shows that the lowest overall averages for outcome *e* are registered by the programmes of Electric and Electronic Engineering (average 0.81) and Electronic and Computer Science (average 0.88)

Looking at the percentage of modules self-assessed with each of the 0-4 POLO scores, we observe a variation in their distribution in the 17 programmes. According to Table 6, the percentage of total number of modules that self-assessed with 0 (as “not contributing to the programme outcome”) ranges from 0% to 58%, while the percentage of total number of modules that self-assessed with 4 (as making a “fairly strong contribution, with significant assessment relating to the programme outcome”) ranges from 0% to 30%.

When considering the distribution of self-assessment scores of 0 and 4, we can notice a significant variation among the programmes in the delivery of the ethics outcome. Turning our attention to the percentage of modules within a programme self-assessed with a score of 0, we notice two programmes that reported that more than half of their modules do not contribute to outcome *e*, followed closely by three programmes for which more than 40% of their modules received the score 0. At the other end we have five programmes for which less than 20% of the modules have no contribution to outcome *e*. Turning to the percentage of modules self-assessed with the score 4, nine programmes have deemed that less than 10% of their modules have a strong contribution to outcome *e*, while three programmes recorded a strong contribution to outcome *e* for 10-19% of their modules, and five programmes recorded a strong contribution to outcome *e* for more than 20% of their modules, with a maximum recorded of 30%:

Table 6. Distribution across programme for modules' scores for outcome *e* (n=17)

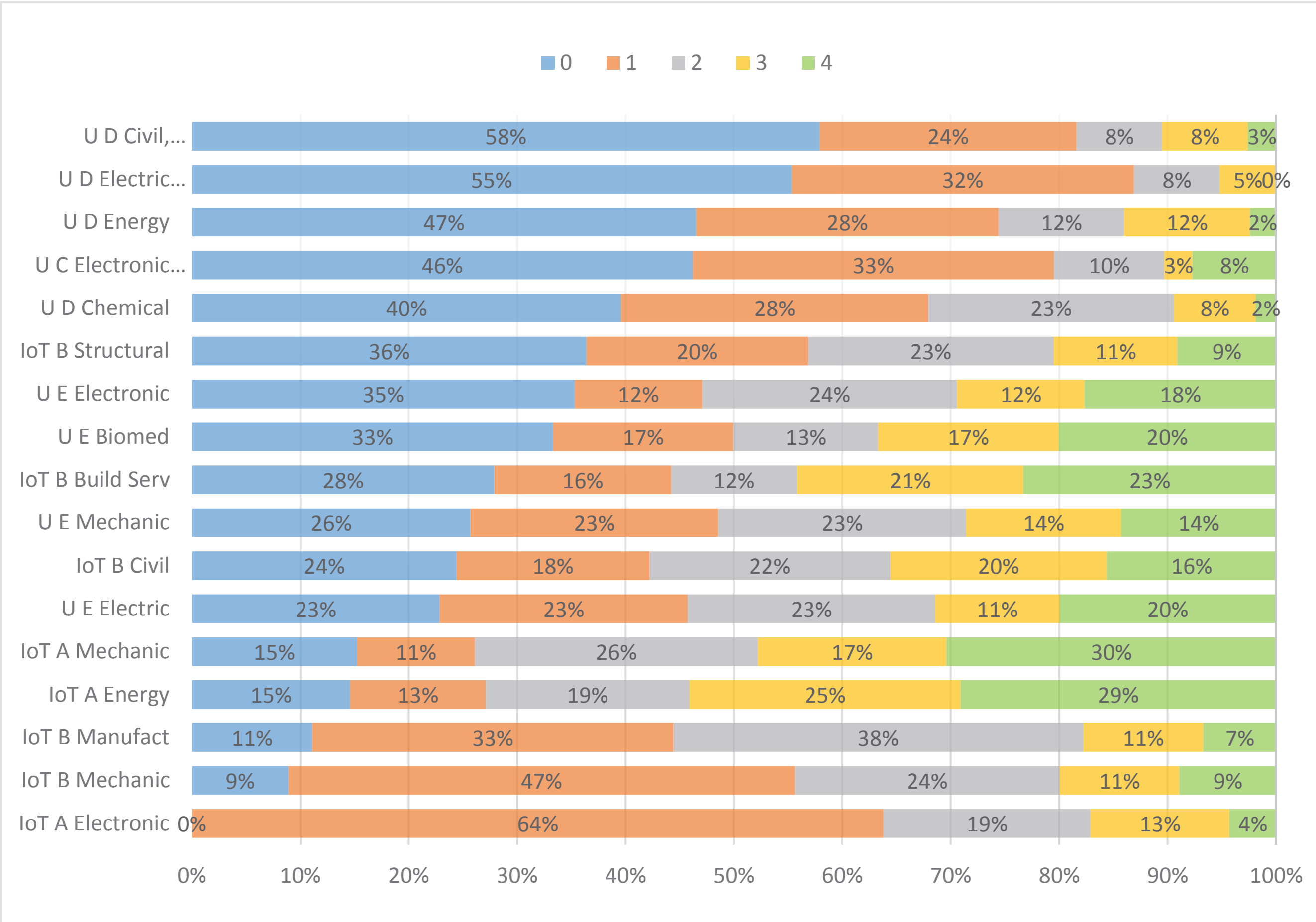

Table 6 shows a variation among the participant programmes in their delivery method of ethics education.There are two main methods of delivering ethics education in engineering programmes: in standalone modules dedicated to ethics or across the curriculum, with ethics permeating technical as well as non-technical modules. A high percentage of modules self-assessed a score of 0 and 1, with only a few modules deemed to have a strong contribution to outcome e, can be interpreted as suggesting a method of delivery of ethics education in standalone modules, while an even percentage of modules for each score would point to a method of ethics delivery envisioned to be across the curriculum. Six programmes mention explicitly in the programme description that they aim to deliver ethics across the curriculum, but in some cases the POLO scores seem to contradict this statement. For example, in one of the programmes that explicitly mentions an integration of ethics across the curriculum, almost half (46%) of modules score 0 for outcome e, while 33% of its modules have a score of 1.

4 SIGNIFICANCE

The study identifies major features of the current landscape of engineering ethics education. Given the limited empirical research on the implementation of ethics education in engineering programmes, the paper provides a unique insight into the provision of ethics education in Engineering programmes in a European setting. The findings can be of benefit to programme chairs, serving as guidance in the provision of ethics education in their own programmes, as well as to accreditation bodies in their effort to ensure that all accreditation outcomes are on the same par in regards to their implementation. The present findings are part of a wider research study which examines in depth, through participant observation at accreditation events and interviews with engineering lecturers and accreditation evaluators, the coverage of ethics education, the experience and challenges encountered in the preparation of documentation submitted for accreditation and the evaluation for accreditation of the ethics outcome.

5 CONCLUSION

The study reveals that ethics, alongside other non-technical skills, is given less weight in the curricula of engineering programmes in Ireland, showing a still persistent division between traditional technically oriented engineering education and the contemporary calls for a hybrid socially oriented engineering education. The study also notes the lack of uniformity in the programmes' provision of ethics education and self-assessment of programmeoutcomes, leading to further questions as to how the programmes are assessed and deemed to have met by accreditation evaluators the ethics criterion.

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The relationship between ICT based formative assessment and academic achievement in a Mechanics of Materials course

M.A.H.A. Meijers[1]
Avans University of Applied Sciences
Breda, The Netherlands

P.P.J.L. Verkoeijen
Avans University of Applied Sciences
Breda, The Netherlands

Conference Key Areas: Open and Online Teaching and Learning, Integrated learning environments for the digital native learners

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ABSTRACT

Formative assessment can be understood as assessment for learning rather than of learning. Research has demonstrated that formative assessment/feedback is strongly and causally related to students' achievement in higher education. At Avans University of Applied Sciences, the first-year course Mechanics of Materials 2 (MoM2) does not contain formative assessment due to constrained personnel and financial resources. In this study, we introduced formative assessment in the MoM2 course using an innovative ICT tool. This tool provides students with personalized feedback on both task and process level to improve their learning and to enhance adaptive teacher class instruction.

To assess the impact of the ICT based formative assessment, we obtained the final course exam pass rate, the average grade and student satisfaction on the 2018-2019 course MoM2. We compared these outcomes to those in the previous 3 runs of this course (2017-2018, 2016-2017, 2015-2016). These courses were identical to the most recent version of MoM2 but they did not include ICT based formative assessment. In addition, we compared the 2018-2019 run of MoM2 with the 2018-2019 run of Mechanics of Materials 1 (MoM1), which is a highly similar course, which does contain a form of non-ICT based formative assessment.

The results show that the use of ICT based formative assessment did not improve academic achievement in the course MoM2 2018/2019 compared with previous runs of the same course and did not improve academic achievement compared to the similar course MoM1 2018/2019.

[1] M.A.H.A. Meijers
maha.meijers@avans.nl

1 INTRODUCTION

Summative assessment usually comes at the end of a course to evaluate student performance with respect to learning goals. In contrast, formative assessment takes place during a course with the aim to provide feedback that students help to observe, enhance and accelerate their learning process (e.g., [1] and [2]). In addition teachers, use formative assessment to adapt their instruction and to enhance student learning.
There are several reasons to assume that meaningful learning, self-efficacy and self-regulated learning are supported by formative assessment. First, the provided feedback informs the student about the learning goals and the criteria used during summative assessment. In addition, the formative assessment also informs the student about the current performance level with respect to those learning goals. This helps students to direct and/or adapt their future learning effort and learning strategies towards the learning goals [1]. Research has demonstrated that formative assessment/feedback is strongly and causally related to students' achievement in higher education. For example, review articles by Black [3], Hattie [4] and Schneider and Preckel [5] suggest that formative assessment may have a strong positive effect on academic achievement. In [4] and [5] feedback – which is a crucial part of formative assessment – is even rated as one of the top ten factors related to academic achievement.

At Avans University of Applied Sciences Mechatronics (BSc.) program, the first-year course Mechanics of Materials 2 (MoM2) (2 ECTS) contains limited formative assessment due to constrained personnel and financial resources. Students only receive task level feedback: they receive worked-out solutions to their homework one week after submission. Additionally there is the possibility for students to review the results of the summative end-of-course exam. Feedback at the process level is absent. In this study, we introduced formative assessment in the MoM2 course using an innovative ICT platform. This platform provides students with personalized feedback on both task and process level to improve their learning and to enhance adaptive teacher class instruction, while limiting the necessary financial and personnel resources. Our research question was if this ICT based feedback improves academic achievement in the course MoM2.

2 METHODS

2.1 Course and participants

At Avans University of Applied Sciences, the first-year of the Mechatronics curriculum is divided into 4 quarters, each of which consisting of 10 weeks. In these quarters, the first nine weeks are reserved for educational activities and end-of-course exams; the final week is reserved for re-sit exams. MoM is covered in two courses during the first-year: MoM1 is conducted in the first quarter and MoM2 in the third quarter. Both courses have a work load of 2 ECTS and within their quarter each MoM course runs parallel to other courses and projects with a total course load of 13 ECTS. Hence, each MoM course covers only a small part of the load in each quarter.

Furthermore, MoM2 is conducted after a first informal selection point in Dutch higher education, i.e., February 1st. Students who have not been able to meet a program's standard, have the opportunity to leave the program without financial consequences. This means that MoM2 is likely to contain a subset of students who performed relatively well.

In MoM2, as well as in MoM1, classes with a maximum of 32 students take part in 7 instructional sessions (1 per week) of 90 minutes. During these sessions, new theory and problem solving strategies are explained and students work on practice problems. The MoM2 course in 2018-2019 was similar in content and design [6] as the MoM2 course in previous years. Furthermore, the lecturer of MoM1 and MoM2 was the same in all courses considered in this study.

Participants in this study were first year undergraduate students that actively participated for the first time in MoM1 and MoM2. Active participation implies that a student made his/her homework for at least one course meeting. Hence, non-active students are those who did not make any homework assignment at all during a course. Students were allowed to opt-out from this study and provide their homework according to the procedures of previous years.

2.2 Intervention

The intervention consisted of formative feedback based on data from our ICT tool [7]. Each week, this ICT tool assigned a unique set of practice problems to each student. Each set consisted of 3 to 6 problems. The ICT tool provided feedback to students in the form of either adaptive explanatory or socrative feedback. The explanatory feedback was to some degree dependent to the answer given to problems provided by the tool. For example, the tool can recognize when a "sine" is used instead of a "cosine" and will provide feedback to the student to review the trigonometric relations used in solving the problem. Socrative feedback was provided when students asked for a hint in the ICT tool. A hint consists of a decomposition of the stated problem according to the problem solving procedure. The student provided answers to partial problems and received explanatory feedback.

Additionally students received a grade (1 to 10) for each week's set of practice problems to give them insight into their progress during the course.

Our ICT tool [7] provides feedback to the lecturer at both group and student level. Learning performance and time-on-task were used during the course to perform two weekly interventions. Those students who spent less than 2 hours on their homework assignments and performed below 40% on the homework assignment were separately addressed after the instruction in the following week. These student have been asked if they were aware of their underperformance and if they encountered any problems during their homework. Based on the average performance of the students on the problems in the homework assignments, the problem with the lowest performance was selected by the lecturer. This problem was then discussed in class by the lecture in the successive weekly instruction.

2.3 Design

To assess the impact of the ICT based formative assessment, indicators of student achievement and student satisfaction have been obtained from the registrar for the course MoM2 for the academic years 2015-2016, 2016-2017, 2017-2018 and 2018-2019. We compared these outcomes to those in the previous 3 runs of this course (2017-2018, 2016-2017, 2015-2016). These courses were identical to the most recent version of MoM 2 but they did not include ICT based formative assessment. In addition, we compared the 2018-2019 run of MoM 2 with the 2018-2019 run of MoM 1. Both courses are comparable in terms of content [6], types of homework assignment, lecturer and difficulty level and format of the final end-of-course exam. Both courses only differ in the way formative feedback is administered. This is provided by the teacher without assistance of the ICT tool in MoM1 and with the ICT tool [7] in MoM2. Hence, this within-cohort comparison allows for an additional assessment of the effectiveness of our ICT tool apart from the cross-cohort comparison in MoM2.which is an highly similar course, which does contain a form of non-ICT based formative assessment.

Student achievement has been measured with pass rates and the grade on the final end-of-course exam. The grade is expressed as a figure between1 and 10 (note that a grade of at least 5.5 corresponds to a pass). Pass rates and grades of re-sit exams have not been taken into account. Furthermore, any assigned compensation (performed homework) to the final end-of-course exam grade has not been taken into account when determining the pass rate or grade.

With respect to student achievement, we hypothesized the following:

1. The implementation of ICT based formative feedback in the 2018-2019 course MoM2 will enhance students' achievement relative to the MoM2 course in the academic years 2015-2016, 2016-2017 and 2017-2018, where formative feedback is hardly present. I Specifically, for the final end-of-course exam of sterkteleer 2, we expect the following pattern for pass rate (PR), mean grade (M) and median grade (Med):

$$\begin{aligned} \mathrm{PR-M-Med}\ (2018-2019) > \ & [\mathrm{PR-M-Med}\ (2015-2016) \\ = \ & \mathrm{PR-M-Med}\ (2016-2017) \\ = \ & \mathrm{PR-M-Med}\ (2017-2018)] \end{aligned}$$

2. H2: The implementation of ICT based formative feedback in the 2018-2019 course MoM2 will lead to a comparable or better student achievement with respect to the 2018-2019 course MoM1, where formative feedback is provided by lecturers instead of an ICT tool. Specifically, for the final end-of-course exam, we expect the following pattern for pass rate (PR), mean grade (M) and median grade (Med):

$$\mathrm{PR} - \mathrm{M} - \mathrm{Med}\ (\mathrm{Sterkteleer}\ 2\ 2018 - 2019) \geq$$
$$\mathrm{PR} - \mathrm{M} - \mathrm{Med}\ (\mathrm{Sterkteleer}\ 1\ 2018 - 2019)]$$

For explanatory purposes student satisfaction and perceived competence has been measured and analytical data from our ICT tool is collected. Student satisfaction has been measured by means of a standardized questionnaire that is similar over the academic years examined in this study. In this questionnaire participants responded to various statements and in the present study we will focus on the following two:

1. "The teaching aids (blackboard, books, lecture notes, ICT applications, etc.) during the project/subject /practical exercises supported my studies"
2. "The methods used during the project/subject/practical exercises contributed to my learning."

Participants provided an answer to each of these statements on a 5 point-Likert scale ranging from 1= "completely disagree" to 5 = "completely agree". Per student, the mean score on these two variables has been used as a proxy of student satisfaction with respect to the intervention.

In the 2018-2019 run of MoM2, students' perceived competence has been measured halfway (week 4 of 7) through the experiment and at the end (week 7 of 7) of the experiment, a week before the final end-of-course exam. This allowed us to explore the development of perceived competence throughout the course. Perceived competence was measured with a short 3-statement questionnaire:

1. "I am not confident that I will be able to master the content that is covered by the final end-of-course exam of Mechanics of Materials 2"
2. "I am confident that I will achieve my learning goals for the course Mechanics of Materials 2"
3. "I am confident that I will pass the final end-of-course exam of Mechanics of Materials 2"

Participants provided an answer to each of these statements on a 5 point-Likert scale ranging from 1= "completely disagree" to 5 = "completely agree". Per student, the mean score on these three variables has been used as a proxy of perceived competence.

Finally analytical data (i.e., homework duration and performance), from our ICT has been collected for the 2018-2019 run of MoM2.

The design of this study has been pre-registered [8] to exclude confirmation bias and the negative effects of researchers' degrees of freedom.

3 RESULTS

3.1 Descriptive statistics

Descriptive statistics of student achievement, student perceived competence and student satisfaction in MoM1 and MoM2 can be found in Table 1, Table 2 and Table 3 respectively.

Table 1. Descriptive statistics of student achievement

Course	MoM2				MoM1
Year	2015 2016	2016 2017	2017 2018	2018 2019	2018 2019
Proportion of active students	NA	NA	NA	100%	NA
Pass rates	0.30	0.71	0.65	0.63	0.76
End-of-course grade mean	4.0	6.2	5.8	5.7	6.7
End-of-course grade median	3.8	6.5	6.3	5.9	7.3
End-of-course grade SD	2.1	2.3	2.1	1.9	2.1
End-of-course grade minimum	1	1	1	1	1
End-of-course grade maximum	8.8	9.6	9.7	9.7	10

Table 2. Descriptive statistics of student perceived competence (MoM2 2018).

	Week 4	Week 7
n (number of students)	53	35
Perceived competence mean	2.8	2.9
Perceived competence median	2.7	3.0
Perceived competence SD	.5	.5
Perceived competence minimum	1.3	2.0
Perceived competence maximum	4.0	4.6

Table 3. Descriptive statistics of student satisfaction

Year 2018/2019	Teaching aids	Teaching methods
n	42	42
Mean	3.4	3.7
SD	1.0	0.8

Lastly, for the MoM2 course in the academic year 2018-2019, the relevant descriptive statistics of the two variables related to homework performance (i.e., homework duration and performance) are provided in Table 4.

Table 4. Descriptive statistics of student homework.

	Duration (min)	Performance
n (number of students)	52	52
Mean	67	4.1
Median	76	3.8
SD	17	2.0
minimum	1.5	0.7
maximum	135	8.8

3.2 Confirmatory analyses

To test **hypothesis 1** (see section 2.3), we carried out the analyses according to the pre-registration [8]. A logistic regression analysis on the pas-fail scores, showed a significant relationship between Course year and the probability of passing the test, χ^2 (3) = 30.329, p < .05, Nagelkerke R-square = .168. To follow up this significant effect, we performed a repeated contrast analysis. This analyses showed that the probability of passing the test was significantly lower in the Course year 2015-2016 than in the Course year 2016-2017, *Wald* χ^2 (1) = 22.165, p < .05, *Exp(B)* =.149 [95% CI EXP(B) = .067; .329]. The other two comparisons of the pass rate, i.e., Course year 2016-2017 with 2017-2018 and Course year 2017-2018 with Course year 2018-2019, did not yield significant outcomes.

Furthermore, we performed a single-factor between-subjects Analysis of Variance (ANOVA) on to compare the course years on the mean grades. The ANOVA revealed a significant relationship between Course year and grade, $F(3, 230)$ = 12.481, p < .05, eta-squared = .14. Bonferroni corrected comparisons showed that the mean grade in Course year 2015-2016 was lower than in the Course year 2016-2017, *Mean difference* = 2.250*, Standard error* = .388*, p* < .05. The other two comparisons of the mean grades, i.e., Course year 2016-2017 with 2017-2018 and Course year 2017-2018 with Course year 2018-2019, did not yield significant outcomes.

A Kruskal-Wallis test on the median grades per course year revealed a significant effect, $H(3) = 31.633$, $p < .05$. Similar to the outcomes for the pass rates and the mean grades, the median grade was significantly lower in the Course year 2015-2016 than in the Course year 2017-2018, $H(1) = 66.079$, $p < .05$. The other two comparisons did not yield significant outcomes.

Taken together, the outcomes of the analyses on the pass rates, the mean grades and the median grades were highly consistent. Performance was worse in the Course year 2015-2016 than in the Course year 2016-2017 but from 2016-2017 onwards performance remained constant. This was contrary to our hypothesis as we expected to performance to be better in the Course year 2018-2019, when the intervention took place, than in the previous years.

To test **Hypothesis 2** (see section 2.3) we planned to perform three analyses to compare MoM1 and MoM2: a logistic regression on the pass-fail scores, a repeated measures ANOVA on the mean grades, and a Wilcoxon test on the median grades. However, the descriptive statistics in Table 1 actually showed that performance according to these three criteria was actually *better* in MoM1 than in MoM2, the course in which the intervention took place. Because the results are diametrically opposed to our one-tailed hypothesis, we refrained from conducting the planned analyses for hypothesis testing purposes. After all, the obtained *p*-values would be uninformative with respect to our hypothesis. It should be noted that we carried out the analyses for exploratory reasons and these analyses showed that pass rate, mean grade and median grade were higher in MoM1 than MoM2. However, and consistent with the outcomes of the analyses we performed to assess out first hypothesis, the outcomes for the MoM1 versus MoM2 comparison were inconsistent with our expectation that students would perform better in MoM2 than in MoM1.

3.3 Exploratory analyses

A repeated measures ANOVA on the perceived competence scores, showed that mean perceived competence was comparable at week 4 and week 7, $F(1, 34) = .090$, $p > .05$, partial eta squared = .003.

Lastly, we explored the relationship between the total time spent on homework collapsed across the six meetings of the course and the total grade received for the homework assignments (minimum score = 0; maximum score = 60) with performance on the end-of-course grade of MoM2. A multiple linear regression analysis revealed that time spent on homework and homework grade together had a strong positive relationship with end-of-course exam, $F(2, 49) = 7.877$, $p < .05$, r-square = .24. Both time spent on homework (Standardized beta = .465) and homework grade (Standardized beta = .033) were positively associated with the end-of-course exam grade after controlling for the other variable in the model. However, neither the unique contribution of time spent on homework to the end-of-course exam grade, not the unique contribution of homework grade was statistically significant. This was due to an extremely high positive relationship between time spent on homework and homework grade, r = .856.

4 DISCUSSION

In the present study, we examined whether the introduction of an ICT based formative assessment in a MoM course would be associated with an increase in academic achievement. The lecturer of the course MoM2 was heavily involved in this study and much attention has been paid to the proper implementation of the ICT tool. Therefore, we think it is reasonable to conclude that the “treatment” has been delivered according to plan. Nevertheless, the use of ICT based formative assessment did not improve (but also did not deteriorate) academic achievement in the course MoM2 2018/2019 compared with previous runs of the same course and did not improve academic achievement compared to the similar course MoM1 2018/2019. These findings were not in line with our expectations. For this, we have two explanations.

First, the entire instructional design (i.e., worked examples, ordering of practice problems, introduction of theory) within the MoM2 course were of high quality. The same could be said about the lecturer who is an experienced, knowledgeable and skilful teacher. Furthermore, and probably as a result, pass rates of previous runs of MoM2 were already relatively high (>.65, except for the run 2015/2016). In hindsight, therefore, it may be possible that given the quality of the course and the lecturer, there might have been limited room for our ICT-based formative assessment to enhance the end-of-course performance.

A second explanation might lie in suboptimal aspects of the way in which the formative assessment was delivered. For one, from conversations with students, we learned that they perceived their homework results in part as summative instead of purely formative assessment. This might have hindered them to learn from the mistakes they made on the practice problems. As a result, they might have learned less from the practice problem than if they had taken a more formative perspective. This might explain why the perceived competence did not increase during the course (Table 2).

Second, students indicated that they had some problems with the ICT tool, although this is not directly clear form the student satisfaction results (Table 3). They indicated that they could not study together with peers due to personalization of the practice problems and that they spent a lot of time on troubleshooting when they made mistakes. The later arose because the ICT tool returns correct explanations; it does not always indicate why an erroneous student response is incorrect. The way students perceived the feedback, i.e., partly summative, and technical characteristics of the ICT tool might have stood in the way of realizing the full potential of the ICT-based formative assessment.

The use of the ICT tool will be improved with the results of this study. Improvements will focus (among others) on the use of homework results to learn from errors. A new study on the implementation of the enhanced use of the ICT tool will take place in the 2nd quarter of 2019.

5 ACKNOWLEDGMENTS

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Was It Worth It? Results of an Engineering Educator Capacity Building Program

L Morell
InnovaHiEd, Beihang University
Mayagüez, Puerto Rico

H Sjursen
New York University
New York, USA

U Cukierman
Universidad Tecnológica Nacional
Buenos Aires, Argentina

W Rivera
Universidad de Puerto Rico – Mayagüez
Mayagüez, Puerto Rico

E Vendrell
Universitat Politècnica de València
València, España

MF Guzmán
Universidad Nacional de Tucumán
Tucumán, Argentina

R Buxeda
Universidad de Puerto Rico – Mayagüez
Mayagüez, Puerto Rico

L Correa
Universidad Tecnológica Nacional
Buenos Aires, Argentina

L Saliceti
Universidad de Puerto Rico – Mayagüez
Mayagüez, Puerto Rico

JM Palmieri
Universidad Tecnológica Nacional
Buenos Aires, Argentina

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ABSTRACT

Many institutions and organizations provide engineering (and STEM[1]) educators capacity building programs around the world. Some of these programs are short, other are longer, some are mostly theoretical, others include hands-on, practice-based activities. This paper presents the results of a newly developed capacity building program for STEM educators, the International Engineering Educator Certification Program (IEECP). After briefly describing the program content and teaching methods, the paper summarizes the hard outcomes as well as the results of a survey undertaken to understand the lessons learned by participants. The survey included data on participants' previous knowledge in pedagogy, their capacity building experiences, as well as an exploration of program learning outcomes and the deliverables required. Perceptions on the quality and usefulness of learnings and activities are also be discussed. Analysis of the survey results indicate the IEECP achieved its objectives, was well received by participants and had an impact on participants academic life.

[1] STEM stands for Science, Technology, Engineering and Mathematics

1 INTRODUCTION

1.1 The engineering educator capacity building program and motivation for the study

Developing capacity of STEM educators at all levels is one of the first priorities of many countries and regions worldwide to ensure economic and well-being of knowledge economies. In the USA for example, the White House's recent report on its STEM education outlines the vision and strategic planning to advance "the innovation capacity of the United States—and its prosperity and security — depends on an effective and inclusive STEM education ecosystem [1]. This report sets out a Federal strategy for the next five years based on a Vision for a future where all Americans will have lifelong access to high-quality STEM education and the United States will be the global leader in STEM literacy, innovation, and employment. It represents an urgent call to action for a nationwide collaboration with learners, families, educators, communities, and employers—a "North Star" for the STEM community as it collectively charts a course for the Nation's success.

In Europe, there are also different initiatives coordinated and supported by the European Commission (EC) on STEM main issues: the low attractiveness of these studies and the lack of professionals well prepared to cover labour-market needs. As an example, SCIENTIX [2] is a long-term project supported by the EC that promotes and supports a Europe-wide collaboration among STEM teachers, education researchers, policymakers and other education professionals. Recently, Scientix has issued some reports that summarize STEM education policies and practices in Europe.

Another interesting initiative is the STEM Alliance [3]. This is an initiative that brings together Industry, Ministries of Education and education stakeholders to promote STEM education and careers to young Europeans and address anticipated future skills gaps within the European Union.

Similarly, other nations like Singapore and India, are undertaking like-focused approaches to develop STEM human resources. Research shows that faculty development programs have been growing globally [4] and many institutions and organizations are providing engineering (and STEM) educators capacity building programs around the world as part of this transformation.

Building faculty capacity to address the higher education STEM challenges associated with these initiatives is of paramount experience. The United Nations Development Programme [5] defines capacity-building as: "the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time". Central to such capacity building is transformation, or the changing of mindsets. Changing mindsets takes buy in, ownership of process, knowledge and practice.

In 2016, **InnovaHiEd,** a consulting and capacity building group [6] developed the **International Engineering Educator Certification Program (IEECP)** [7] and was authorized by the International Society for Engineering Pedagogy (IGIP) [8] to establish an IGIP Center to provide training to STEM faculty to obtain IGIP's International Engineering Educator Certification. The hybrid, hands-on, practice-based program and its components and unique requirements and implementation is described in a recent paper [9]. Teaching methods utilized in the IEECP include face to face lectures/workshops, flipped learning, teaching/learning with technology, reflection (developing a teaching portfolio), proposal writing, project implementation and peer-reviewed paper writing and submission. The IEECP has been offered twice to about 75 STEM deans and faculty members in the years 2017 and 2018. As part of the program's continuing quality improvement process, in addition to the cohort assessments carried as part of the delivery itself, program's leaders wanted to understand the hard outcomes and the lessons learned by participants. Therefore, in the Spring of 2019, a survey was distributed to all the program participants in the two cohorts mentioned above to collect data on their perceptions on the quality and usefulness of learnings and activities undertaken by the program in order to reflect and make decisions to improve future offerings. A total of forty five (45) survey replies – a sixty percent (60%) response - was received. This paper summarizes the analysis and conclusions of the survey results.

1.2 Objectives questionnaire

This study is a follow-up to participants of the International Engineering Educator Certification Program for the cohorts of 2017 and 2018. A survey was developed with the goal of understanding the impact of this faculty development program in providing a capacity building to the participants. *Fig. 1* provides the schematic representation of the survey sections. The questionnaire consisted of three parts: (1) understanding the profile of the participants prior to attending the program, (2) assessing the program effectiveness, and (3) determining faculty interest in continuing educational training development and institutional impact. In the first part of the survey, we wanted to assess our participant's level of exposure to pedagogical methodologies, their experiences in using them in their classrooms, and in publishing experience in pedagogy and innovative educational projects prior to the program. The second part of the survey focused on the program's deliverables. Participants were surveyed with regards to the program structure in areas such as organization, length, educational objectives, planning, added values of the program, and instructors' performance. Furthermore, participants provided their input with respect to program ability to improve their teaching and learning capabilities, classroom implementation experiences and the development of an innovation project that could result in a peer-reviewed publication. The third part of the survey was to inquire about the program effectiveness in provoking the participants the desire for continuous improvement in STEM pedagogical education. Among the areas to be surveyed were included those of trainings that participants would like to address and potential challenges in participation in educational trainings.

For the most part, participants in both cohorts were quite appreciative of the program and believe it will strengthen their teaching practice. Here is one testimonial: "*I wish to give thanks for all that I have learned. I have been able to implement some of the things I learned [in the program] and wanted to share the happiness we are witnessing daily with the outcomes. Change is really happening… and for me, one of those for which change is difficult, the fact that I am able to share with two colleagues has made your "teaching tips" easier to implement. Thanks for everything*"[2].

[2] Daniel Echaradía, UNS, Argentina, 2018 Cohort

Fig. 1. Schematic of the questionnaire's sections.

2 PARTICIPANT'S PROFILE

2.1 Learning styles

As part of understanding our participants profile, a learning style inventory was performed. The Felder and Silverman learning styles test [10] was used to understand the preferred learning styles of the population. *Fig. 2* shows a predominance of active, sensorial, visual, and global learners among thirty-eight (38) participants learning styles test results.

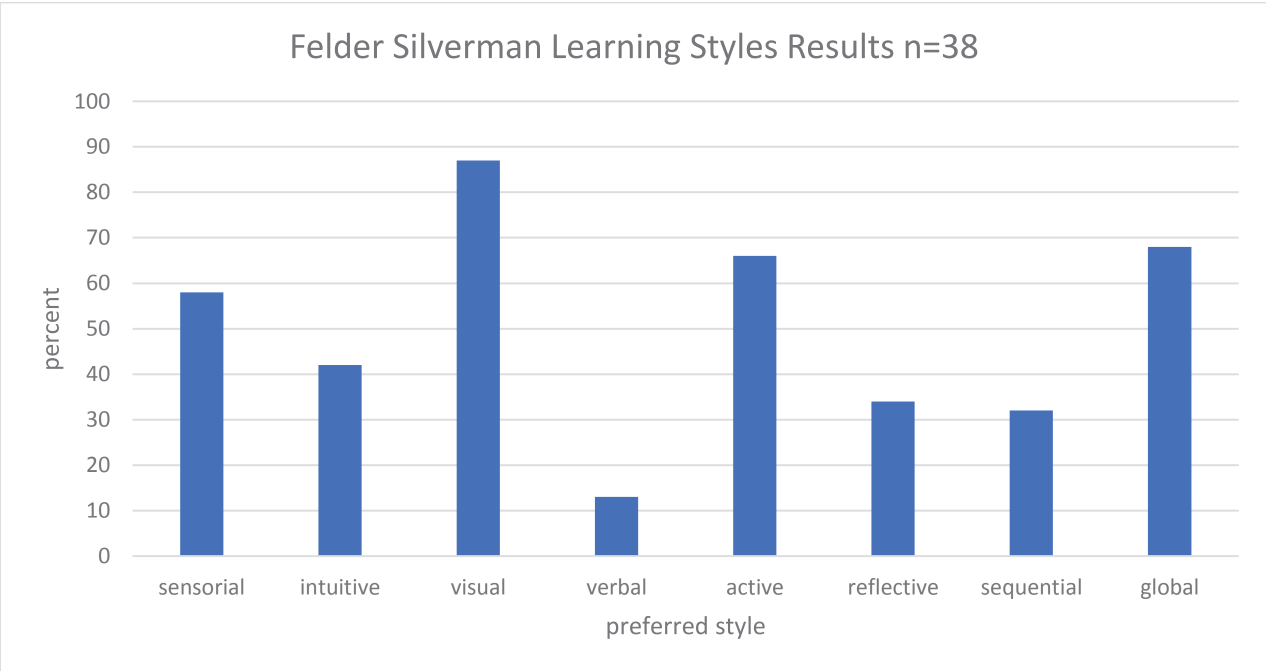

Figure 2 Preferred Learning Styles of Participants (n=38)

As can be seen in Figure 2, all learning styles were represented in the population. This important information was used to determine the program's teaching strategies to be used to ensure that all the preferred learning styles benefited from the program's teaching methodology. Course participants were made aware that both instructors and students learning styles preferences are to be considered when teaching methods are selected.

2.2 Teaching experiences prior to participating in the program

The participants represented an interdisciplinary population of STEM disciplines with 66.7% from engineering, of which 29% had less than ten years of teaching experience. Although 88.9% of the participants indicated having previous experiences using active learning and taking courses or training on pedagogy, about half (49%) had published peer-reviewed papers on STEM education. Furthermore, 53.3% had not published articles related to pedagogical innovation. *Table 1* shows the profile of the respondents.

Table 1. Participant’s profile prior to training.

Profile	Percent of respondents
Disciplines of participants	66.7% engineering
	6.7% sciences
	17.8% mathematics
	8.8% education
Years of teaching	60% over 15 years
	11.1% 11-15 years
	15.6% 6-10 years
	13.3% 0-5 years
Respondents with previous experiences with student-centered teaching	88.9%
Participants with available of pedagogical training centers at the participant’s institution	57.8%
Respondents that had published peer-reviewed papers in STEM education research articles in pedagogical innovation	46.7%
Faculty with previous courses or training in pedagogy	82.2%

2.3 Experiences during the program

The IEECP curriculum consists of twenty ECTS[3] to be completed in a minimum of eight (8) months [6]. While the participants of the two cohorts being studied (2017 and 2018) took longer than eight months only seven percent (7%) of the participants considered that the program was too long. The program used a learning management system (LMS) to communicate with students and as the teaching/learning and assessment platform. All the program’s materials and resources were available to participants. Eighty four percent (84%) of the respondents rated as useful or very useful the use of the LMS.

Since the program is learned-centered and was developed on the philosophy of learning by doing, each module requires the participants to implement the learning

[3] ECTS = European Credit Transfer System

experiences in their classrooms. Eighty-four percent (84%) of the participants considered that program requirements and workload to be appropriate in order to accomplish the program's educational objectives and that all or most of the program instructors taught they what they preached.

Furthermore, eighty one percent (81%) of the respondents considered that the organization and planning of the learning experience were appropriate or very appropriate. The overall level of satisfaction of the participants of the program is reflected in two ways: ninety three percent (93%) would recommend the program to their peers, and, all respondents evaluated the IEECP as good or very good.

Concerning participants' motivation during the program, ninety-eight percent (98%) of the respondents expressed that they felt very motivated or motivated, and, one-hundred percent (100%) felt that the program transformed their teaching-learning experiences at different levels. Ninety five percent (95%) of respondents experienced a high level of transformation due to the program and eighty eight percent (88%) considered that the pedagogical knowledge acquired as result of this training was good or very good.

Fig. 3 shows the respondents assessment of the most valuable experiences of the program. Over sixty percent (60%) considered that the planning and implementation of an innovation project and the development of an outcomes-based program/course were the two of the most valuable experiences. These were followed by learning about the innovation process, teaching/learning methodology and learning from colleagues/peers.

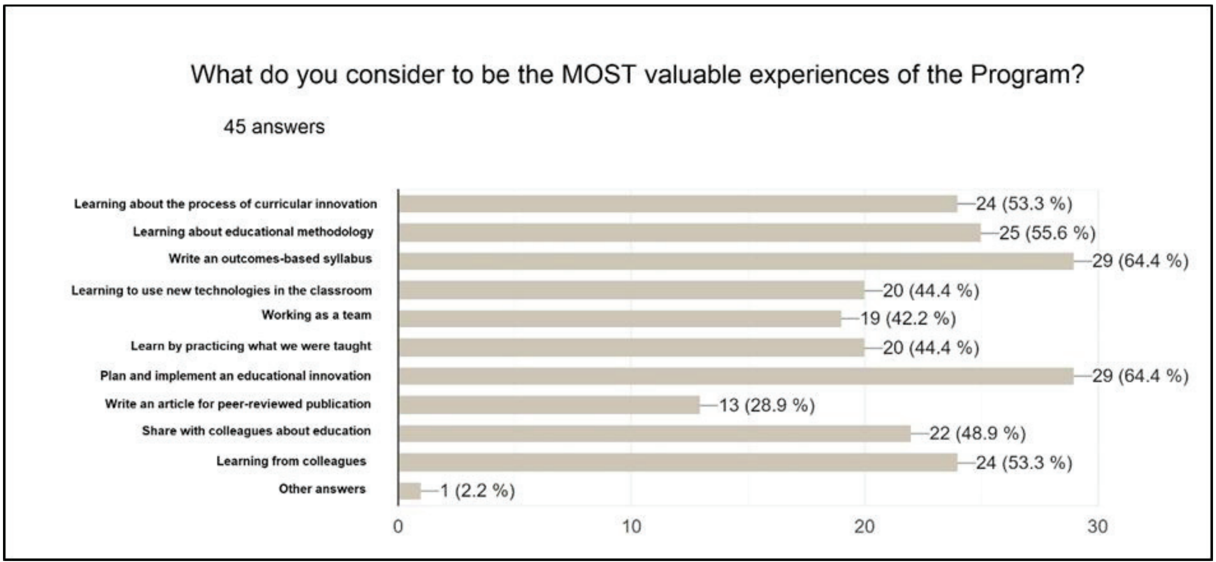

Fig. 3. Most valuable experiences of the program.

Since the program was structured in modules it was important to assess the perception of the participants to learning experiences in each module. *Fig. 4* indicates participant's appreciation of the modules they enjoyed and learned the most. The modules of fundamentals of assessment, outcomes/competency-based curriculum, course management, and teamwork received over 50% acceptance.

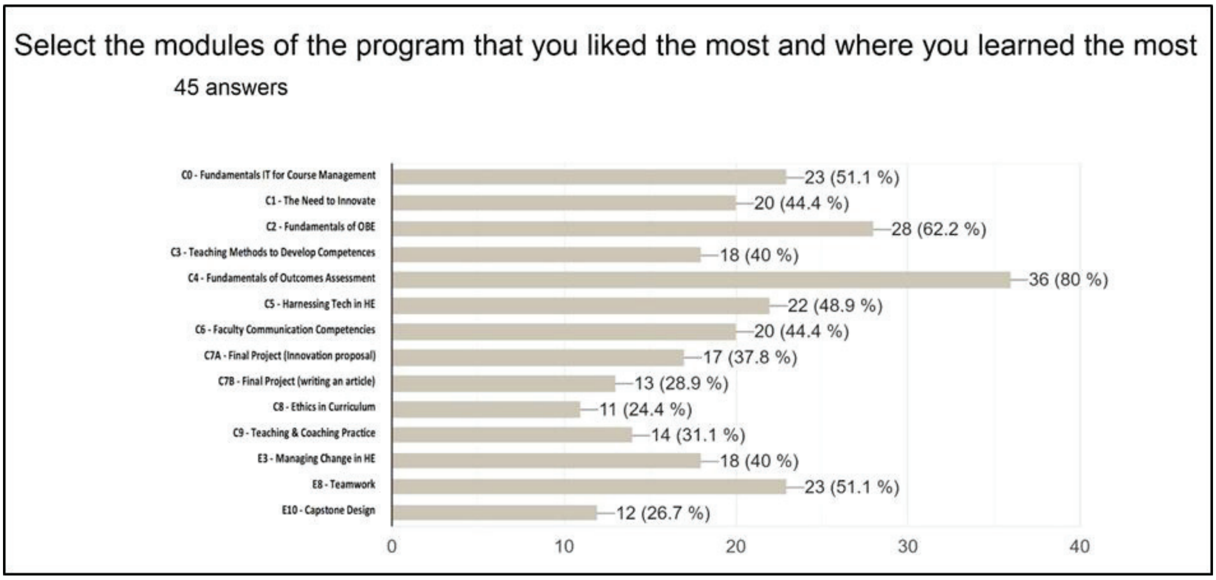

Fig. 4. Program modules that participants considered as a high-level learning experience.

After completing the program, participants were assessed with regards to their use (or planned use) of teaching-learning methodologies. *Fig. 5* indicates that the predominant teaching-learning methodologies participants were using include active learning, teamwork, and flipped learning.

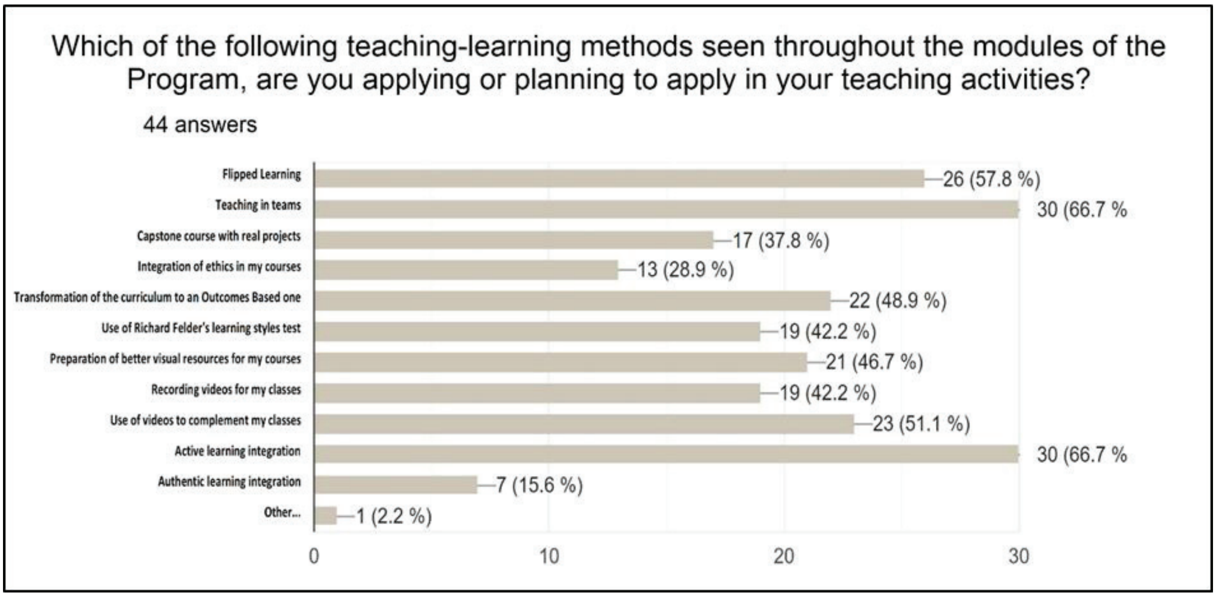

Fig. 5. Teaching-learning methodologies which are being used or are being planned to be used by participants.

One objective of the program was to facilitate that all participants developed and implemented an educational innovation project. Except for three respondents (who are still working on their projects at the time of the writing of this paper), all participants developed and implemented an innovation project either in their classrooms, in a program or at the institutional level. Some of the innovations involved: student-centered mathematics teaching, collaborative design of rubrics between faculty and students, hybrid teaching in mathematical analysis, innovation in the learning outcomes, assessment of a mathematics course for engineering programs at three

Latin American universities, development of soft skills, and the use of LMS in the elaboration of practical projects in an introductory engineering course.

Another objective was that the innovation project was to be presented in a conference and/or a peer-review article to be submitted for publication. Thirty-three (33) of the forty-three (43) respondents have presented or submitted a paper to peer-reviewed journals about their innovation project. Overall, sixty one percent (61%) of the participants considered that they had satisfactorily achieved the majority of the program objectives, while thirty percent (30%) considered achieving all of the objectives, and nine percent (9%) considered having partially achieved the objectives (we assume these are the ones that are still working on some of the program's required tasks). Ninety one percent (91%) of the respondents have completed or are in the process of completing the Ing.Paed.IGIP certification.

More than fifty percent (50%) expressed that the program changed their attitude towards the social responsibility of engineers in such a way that the topic should be included as part of the engineering courses. In addition, eighty one percent (81%) considered that the program experiences allowed them to change their perception in that the engineering education should be linked to other disciplines in order to allow the development in students of political and social competencies, as well as soft skills. The respondents felt that engineers must increase their collaboration with IT and data management, digital art & design, life sciences, business and the social sciences (*Fig. 6*).

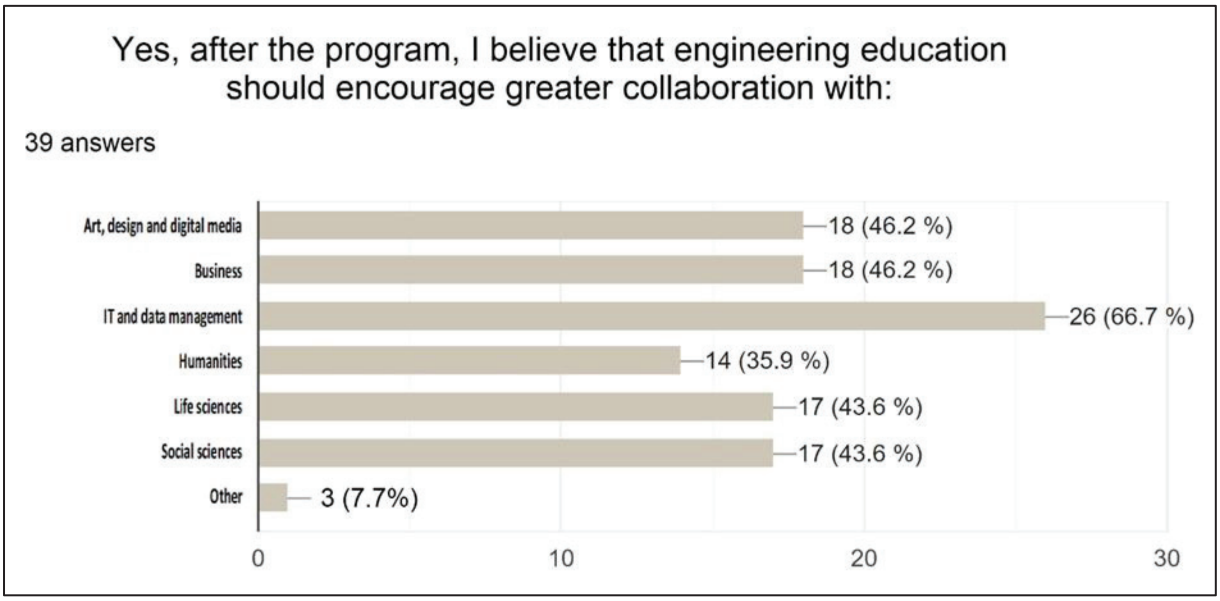

Fig. 6. Program participants perception of linking engineering to other disciplines.

2.4 Future plans

After completing the program, ninety three percent (93%) of respondents continue to practice innovations in their classrooms and/or working on an innovation paper. Eighty one percent (81%) plan to continue training in STEM education and pedagogy. Among the areas of education that participants would like to continue to learn are active learning and curriculum development based on outcomes, and, planning for accreditation. Some of the challenges that respondents believe they will be facing in their continuous education include availability of time, economic resources and workload. Besides the topics covered in this Program, some other topics respondents would like more training include: industry-university collaborations, outcomes-based accreditation, integrating 4th industrial revolution, big data & artificial intelligence into the curriculum, best practices in faculty evaluations, project-based learning, Learning Factory, CDIO and EPiCS, the Global Challenges Scholars Program, STEM student retention, and, analytics in higher education.

Finally, eighty eight percent (88%) indicated that they are planning to continue participating in engineering education conferences and learning from colleagues.

3 CONCLUSIONS

The International Engineering Educator Certification Program (IEECP) offered by InnovaHiEd is an academic program that provides training to STEM faculty in order to obtain IGIP's International Engineering Educator Certification. It is a hybrid, hands-on, practice-based program that includes face to face lectures/workshops, the use of teaching/learning technology, the development of a teaching portfolio, a teaching innovation project proposal and a peer-reviewed paper writing and submission.

After completing two cohorts of the IEECP, some conclusions can be extracted according to a survey completed by a significant number of participants:

- The IEECP is well focused and organized, achieving its objectives and was accepted and appreciated by student participants.
- The planning and implementing of an innovation project as well as the development of an outcomes-based program/course were the two of the most valuable experiences.
- The IEECP transformed all the participants' teaching-learning experiences at different levels.
- Some of the IEECP's modules need to be further assessed in content and delivery.
- IEECP participants were very motivated during the learning experience, plan to continue to further their knowledge and education in pedagogy areas and are practicing what they learned in the program or are planning for the incorporation of learnings into their academic life.
- This research demonstrates that new effective teaching methods need to be used to ensure learning objectives. These must be based on ample research on learning effectiveness that emerges from learners' preferred learning styles. These include hands-on practiced based learning, reflection, community learning, using technology for communication between instructor-students and to enhance learning experiences and the awareness of the needs of industry and society to transform the engineering curricula and students' learning process.
- This study confirms what engineering education societies like the American Society for Engineering Education (ASEE) [11], the European Society for Engineering Education (SEFI) [12], Scientix [2] and the International Society for Engineering Pedagogy (IGIP) [8] promote among its members: the need of and facilitation of STEM educators capacity building.
- Finally, this study confirms that this program was worth it for student participants!

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Take the way of excellence! What makes French engineering schools so attractive for talented students?

R. Moulignier[1]
ENSTA Bretagne, ENSTA BEST
Brest, France

M. Gille
ENSTA Bretagne, ENSTA BEST
Brest, France

K. Kövesi
ENSTA Bretagne, Laboratory of Training and Professional Learning (EA 7529)
Brest, France

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ABSTRACT

Recruiting talented engineering students is a major challenge in most European countries. In France the 'Grandes Ecoles' of engineering have no difficulties attracting the best and brightest students. In this contribution, we would like to investigate why French engineering schools are so attractive. There already exists a great deal of research focusing on the difficulty of entering into these nationally-recognized and highly-prestigious French engineering schools. However, as far as we know, no previous research has investigated why and how these schools have attained this level of attractiveness. The findings that will be presented come from a qualitative research approach carried out in 18 semi-directive interviews with engineering students of diverse origins identified with the help of the BEST student network. In the framework of our exploratory study, we conducted a content analysis for the data in order to isolate and classify emergent themes. Our findings indicate the influence of diverse factors that make French engineering schools attractive for students including their prestige of excellence, professional specialisation in engineering, extracurricular and networking activities, exceptional employability perspectives with access to high ranked positions and the high social status and recognition of engineering profession. The aim of this work is to give a better understanding of why talented students choose to engage in engineering studies within the French context. The overall aim is to try to isolate lessons and good practices that may be applicable to increasing the attractiveness of engineering education in other contexts.

[1] Corresponding Author: R. Moulignier, romain.moulignier@ensta-bretagne.org.

1 INTRODUCTION

With the development of Industry 4.0, there is undeniably a growing demand for graduate engineers in our globalised and digitalised societies. Despite this growing need for engineering workforce, there is a lack of interest in engineering among young people explained by various reasons like current social ideas about engineering, the image and social status of engineering profession or the financial rewards compared to other career opportunities [1]. It is not surprising that most universities in Europe are currently experiencing difficulties to attract talented young people and engage them in engineering studies.

On the contrary, in France, engineering schools have no difficulties to attract prominent young talents of the country. According to the recent survey of CDEFI (Conférence des Directeurs des Ecoles Françaises d'Ingénieurs) in January 2019, there are 201 engineering schools in France (54 private and 147 public engineering schools) [2]. These engineering schools have a rapidly growing student body with 4% of annual growth during the last decade. From 1990 until today, the number of students graduated in engineering schools has nearly doubled in France. To satisfy the growing demand of the labour market for graduate engineers, the French Ministry of Higher Education, Research and Innovation introduced a long-term strategy to increase the enrolment rate of engineering students by 22.4% until 2026.

In this article, we investigate what reasons French engineering schools are so attractive for gifted students. Our objective is to identify what are the influencing factors of engineering students to enrol in their engineering school. First, we will discuss the very specific engineering education system in France. Then, we will explain the applied methodologies for our research survey. In the next section, we will highlight significant results and their interpretations by outlining unexpected findings. To conclude, we are going to point out the possible implications and the limitations of our study as well as define future perspectives.

2 'GRANDES ECOLES D'INGENIEURS' IN FRANCE

To better understand the culture of 'Grandes Ecoles d'Ingénieurs' in France, we propose to give a historical overview on the origin of this very particular way to educate engineers in the framework of the elite educational system. The creation of the famous 'Ecole Polytechnique' in 1795, considered as the foundation of French engineering education, was the beginning of these very specific engineering schools called 'grandes écoles'. These elite educational institutions provided highly skilled engineering workforce of public servants to conduce to the progress of the French society [3].

The historical development of these engineering schools is closely linked to the political, economic and social upheavals of the 19th and 20th centuries. Thus, the 'Polytechnicians' had an important mission during the Battle of Paris in 1814, during the Three Glorious and during the establishment of the second republic in 1848 where they played a mediating role between the various parties and participated in the protection of the Provisional Government. After 1870 these engineers strongly influenced the development of transport and modernized the country in depth by creating major traffic networks, new industries, modernization of cities, conquest and organization of a vast colonial empire. In parallel, after 1829 to satisfy the needs of private industrial companies for well-trained engineering managers a special private school network had been developed such as the School of Arts and Crafts for training industrial engineers [4].

Traditionally, the recruitment of French engineering schools is only at postgraduate level. After the A-level exam, young people interested in engineering studies have a choice to enrol in a university without any selection, in a University Institutes of Technology (IUT) with a selection based on satisfying and good results or in a Preparatory Classes to the Grandes Ecoles (CPGE) requiring students with excellent results in secondary school. Even if it’s possible to enter engineering schools for a minority of students from universities, IUTs or other ways (e.g.: higher engineering apprenticeship program) the large majority of future engineering students chose to enrol in preparatory classes.

These preparatory classes, viewed as an intensive preparation for the entrance exam in engineering schools, are taking part in the French elite education [5]. They have a reputation as a very high level scientific training, requiring a very intensive daily work during two years and reserved only for outstanding students on the national level. It is interesting that preparatory classes considered as part of higher education but situated mostly in the buildings of secondary school even today. However, breaking this tradition, there are several engineering schools proposing integrated preparatory classes to their future students to facilitate their recruitment process.

The entrance exams, called commonly ‘concours’, are aiming to recruit the best students: they are highly selective and widely considered as a meritocratic competition requiring not only strong scientific knowledge but also general skills. At the national level, there are five centralised and ranked entrance exams. The exam called ‘X-ENS’ which is the entrance exam to the Ecole Polytechnique and the different ENS (Superior National Schools) exams are generally considered as the most difficult one, followed by exams called ‘Mines – Ponts’ and ‘Central’ grouping together several prestigious engineering schools. The ‘CCP’ and ‘E3A’ exams bring together many good engineering schools of various levels. Interesting controversial phenomenon of this selection process that we can find engineering schools with a very various ranking position in the same exam group. For example, the best-ranked engineering school of ‘CCP’ is considered having a higher prestige than some ‘Mines-Ponts’ schools or the ‘E3A’ competition enables to enter the School of Arts and Crafts which is considered quite prestigious.

The first step of the selection process is based on students’ results during their CPGE years allowing them to make their inscription generally in several entrance exams.

After this, they have to pass written exams for each ‘concours’ and in case of satisfactory results an oral exam. At the end of the exams, students are ranked based on their results. Their admission to an engineering school depends not only on their ranking but also the ranking of other students who want enter the same school. As a general rule, students are supposed to choose the better-ranked engineering school available with their results. The ranking of engineering schools changes every year in function of their new students’ ranking: the higher the number of students from the top of the competition table, the higher the level of the school. Consequently, the entrance threshold becomes higher attracting even better students in the following years. On the other hand, the oldest schools are generally highly ranked due to their reputation and history as well as the prestigious careers of their former students.

3 ATTRACTIVENESS OF GRANDES ECOLES

During the last two centuries ‘grandes écoles’ became progressively the symbol of excellence for the French society. What were the reasons for this common belief in their excellence? For Béraud [6], the reputation of these institutions as being the “way of excellence” is based on several reasons. First of all, they provide a high-level professional training with strong knowledge in sciences and human sciences at the same time. Then, the competition based selection with a very high level of entrance exam for recruiting the brightest student on the national level. An engineering diploma of ‘grandes écoles’ is associated with a high social status and prestige, considered a noble way to obtain high and influential positions like a “ticket for power”.

We have to note that these engineering schools have a strong institutional image and identity based on their history and prestige. In his study, including not only engineering schools but also management and business schools, Draelants [7] confirmed the influence of French ‘grandes écoles” institutional image on their attractiveness. On the one hand, their attractiveness could be based on this image of excellence explained mainly by instrumental attributes in line with the explanation of Béraud [6]. On the other hand, it could also be based on an image of prestige explained by symbolic attributes like the history of the institution or the identification of students, with their institution. Traditionally, ‘grandes écoles” students’ are from the middle or upper class of the French society [8]. For these students this image of excellence and prestige increase the attractiveness of these schools. However, it was highlighted that the image of prestige with an extremely competitive selection process could be an obstacle for talented students from lower social classes [9].

Daverne and Massy [10] underlined the role of preparatory classes to influence students’ preferences, future ambitions and their choice for engineering school. Many gifted students, with excellent secondary school and baccalaureate results, make the decision to enrol to a preparatory class instead of making a premature choice toward a not sufficiently well-defined professional project. For these students, to go to a university is viewed too risky for their future while the CPGEs providing a recognised high-quality training and the possibility to have an equivalence represent a sure value.

In France, 'grandes écoles' are traditionally considered as an important element of the social reproduction where the social environment, in particular the family has an important role to provide information and to direct their child towards the engineering profession [9]. Beyond the social environment, it is evident that the alumni network of engineering school has a strong influence on their attractiveness. These networks not only reinforce the image of institutions but give the possibility for students to build their social capital during their studies. In several situation (e.g.: internship, first job, professional project, etc.) members of their school's alumni network could provide interesting professional opportunities [11].

4 APPLIED METHODOLOGY

To our knowledge, no prior studies have examined the attractiveness of French engineering schools. For this reason, we decided to apply a qualitative research methodology with a constructivist epistemological approach. Our exploratory study aims at investigating our problematic and provide a better understanding of it for eventual future researches [12].

Our research design based on qualitative data collection by carrying out 18 in-depth interviews with engineering students in three French engineering schools (6 interviews in each school) situated in Paris, Grenoble and Brest. The selection of the participant engineering students was based on the non-probabilistic chain or snowball sampling method relying on initial subjects to generate additional subjects that are relevant to our research topic. We applied this sampling method not only for its cost and time effectiveness but also for the simple reason that it is not easy to reach and involve this specific student population [13]. We contacted and involved our interview participants with the help of local groups of BEST (Board of European Students of Technologies) network.

Our interview guide composed on questions focusing on engineering students' decision-making for choosing their engineering school including their social and personal context. To test our interview guide design, three pilot tests were carried out by three different researchers to reveal the eventual weaknesses and correct them [12]. Before starting the interviews, all participants were informed about the purpose of the study and their right of withdrawal at any time when they desire. Following the principles of ethical research, they received written information about our engagement of confidentiality. They were required to give their written consent to participate in our study. The interviews lasted between 30 and 90 minutes depending on participants' involvement. They were digitally recorded and partially transcribed to make our data analyse process easier.

Our data analyse is based on the qualitative thematic analysis method following the recommendations of Silverman [14] by conducting a comparative keyword analyses (CKA). We followed a three-stage data analysis process. The first stage was a preliminary data analysis stage when three researchers were working independently on the first interpretation of the corpus by carrying out an initial coding. Then, during the second stage of our data analysis process, these initial codes were converted into standardized codes. In the third stage, we conducted a comparative analysis when researchers used the same codes for corpus analysis. During the data analysis process there was a regular discussion between researchers for reducing the interpretation bias and improve the interpretative validity of our research.

5 RESULTS AND DISCUSSION

Our findings allowed us to identify the following factors of French engineering schools' attractiveness: their prestige of excellence, high quality professional training and extracurricular activities, networking for social capital building and excellent employability and career opportunities.

5.1 Prestige of excellence

It was evoked by several interviewed students that in their high school as they "had great results, especially in physics" (E9) or other STEM subjects, "(our) teachers guide us generally to enter a preparatory class" (E7). In general, their family encouraged them, especially when there are engineers in the family, to follow their career path: "The choice was made for me, because I was good at maths and that I did not know what to do" (E13). Our findings is in line with the work of Dubruc and Boudarel [9] as we perceived a social pressure on students as witnessed by one them: "I was told that it was a bit of the royal way" (E2).

As the principal way to enter an engineering school is to take CPGE, the prestige of excellence of these preparatory classes has a direct positive influence on engineering schools' prestige of excellence. These preparatory classes take on only the brightest students with excellent results as one student in our study said "I think there is really an elite side [...] because being graduated from a preparatory class in not possible for everyone" (E10). Moreover, the prestige of a school is clearly linked to its ranking as it was affirmed by several interviewed students "I tried to have the best I can have, the better ranking" (E3). However, it was surprising that institutional prestige was not mentioned by interviewed students as a consequence the results of Draelants [7] could not be confirmed.

5.2 Professional training and extracurricular activities

Our results show that French engineering schools attract talented young students by providing high quality engineering training with interesting professional specialisations. The interviewed students' choice of their engineering school was often based on the proposed engineering specialisation. As one of them put it into word: "It was a very difficult choice as I hesitated between the prestige and my personal ambitions…I could had been enrolled in [name of a prestigious French engineering school] but my choice was to go in this school because of my passion in [name of a specialisation in engineering]" (E1) and another one added: "I really made my choice based on the specialisation" (E16). In comparison to universities, engineering schools apply a more student-centered pedagogy: teachers are more in the role of a "professional coach" than a “knowledge transmitter”. Many of the interviewed students affirmed that they feel “well supervised by their teachers”. As one of them affirmed, “The number of students per teacher is less important in engineering schools so we feel to have a good supportive supervision” (E2).

French engineering schools provide traditionally a wide-ranging choice of extracurricular activities to their students. These extracurricular activities, including many students’ clubs, associations with various activities contribute to attract young students to enrol in an engineering school. “Since we are in CPGE, we hear about clubs and associations in engineering schools and it attracts us to enter engineering schools” (E13). An unexpected finding of our study is that these extracurricular activities are viewed by students as an excellent opportunity to develop not only their technical skills but also their transversal skills worthwhile for their future career. All interviewed students participated in several extracurricular activities (in average in three activities).

5.3 Networking and social capital building

As it was confirmed by our findings, networking and social capital building opportunities are an important factor in engineering schools attractiveness. The possibility to create their professional network was considered as one of the major benefits for students to attain their engineering school. As several interviewed students emphasised, it is important to enlarge their friends’ network: “to go in contact with others for the success of my project” (E1) and “to develop relationships with people” (E11) which can be an asset for their future carrier.

Furthermore, according to our findings we have to highlight the role of engineering schools’ alumni to attract gifted young students. Thus, all the interviewed students claimed that they had been influenced in their choice by engineering schools’ alumni: “speaking with alumni is still very important” (E2) and schools, who are aware of that, count on alumni to present their institutions to students in CPGE in the framework of students’ forums. Several interviewed students have been influenced by such events: “Each year, in my preparatory class, there was a forum where all the alumni came to present their school and I discovered my current school at this moment” (E10).

5.4 Employability and career opportunities

Our findings demonstrated the key role of excellent employability and career perspectives in their choice of enrolling in a ‘grande école”. For all participating engineering students, graduating from an engineering school represents a “job security” for their life and a kind of guarantee “being in a financially comfortable situation with a correct salary” (E7). Another student added that “there is no concern about employability” (E5). However no one from the interviewed students has even a rough idea what could be exactly a correct salary. It could be explained by the fact that we interviewed Z generation students (were born after 1995) whose importance is “having happiness and enjoyment in their career” and not particularly worried about money [15:4].

This job security means not only having a satisfactory job but also having excellent long-term career perspectives. Being graduated in an engineering school was considered as a kind of guarantee to be in a good position on the labour market as it was affirmed by Béreau [6]. "When you come out of engineering school, you have more credibility than when you come out of a [name of a university diploma] (E7). It is interesting that the flexibility and manifoldness of engineering career was perceived by interviewed students as an important motivational factor for enrolling in an engineering school. A participating student indeed explained: “The flexibility [engineering studies] enable in one's choices of life comforts me” (E6).

6 CONCLUSION

Attractiveness of engineering is an important matter all over in Europe and considered as one of the five priority themes of SEFI. Consequently, attractiveness of engineering schools with a direct and significant influence on engineering education is a hot topic. Our exploratory study intends to give a better understanding of engineering schools attractiveness thorough our investigation of French engineering schools good performance to attract talented young students that could be extended in an international context.

Being an engineering student in a prestigious French engineering school is related to a very positive image and high social status. It seems to be obvious that the attractiveness of French engineering schools could come from their prestige. However, in our study we identified other important influencing factors on engineering schools’ attractiveness. Between these factors, we would like to highlight the importance of job security and employability perspectives evoked by all students participating in our study. As a consequence, engineering schools in their recruitment process should put more emphasis on good engineering employability perspectives for improving their attractiveness. According to our findings, the direct involvement of their alumni in it could provide an efficient promotion for recruiting future students.

The principal limitation of our study is that we interviewed only engineering students who passed a successful entry exam to enrol in their engineering school. Future studies could fruitfully explore this issue further by questioning students who are in preparatory classes. It would be interesting to investigate the perception of teachers and academic staff in engineering schools and preparatory classes. Regardless, future research could continue to explore this question at the European level in the framework of a comparative study.

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Understanding international students' barriers in their first-year at a U.S. university

H. Murzi [1]
ORCID: 0000-0003-3849-2947
Department of Engineering Education, Virginia Tech
Blacksburg, Virginia, United States of America

M. Greene-Havas
Department of Engineering Education, Virginia Tech
Blacksburg, Virginia, United States of America

J. Woods
Department of Higher Education, Virginia Tech
Blacksburg, Virginia, United States of America

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ABSTRACT

International students in the United States face several challenges when transitioning into college. The purpose of this paper is to understand how international students perceive the barriers they face in their first year attending college in the United States and to learn about the resources international students are utilizing for support. Data were collected qualitatively through individual interviews with 6 first-year international students. Data were transcribed and analysed using thematic analysis procedures. Results suggest that the barriers international engineering students face when attending college in the United States are complex and are summarized in terms of academic challenges, social and emotional adaptability, cultural clashes, and relationships with domestic students. Our findings provide implications for engineering education research on how to study international students' barriers, for practice on how to make first year classrooms more inclusive, and for advising on how to provide support that is required for international students.

1. INTRODUCTION

The international student population in the United States (U.S.) has been growing considerably in the last decades. This population is important because of the unique assets they bring into the classrooms by providing a variety of insights coming from their early academic and life experiences in their home countries [1-4]. Furthermore,

[1] Corresponding Author
H. Murzi
hmurzi@vt.edu

STEM programs rely considerably on international students, especially at the graduate level. Though it varies between institutions, in the last two years there has been an overall decrease in the international student enrolment at U.S. institutions. Hence, there is a need to provide a more positive experience for current international students in order to increase their attraction to higher education institutions in the U.S. and in order to increase the quality of their experience.

International students face at least three major barriers when coming to the U.S. to attend college: (i) engaging in a new social and academic environment [2, 5], (ii) in some cases, using English as a second language and in academic settings [5, 6], and (iii) experiencing “culture shock” relating to American culture and academic culture of higher education institutions [1, 2]. Although extensive research has been conducted on international students [2, 3, 7-12], there are no studies as far as we know that analyse the challenges of first-year international students while also exploring the support systems utilized to increase the engagement and motivation of this population at their new institution.

Extensive research has been done on how to increase students’ motivation and engagement in higher education. Engagement is seen as an important part of learning [13-15]. Students need to feel a sense of belonging within their academic program in order to effectively develop their identities as future professionals. Sense of belonging has been directly linked to successful outcomes in academic programs including persistence, self-efficacy, and perceptions of technical competence [16-18].

One purpose of this study is to understand how international students perceive the barriers they face in their first year attending college in the U.S. Another purpose is to learn about the resources international students are utilizing for support and use this knowledge to create more effective supports for this population of students. The primary research question that guided this study is:

RQ1: How do international students identify the barriers faced in their first year of college in the United States?

To answer the research question, data were collected qualitatively with international students attending their first semester of college at a large research institution in the United States. Sense of belonging was used as the theoretical framework to guide this study.

2. THEORETICAL FRAMEWORK

2.1. Sense of Belonging

Studies suggest that students become more engaged when they feel as though they belong. Carini, et al. [15] argue that research has demonstrated that student engagement is linked positively to desirable learning outcomes in students such as critical thinking and good grades. Understanding the importance of engagement, we also recognize that students become engaged with their academic program and their institution when they feel they belong. Floyd-Smith, et al. [19] explain that developing sense of belonging includes the development of a community where students can participate and interact with others. The authors developed a conceptual framework that emphasizes the impact of sense of belonging and academic outcomes for students in undergraduate education. According to Floyd-Smith, et al. [19] when students are engaged (i.e. feel they belong) they will also demonstrate intrinsic motivation. This engagement will lead to short-term and long-term positive academic and affective outcomes. It becomes crucial for the international students in the U.S. to find communities, and significant experiences to positively engage with their academic programs and their institution. Extensive research has been conducted on the importance of developing positive relationships, engaging in out-of-the classroom learning experiences, and feeling included as a member of an academic community to promote students' engagement that lead to short and long term positive outcomes [17, 23, 24].

Participation in extracurricular activities is another factor that leads to increased academic success. Wilson, et al. [23] explain that research suggests that when the student participation in extracurricular activities is voluntary, students have higher levels of "academic conscientiousness," (p.627) which the authors define as a willingness to raise their standards for academic performance. This includes how they perform in the classroom, understand class materials, but also is related to how they conduct research, and help and interact with classmates. The expectation is that students can develop short-term academic outcomes such as improving their critical thinking, problem solving, and research skills, developing productive relationships with their peers and mentors, and performing well in the classes they are enrolled. Some of the long-term academic outcomes that students can develop are to become engaged professionals who are able to successfully finish their academic program and effectively adapt to their first professional job.

According to Allendoerfer, et al. [18] providing students with opportunities to belong helps them overcome some of the needs they face during their time in college, and provides "the most return of investment for engagement in academic endeavours" (p. 512). The authors suggest that the most important part of providing sense of belonging and engagement are activities that enable students to receive family-like support, such as [18] (p.531):

- Formal cohorts of incoming students in classroom and/or labs
- Living/learning communities, such as residence halls
- Design teams/lab partners, scaffolded for success with respect to the team relationships as well as the project goals
- Weekly informal gatherings with faculty and students for non-academic reasons (e.g., departmental tea, lunches in the dining halls, etc.)
- Service learning opportunities
- Academically-related clubs, with space to meet and 'hang out' to facilitate community

Many of these suggestions are included in first-year programs in most Universities in the U.S., however, these programs are created for the U.S. context. For international students these initiatives might require additional efforts since they might face different barriers that prevent them from taking advantage of interventions created to welcome students into college.

Furthermore, learning environments that foster a sense of belonging offer more opportunity for students to learn in a more socially-complex manner. Baxter-Magolda [20] explains that knowledge is socially constructed based on interactions between the "self" and peers. Therefore, learning environments designed to promote mutual construction of knowledge will also promote self-authorship providing students with the opportunity to develop strong skills to learn and adapt knowledge to different situations –a desired skill for any profession. Candy [21] explains that learning is rarely a phenomenon that occurs entirely individually, rather it usually occurs in the context of social grouping. It becomes important to understand how to better provide social experiences that lead to international students' sense of belonging.

3. METHODS

A qualitative approach was used in this study to answer our research question. We used a case study as the methodological framework to explore the barriers international first-year students experience when attending college in the United States. Case study research is based on the examination of the context and every complex condition in the real-world setting of the phenomenon in order to have an integral understanding of it [26]. The unit of analysis for the case study are 6 first-year international students. We made this methodological decision because our goal was to better understand the students' experiences in their first year of college in terms of the barriers the students face which is considered a complex phenomenon.

3.1. Participants

Participants in this study were 6 international students in their first semester attending college in the U.S. from the following countries: China (2), India (2), Brazil (1), Vietnam (1). Four students are male (China, India, Brazil, and Vietnam) and two students are female (China, India). Each student participated in a semi-structured interview during the Fall semester 2018. Following IRB approval, participants were recruited via email. All participants received a $15 (USD) gift card upon completion of the interview and all interviews were audio-recorded and transcribed verbatim.

3.2. Data collection

The interview protocol utilized in the semi-structured interviews was piloted and contained questions about the experiences of international students during their first semester at a large, four-year research institution. Prompts focused on eliciting concrete descriptions of students' first week and month in the United States, experiences with their classes, developing friendships, and adapting to the new culture. The questions also asked the students to reflect and compare how their experience could have been different if they were U.S. students. Interviews lasted no more than 45 minutes and were conducted in a place mutually agreed upon by the interviewer and the student. Students signed a consent form prior to participation.

3.3. Data analysis

Data analysis was conducted by three members of the research team using the thematic analysis approach outlined by Robson and McCartan [22]. Thematic analysis uses individual experiences, interpretations, realities, and discourse as avenues for exploring the group to which the individual belongs [22, 23]. For this study, thematic analysis provided a means to understanding barriers that international students might face as constructed through the experiences and interpretations of our participants.

Transcripts were analysed using line-by-line open-coding to allow codes to emerge from the data. “In Vivo” coding was deemed appropriate since using the words from the participants, their terms and conceptualizations, is more likely to accurately capture the participants’ experience [25] . Codes were then grouped into themes to

support both within- and cross-participant analyses. Our themes were guided by the codes that emerged most often. Dedoose qualitative software was used to conduct the analysis and to identify patterns among the researchers.

3.4. Limitations

The study limitations are related to the transferability of the findings. Since the participants are a small sample, it might not be representative of all international students. In addition, results should be considered with caution as the students’ experiences represent a specific institution. Other Universities may utilize different approaches to support international students as they transition into their first year. Another limitation with regard to language proficiency is that all participants speak English as a second language. In some cases, the authors had to adjust student responses based on interview notes because the transcripts could not be understood. We recognize that some of the students’ experiences could have been lost by language translation.

3.5. Measures of research quality

Limitations were mitigated by having a set of procedures to ensure the results were of quality. Firstly, multiple coders met and agreed on analysis suggested in qualitative inquiry [25]. The coders met to discuss the early stages of data analysis. An agreement was reached after having discussions on initial differences in coding to increase the trustworthiness of the results. The credibility of the findings was determined to be aided by the immediacy of the interview. Students were interviewed in their first weeks at the University, allowing the interviews to capture their initial experiences promptly. The confirmability of the results was strengthened further in two ways. Coding was conducted by three authors, ensuring codes were not only decided by one author at any given time. In addition, data analysis was discussed collaboratively and results were deliberated by the three authors.

4. RESULTS

In answering the research question, our results clearly determined patterns in the responses of the students. We found several key patterns that emerged as barriers first-year international students face in the United States. These patterns are summarized into four major categories discussed below. They include academic challenges, social and emotional adaptability, cultural clashes, and relationships with domestic students.

4.1. Academic challenges

Academic challenges are described as the students' experiences with teaching and learning processes. Our data revealed that teaching practices including workload, teaching structure, and format of classes are major issues that students consider challenging in their first year. Students compared these with the educational system and structure in their home countries as well as with their high school context. For example, in describing the teaching practice, a student mentioned: "You really need to do more…you can't just go to class, watch the lecture and you are done. You need to do it more by yourself." Commenting on workload and structure, one student mentioned: "The first week it is just introducing something. There is no assignment you actually do by yourself. But now, they are just kind of overlapping the schedule and so many dues in deadline." Similarly, another student indicated:

> The schedule here is more of, the deadlines for different assignments is on different days, according to which program or which course you are taking. In [my home country]…there is a deadline, on the same day, for literally everything or a deadline week which will have all the exams and deadlines together. You can really figure out what you are going to do first, or what you are going to take time so you can start before that. Here it feels a little disorganized.

Being involved in a new academic system and adapting to new teaching styles represent a challenge for international students. They became used to a particular educational system and must now adapt to different processes and expectations.

4.2. Social and Emotional Adaptability

Social and emotional adaptability accounts for challenges students encounter in adjusting to their new society and processing emotional matters such as being away from home/family, taking responsibility for self, and making connections with others. For example, a student said: "Being away from home, trying to meet people" has been the most difficult aspect of beginning school in a different country. Students recognize that one major difference between themselves and the U.S. students is their access to family. This is not only with regard to being able to visit but also the feeling of having someone close to support them in case of an emergency. Another student described the challenge of being away from family members and taking responsibility, saying:

> There are things that you don't consider when living with your parents, because they are just there, available to you. Doing your laundry, or maybe

> doing the dishes, these are things that you don't really add on till you think you're just going to study, that's it. But then at home, there are parents who are doing your laundry, the dishes, or waking you up on time, making sure you're studying, making sure you are getting good grades, but here you are kind of responsible for whatever you do.

With regard to making connections with others, a student said: “There are always stereotypes about every community…so we are not sure how people might perceive us or treat us. I think that induces a little bit of nervousness. And kind of prohibits us from talking to people here.” This concern likely makes it harder to form friendships with domestic students, which is explored further in section 4.4.

4.3. Cultural Clashes

Cultural clashes describe the challenges experienced by the participants in terms of cultural differences. The most prevalent observations shared by students include interacting with the people, food, community, and language. As an example of clashes in interacting with people, a student said: “I think when international students come here, the biggest problem that they face is that here, people are more individualistic…our home countries are more collective.” Another student stated:

> There are people from almost every country in the world, you have to be more open-minded- and respect[ful]. For example, in [my country], if we don't have too many black people, you have to respect black people here, you don't want to get in trouble, and so on, people from all backgrounds, definitely, you first have to be respectful of everyone.

With regard to food, one student said: “In [my country], we eat rice but when I got here…The rice is very strange.” For students this represents a challenge because they consider food to be such an important aspect of life that not being able to find the food they like might affect other aspects of their academic life.

Regarding community, another student said: “[city] was…I thought it was bigger city.” While location and communities may be diverse, the latter excerpt represents the cultural shock for first-year international students who arrive to smaller communities from large cities.

Language was found to be a prevalent challenge, as in our data, most international students expressed this challenge. For example, a student shared:

> I am taking chemistry right now, which is also kind of a big challenge, because I had to go to learn all the chemistry rules again. Because it is now in English, it is no longer in Spanish…went back to the basics of chemistry to be able to be at the same level with everybody.

4.4. Relationships with Domestic Students

Relationships with domestic students represent perceptions of international students regarding their interactions with students from the United States. Our data showed that first year international students experience difficulties developing relationships with domestic students. For example, a student said:

> I'm the person who spoke pretty much in the class and American just like silent. Sometime they do, but not always, so that not reach my expectation. Yes, so that's the thing. I hope everyone engage more in the class.

As another example, one student mentioned: “Americans in general, they have a much harder time socializing than [my nationality].” Commenting further on the challenge of interacting with domestic students, another student said: “In our group...we can rely on each other more than we could on local students or American students.” For many international students this is an important factor and many of the students interviewed expressed that they would like to have more friends from the United States.

5. DISCUSSION

This work used a qualitative approach to answer the following research question: How do international students identify the barriers faced in their first year of college in the United States? Data indicate that the most prevalent barriers first-year international students experience fall within the themes of academic challenges, social and emotional adaptability, cultural clashes, and relationships with domestic students. Academically, students indicated that course logistics and requirements varied from their previous experiences. In addition to transitioning into the increased responsibilities required of all new university students, international students must adjust to a very different way of teaching and learning than was experienced previously. Socially and emotionally, international students must navigate new relationships in a different culture and with less direct family support. The awareness of cultural differences and stereotypes adds an additional layer of worry to students as they embark upon building new relationships while sometimes also navigating new language demands. Culturally, some of the participants noted explicit differences between habits among students from individualistic societies versus collectivist societies. These differences can impact how interpersonal relationships are created, how school projects are completed, and how different students prioritize their time. Also, participants often discussed how food options or lack thereof contributed to feelings of homesickness. While participants indicated a desire to make more domestic friends, many described difficulties facilitating those connections. All of the factors listed above play an important role in students’ academic success.

Study results lead to multiple implications for first-year programs to consider when serving an international student population in order to create a stronger sense of belonging. Firstly, though findings showed that international students are aware of support resources available on campus, few are utilizing those resources. Therefore, it would be beneficial for academic programs to more thoroughly share the potential benefits of available resources with this population of students. Secondly, it is important that instructors, advisors, and other university professionals be briefed on the various cultural experiences and expectations of international students in order to better understand the extreme transition these students experience as they begin university. This should include discussion of the social and emotional impact students experience when attending university abroad. Thirdly, universities would benefit from providing a space in which international students can share their cultural experiences and surprises. Lastly, as a benefit to both international and domestic students, it would be useful to provide more explicit opportunities for international and domestic students to network with one another.

6. FUTURE WORK

We plan to continue our research to gain further insight into the barriers international students face. Additionally, we plan to implement additional programming that will incorporate the recommendations listed above to provide these students with a stronger sense of belonging. Specifically, we plan to provide international students in the near future with more information about academic expectations in the United States and more detailed information on available resources. Furthermore, we plan to continue sharing our findings with the engineering education community.

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A Web Application for Predicting Academic Performance and Identifying the Contributing Factors

M. Nagy and R. Molontay
Department of Stochastics, Budapest University and Technology
Budapest, Hungary
MTA-BME Stochastics Research Group
Budapest, Hungary
E-mail: marcessz@math.bme.hu, molontay@math.bme.hu

M. Szabó
Central Academic Office, Budapest University and Technology
Budapest, Hungary

Conference Key Areas: Engineering Skills, Recruitment and Retention of students

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ABSTRACT

Data-driven approaches have received a lot of attention recently from higher education researchers and policy-makers as well. At the Budapest University of Technology and Economics, we aim to extract insight from big data stored in the educational administration system in the framework of a project carried out in the cooperation of Central Academic Office and Institute of Mathematics. Among many other questions, we studied curriculum prerequisite networks with a student flow approach, the effect of mathematical remediation, the impact of living on-campus on academic achievement, the connection between grade inflation and student evaluation of teaching and efficient visualization of student flows. However, one of the most burning problems in higher STEM education all over the world is dropping out. In this paper, we present a predictive analytical approach for early detection of students at-risk of academic failure. We achieved relatively high accuracy, compared to the results of related works, which makes it suitable to deploy as a decision support system. We also present a web application that is able to identify at-risk students mainly based on their high school grades and matura scores using machine learning algorithms (e.g. XGBoost). The application can also be used to recommend tutoring sessions and remedial courses for at-risk students. Based on SHAP values, the application is also capable of making suggestions for students which skills to improve in order to succeed in their university studies. Besides Hungarian education system, our proposed methodology is also applicable to other educational environments all over the world.

1 INTRODUCTION

Data-driven approaches have been extensively used in a number of scientific fields, including educational research. The big data stored in educational administrative systems hold great potential for data-driven educational research. Due to this, new scientific fields have emerged such as educational data mining and learning analytics, for systematic reviews we refer to [1, 2].

At the Budapest University of Technology and Economics, we also initiated a project in the cooperation of the Central Academic Office and the Institute of Mathematics with the objective to extract knowledge from the massive educational data of the university. The fruitful cooperation has resulted in a number of publications and the development of decision support applications to help policy-makers and other stakeholders.

We have introduced a data-driven probabilistic student flow approach to characterize curriculum prerequisite networks which can be used to identify courses that have a huge impact on the graduation time [3]. Our approach is also capable of simulating the effects of policy changes and modifications of the prerequisite network [4]. We also developed an efficient visualization tool to analyze student flow patterns by alluvial and Sankey diagrams that allows decision-makers to gain a better insight on how students are processing and it makes easier to understand the effects of policy changes on retention and graduation rates [5]. We introduced a novel approach for ranking secondary schools based on their students' later university performance [6]. Furthermore, in [7] we measured the direct and longer term effects of mathematical remediation on academic achievement using a regression discontinuity approach. The impact of living on-campus on academic performance was also investigated [8]. Moreover, we studied the connection between grade inflation and student evaluation of teaching. As a first study of this nature from Central Europe, in accordance with other studies, we found that increasing the grade of a student by 1, will lead to approximately 0.25 higher evaluations for the instructor [9, 10]. Furthermore, we analyzed the predictive power of the Hungarian nationally standardized admission point score and its variants on academic performance [11].

Predicting students' academic performance is a challenging task of great importance. In particular, predicting dropouts and early detection of at-risk students have attracted a lot of research interest [12], since dropping out is associated with considerable personal and social costs [13] and it is regarded as one of the most burning problems in higher STEM education all over the world. Machine learning algorithms have been applied in many studies to predict dropout risk and academic achievement measures and to discover the important factors affecting student performance [14, 15]. Early detection of at-risk students allows institutions to offer more proactive personal guidance, remedial courses and tutoring sessions in order to mitigate academic failure.

The first two authors of the present study also employed several machine learning algorithms (e.g. neural networks and gradient boosting trees) to predict student dropout mainly based on secondary school performance [16]. The present study extends [16] in several directions, most importantly by extracting insights from the machine learning models, namely identifying the most important features and analyzing the effect of each feature on the prediction. A key issue and one of the hottest topics in machine learning nowadays is model interpretability, especially if there are implications associated with the model's prediction [17]. Interpreting the results also highly assists students, policy-makers, and other stakeholders since it sheds light on factors affecting academic performance and being an "at-risk student". For model interpretation, we use cutting-edge techniques such as permutation importance [18] and SHAP (SHapley Additive exPlanations) values [19]. Another contribution of this work is that we developed a novel web-application by adding several new features to enrich user experience.

2 BACKGROUND ON HUNGARIAN HIGHER EDUCATION

In this section, we summarize some characteristics of the Hungarian education system with an emphasis on the admission procedure to higher education institutions, a more detailed overview can be found in [16]. Hungarian education consists of 8 years of primary education, 4 (or sometimes 5) years of secondary education and optionally of higher education standardized by the Bologna Process. A five-point grading scale is used where (5) corresponds to excellent and (1) is the failing grade.

The nationally standardized higher education admission system defines the Admission Point Score (APS) that is mostly based on the secondary school performance and on the score of the centralized exit exam, called matura. Undergraduate programs rank students according to their APS, while students also have a preferential ranking of the desired programs. The admission procedure is governed by the student-optimal matching algorithm of Gale and Shapely.

Due to the admission system, universities have a lot of data regarding prior academic performance of incoming students such as grades in the core subjects (mathematics, Hungarian language and literature, history, a chosen foreign language, a chosen science subject) from the last two academic years, the level (normal or advanced) and scores of matura exams, foreign language certificates etc. The aforementioned results indicate a broad spectrum of knowledge and skills. In this study, we investigate how future academic performance, particularly dropping out can be predicted based on the prior performance and what the most important contributing factors are.

3 DATA DESCRIPTION

The present study is based on the data of 6,774 students enrolled in one of the undergraduate programs of Budapest University of Technology and Economics between 2013 and 2018. The available attributes are presented in *Table 1*.

Table 1. Overview of the data fields

Feature class		Feature name	Type
University program related		Student ID	Nominal
		Program ID	Nominal
		Financing source	Binary (state-funded or self-funded)
		Re-enrolling	Binary (True or False)
	Label	Final status	Binary (Graduated or dropped out)
High school performance related			
	Matura exam scores	Elective subject	Numeric
		Foreign language	Numeric
		History	Numeric
		Hungarian language and literature	Numeric
		Mathematics	Numeric
	Average of grades	Foreign language	Numeric
		History	Numeric
		Hungarian language	Numeric
		Hungarian literature	Numeric
		Mathematics	Numeric
		Science subject	Numeric
	Certificate of foreign language(s)	Score (based on the number and level of certificates)	Numeric
Personal details			
		Gender	Binary (female or male)
		Years between the dates of matura and enrollment	Numeric
		Location of high school	Categorical (capital city, city with county rights, foreign city and other)

After the data were collected in an anonymized way from the administrative educational system, various data preparation steps were conducted. The data preprocessing and cleaning tasks include pivoting and merging the data sheets, handling missing data, attribute transformation and dimension reduction. For handling missing data, we used Multiple Imputation by Chained Equations (MICE) with Bayesian Ridge Regression.

In order to reduce the high complexity of study related attributes, we carried out several data transformation steps such as merging and combining attributes. For example, by combining the point (0-100) and the level (normal or advanced) of the matura exams into one attribute (by multiplying the score with 1.5 for advanced level exams), we reduced the number of matura-related attributes by a factor of 2. We also merged the results of several extremely similar subjects into a smaller set of more meaningful attributes.

For the sake of simplicity, we define the final status to be binary by omitting the students who are still active in their studies and we consider students as being graduated if they completed the required studies even if they did not obtain a degree certificate (e.g. due to the lack of the required language certificates). It is also important to note that as opposed to other similar studies, we do not face the problem of imbalanced class distribution due to the high dropout rate at our university and due to the fact that students who have started their university studies after 2016 could not graduate yet, meaning that from this student cohort we have more data of dropped out students. Overall, in this study we analyze the data of 3,003 graduated and 3,411 dropped out students.

There are university programs that were launched or terminated during the examined period, we also omit these programs from the data. The aforementioned steps both reduce computational complexity and improve the interpretability of the results. After data pre-processing, we obtained 19 attributes of 6,414 students.

4 METHODOLOGY

The aim of this paper is to predict whether an incoming student will graduate or drop out based on data available at the time of enrollment (prior academic performance, personal details). Since we can rely on historical data where the actual final status is known, this problem is a supervised learning task. More precisely, it is a binary classification task where the label is the final status and the explanatory variables are detailed in *Table 1*.

Various techniques have been proposed for solving binary classification tasks, in our earlier work we also compared several methods for dropout prediction and gradient boosting trees (GBT) turned out to be the best performing model for a restricted number of attributes [16]. In the present study, we also use an advanced implementation of gradient boosted decision trees, called eXtreme Gradient Boosting (XGBoost) [20] that is considered to be the state-of-the-art machine learning algorithm for structured data with many advantageous characteristics such as parallelized tree building, regularization for avoiding overfitting and efficient handling of missing data. For fine-tuning the hyperparameters of the model, we used grid optimization with cross-validation.

For the final evaluation of the model we use ROC/AUC (receiver operating characteristic/area under ROC curve) analysis together with the accuracy, precision and recall measures on stratified test samples (random samples, such that the class distribution in the subsets is the same as in the whole dataset).

For model interpretation, we use two additional techniques: permutation importance for global and SHAP (SHapley Additive exPlanations) for local interpretation. Permutation importance measures how the accuracy of the prediction decreases if a single feature of the validation data is randomly shuffled (mimicking the effect of removing that feature) [18]. SHAP provides local explanations for the output of any machine learning models based on game theoretical concepts [19]. For a particular prediction, it measures how each feature contributes to push the model output from the base value (the average output over the training data) to the output value, thus it directly shows the strengths and weaknesses of a particular student and helps to identify his/her possible skill gap.

5 WEB APPLICATION

The web application was developed in Python 3 using Dash web framework. Based on the user input (the input fields are shown in Fig. 1), the web application returns a prediction whether the student will graduate or drop out together with a probability score of graduation. Moreover, the application also helps the user to interpret the results by showing what contribution each feature has on the prediction, i.e., by the visualization of SHAP values, see *Fig. 2*.

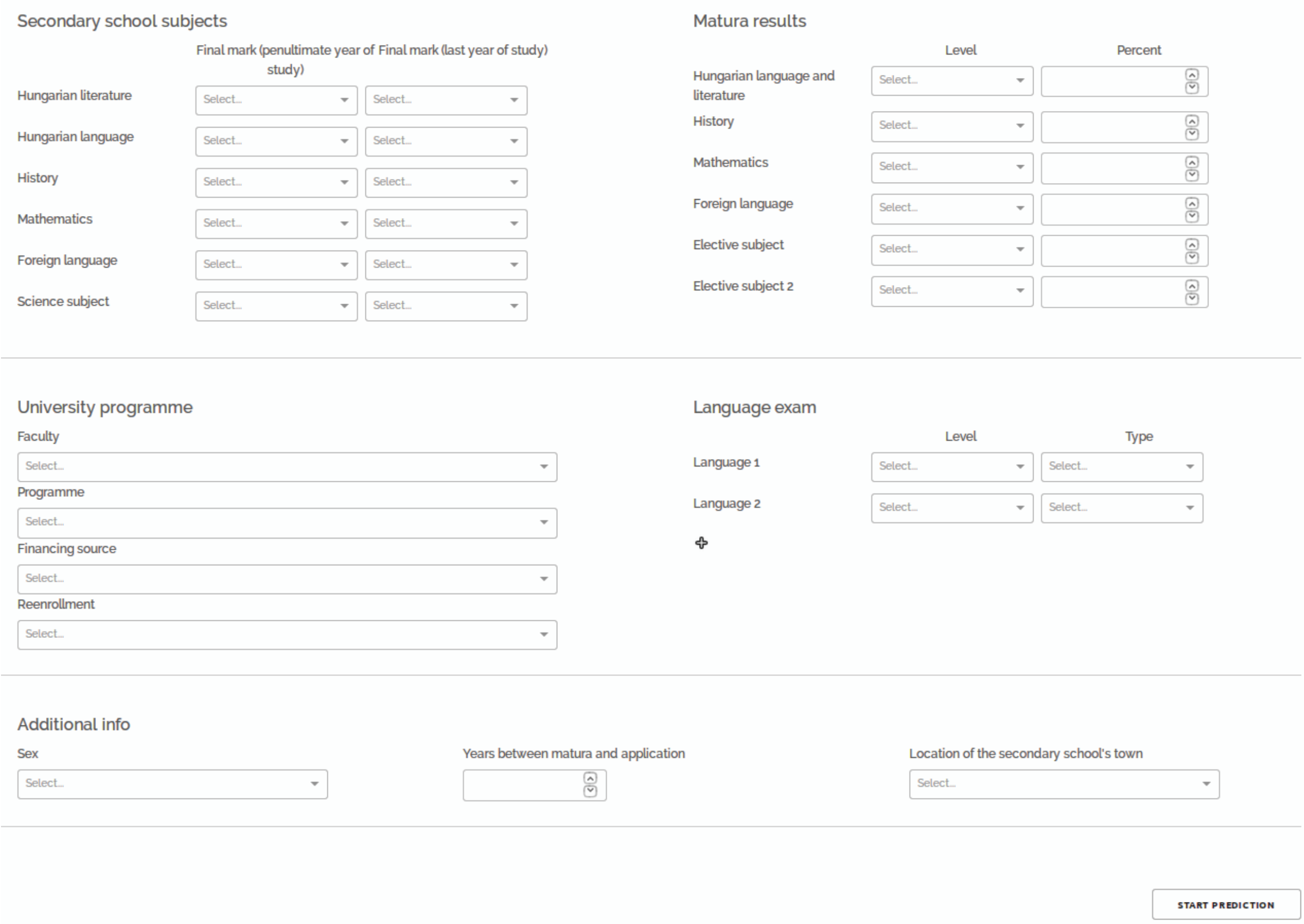


Fig. 1. The user input interface of the web application

In *Fig. 2* we can observe a strong student (bottom row), a borderline student (middle row) and an at-risk student (top row). The output values (probability of graduation) is highlighted in each case together with the interpretation of the prediction. Regarding the at-risk student, we can observe that the most endangering factor is the fact that on the mathematics matura exam (s)he obtained just 62%, followed by the fact the average grades in his/her elected science subject is 3.5 and the average grades in history is just 2. On the other hand, the fact that (s)he enrolled in university right after the matura exam contributes positively to the prediction.

As for the borderline student, his/her good matura scores push the prediction higher, while the fact that two years passed between the matura exam and the university enrollment together with his/her satisfactory (3) high school grades in Hungarian language push the prediction lower. Finally, regarding the strong student, his/her excellent matura scores in mathematics and in his/her elected subject contribute the most to the positive prediction.

The presented results may help the students to understand their strengths and weaknesses and to choose the right action plan. Moreover, it is also advantageous for university policy-makers to understand what characteristics make a student more likely to drop out.

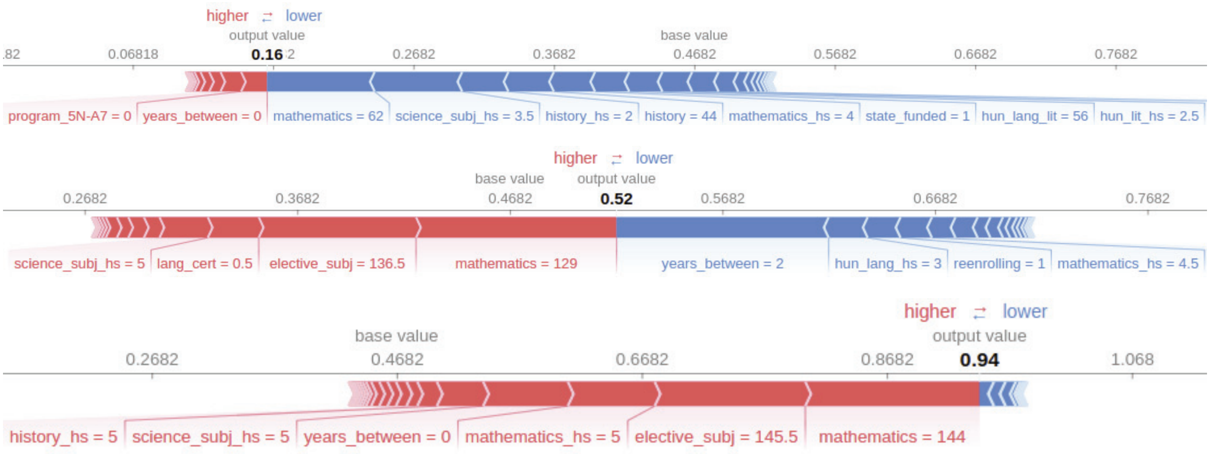


Fig. 2. Prediction explanation for three students of the test dataset. Features pushing the graduation prediction higher are shown in red and those pushing the prediction lower are in blue.

For assessing the utility and clarity of the web application, we presented it for a body of university management and we have already started to test the tool with high school students as well. The overwhelming majority approved the application and found it useful and easy to understand with high potential for further development as it answers the demands of the university to better understand the characteristics of at-risk students and it also assists students in identifying their possible skill gaps.

6 RESULTS

In this section, we present the results of the predictive model together with the global importance of the features and the local interpretation of the prediction.

6.1. Model performance

The (ROC) curves of the models are presented in *Fig. 3*. One can observe that XGBoost algorithm on the original (incomplete, without imputation) data set has the best performance with AUC=0.772, XGBoost and Random Forest algorithms also perform quite well on the imputed data set. The results suggest that the internal treatment of missing values in XGBoost is more efficient than the used imputation method (MICE). XGBoost on the original data set has accuracy of 71.4%, precision of 71.8%, recall of 76.2% and F-score of 73.9%. To compare our results to other related studies, this is a remarkable performance considering the fact that the data are heterogeneous and the prediction only relies on data available at the time of enrollment [16]. Moreover, this performance makes it possible to build a relatively reliable decision support system on this model.

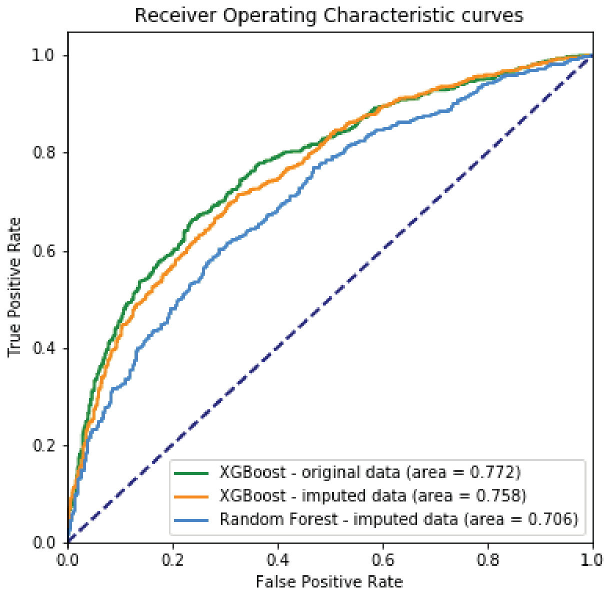
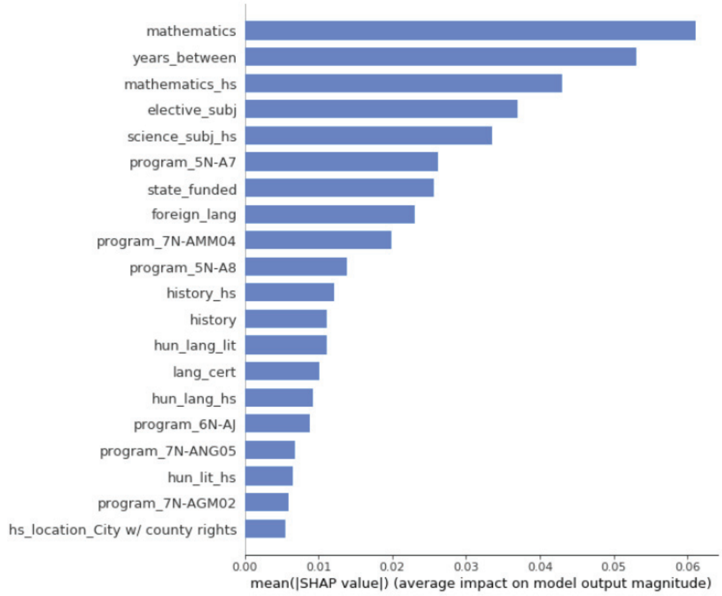


Fig. 3. The ROC curves derived from the test data

6.2. Model interpretation

We have already demonstrated the explanatory ability that SHAP values have regarding particular predictions (see *Fig. 2*). Here we analyze the global importances of the features aggregated from the SHAP values of individual predictions.

Fig. 4 shows the global feature importances based on the SHAP values and on permutation importance method. We can observe that the results are consistent, both methods find mathematics matura score the most important contributing factor on separating at-risk students, followed by the number of years between the matura exam and the university enrollment.



Weight	Feature
0.0526 ± 0.0228	mathematics
0.0349 ± 0.0149	years_between
0.0171 ± 0.0047	elective_subj
0.0120 ± 0.0049	program_7N-AMM04
0.0116 ± 0.0095	state_funded
0.0086 ± 0.0066	foreign_lang
0.0085 ± 0.0095	program_5N-A7
0.0056 ± 0.0071	mathematics_hs
0.0034 ± 0.0019	program_3N-A0
0.0031 ± 0.0087	program_5N-A8
0.0030 ± 0.0025	program_4N-A5
0.0030 ± 0.0015	program_6N-AJ
0.0025 ± 0.0022	program_1N-AEM
0.0017 ± 0.0031	program_2N-AT0
0.0016 ± 0.0017	program_2N-AE0
0.0015 ± 0.0010	hs_location_Captial city

Fig. 4. Feature importances. On the left: the average absolute SHAP values of the attributes are shown. The figure on the right shows the outcomes of the permutation importance method.

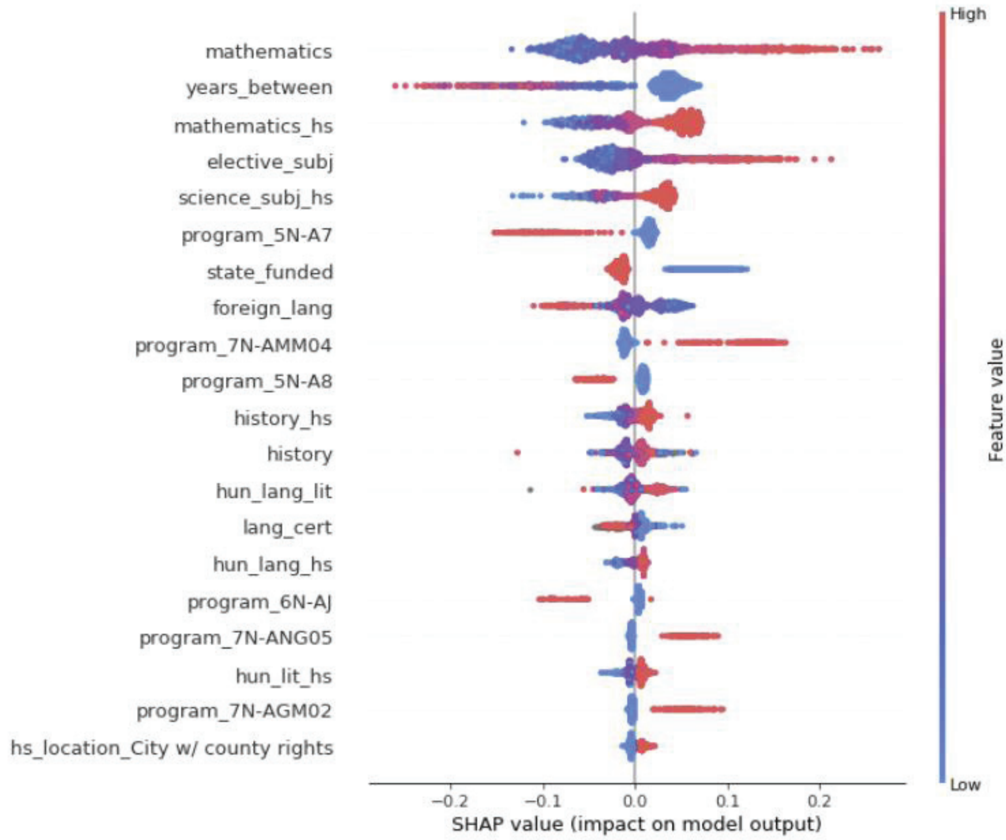


Fig. 5. Summary of the effects of the most important features. Every student (of the test data) has one dot in each row. The *x* position of the dot shows the impact of that feature on the prediction, and its color represents the value of that feature for the student. Dots that do not fit on the row pile up to show density.

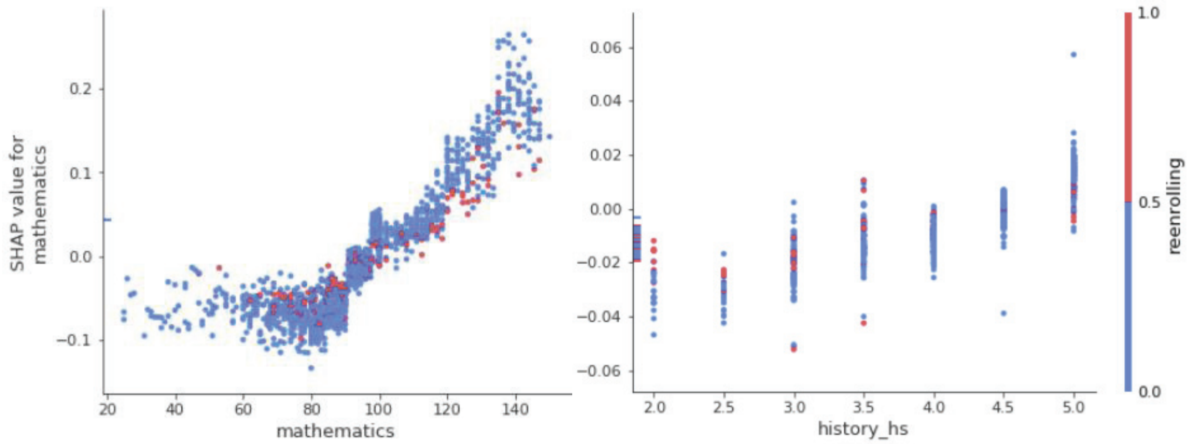


Fig. 6. SHAP dependence plots of mathematics exam scores and average high school grades in history. Each student is represented by a point on each figure, the *x* positions are the marks in the subjects, the colors indicate whether the student is re-enrolled and the *y*-axis shows how and to what extent the subjects influence the prediction.

Fig. 5 illustrates the distribution of the SHAP values for each feature. Here again we see that mathematics matura scores have the highest impact on the probability of graduation. We can also observe important outlier effects, e.g. the financing source (state_funded=0 if fee-paying and 1 otherwise) attribute is not so important globally, but it is an influential feature for the fee-paying students, since they graduate with higher probability. The reason behind the importance of university programs is the fact that graduation rates vary across the programs.

From *Fig. 6* we can observe that higher scores in mathematics or in history imply higher positive effect on a typical prediction. However, in the low range of mathematics scores, the effect seems to be constant.

7 SUMMARY

Predicting academic failure, early-detection of at-risk students and identifying the key contributing factors have ever-growing importance, in particular in STEM higher education where dropping out of students is a serious issue all over the globe. In this paper, we presented a machine-learning based decision support system to assist both students and decision makers. Our web application may assist secondary school students to choose the appropriate major in university based on their skill sets or help them identifying the skills that need to be improved in order to succeed in their university studies. The application is also helpful for higher-education decision-makers to choose the right action plan in terms of offering tutoring and remedial courses for at-risk students. Moreover, our findings may support secondary school policymakers as well to make the transfer from high school to university smoother.

Although our proposed methodology has been developed for the Hungarian education system, this approach is also applicable to other educational environments all over the world. Especially, if standardized pre-enrollment achievement measures are available (e.g. nationally standardized test scores such as the SAT and ACT) to predict college success.

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Changes in perceptions of ethical climate among undergraduate engineering students

S. Nittala[1]
Purdue University
West Lafayette, United States

S. Howland
Brigham Young University
Utah, United States

B. Jesiek
Purdue University
West Lafayette, United States

Conference Key Areas: Gender, inclusion and ethics; Diversity in Engineering Education

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ABSTRACT

Promoting ethical conduct and social responsibility among undergraduate engineering graduates has been an ongoing challenge for many universities around the world. Among many factors shaping such commitments, the ethical climate within engineering degree programs specifically and universities more generally seems especially pertinent. Yet there remains a lack of research on, and understanding about, engineering students' perceptions of ethical climate, including how this changes over time and impacts their professional formation and values. This paper draws on an NSF-funded, mixed-methods, longitudinal research project conducted across four U.S. universities. The larger project aims to investigate perceptions and attitudes around ethics, social responsibility, and related concepts among engineering students. In this paper, we more specifically explore various facets of ethical climate across the three schools through a mixed-method explanatory study. We focus on quantitative survey measures (n=257) and qualitative interview data (n=33) collected from engineering students during their first and final years of college. We more specifically shed light on three main research objectives. First, we investigate how engineering students perceive ethical climate across the four universities. Second, we explore how students' perceptions of ethical climate change over time. Third, we look at how specific experiences may contribute to students' ethical climate perceptions, including changes over time. This study will appeal to engineering educators, policymakers and researchers who are interested in research on ethics, social responsibility, and related topics. By providing foundational insights about students' perceptions of ethical climate, we hope to inform strategies to improve the ethical climate at universities and ethical commitments of engineers.

[1] Corresponding Author
S. Nittala
snittala@purdue.edu

1 INTRODUCTION

Calls for developing ethical and socially responsible engineers have been persistent for many years among engineering educators and professional communities alike. Indeed, a recent revision of the ABET accreditation criteria for engineering degree programs requires as one of seven learning outcomes that graduates have "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" [1]. Further, studies have shown that universities and engineering programs have a significant role in shaping students' beliefs and norms related to engineering ethics [2, 3]. And, as universities continue to explore how to support such capabilities, promoting an ethical climate of conduct within and beyond the classroom would seem synergistic with this larger goal. Yet there remains a lack of research on, and understanding about, engineering students' perceptions of ethical climate, including how this changes over time and more generally impacts their professional formation and values.

In response to this gap, this paper addresses the following research questions:

RQ1. How do students perceive ethical climate and how do those perceptions change over time?

RQ2. What experiences contribute to the shifts in ethical climate perceptions among students?

We additionally intend for our research findings to shed new light on possible connections between ethical climate, academic integrity, and professional conduct within engineering education and practice. We expect the research represented in this paper will benefit engineering educators, academic leaders and administrators, and professional organizations seeking to enhance the ethical climate in universities, and particularly in engineering programs. This work may also help stakeholders identify strategies for developing positive ethical behaviours among students.

2 LITERATURE REVIEW

Prior research has examined ethical climate in a variety of contexts. For instance, Finelli et al. hypothesized a conceptual framework for students' ethical development during college that is comprised of three main parts: each student's individual characteristics, the environment (including peer and organizational context), and the student's specific experiences [4]. As these authors argued, these parts all work together to inform ethical development among students. Their conceptualization of the peer environment and organizational context included specific policies, values, practices, and beliefs of students, faculty, and administrators, which in turn seems to suggest that each institution has a unique ethical climate. Foundational research regarding ethical work climates was similarly conducted by Victor and Cullen [5]. They defined ethical work climates as "prevailing perceptions of typical organizational practices and procedures that have ethical content" (p. 101).

In order to better study and assess ethical climates, Arnaud developed a new measure based on Rest's four-component model [6,7]. The four components are moral judgment, moral sensitivity, moral motivation, and moral character, which are believed to underlie how people make ethical decisions. Arnaud built on Rest's model by proposing that these four components are not just present for individuals making decisions, but are also present for collective or social decision-making. She defined ethical work climates as "the shared, aggregate perceptions of employees with respect to the content and strength of the prevalent values, norms, attitudes, and behaviours of the members of a social system" (p. 348). Her model included six collective factors built on Rest's four individual components: collective sensitivity (moral awareness and empathetic concern), collective moral judgment (focus on self and focus on other), collective moral motivation, and collective moral character. Of these six collective factors, three have been shown to predict ethical behaviour: empathetic concern, moral motivation, and moral character. The present study adopts Arnaud's framework and uses a related survey tool to investigate perceptions of ethical climate among undergraduate engineering students.

3 METHODS

The larger project represented by this paper is a three-phased longitudinal mixed methods study conducted across four universities: Arizona State University, Brigham Young University, Colorado School of Mines, and Purdue University. The project aims to address three main research objectives, namely to: 1) Characterize patterns of ethical development among undergraduate engineering students during their four years of university education, 2) Identify specific context variables and types of interventions that impact student perceptions of ethics and social responsibility, and 3) Identify specific student characteristics that can be leveraged to grow programs oriented toward ethics and social responsibility.

To address these research objectives, qualitative and quantitative data were collected during three main project phases. The first phase data includes interviews and survey measures conducted during participants' first year of study (year 1). The second phase includes mid-point survey measures conducted in the fifth semester of study (beginning of year 3). The final phase includes repeat survey measures and interviews during participants' final semester (end of year 4). The survey includes various measures related to students' views on ethics and social responsibility, engineering ethics, justice beliefs, moral disengagement, ethical climate, etc. The semi-structured interview protocol also includes some prompts that revisit various questions and constructs drawn from the survey.

In this paper we focus primarily focus on data from phase 1 and phase 3 across three universities and related explicitly to the ethical climate construct. We have not included the fourth university in this paper due to a low response rate and small sample in the final round of data collection. The study follows an explanatory mixed method design approach, with the first phase involving quantitative analysis using the survey data. For the quantitative phase, survey data from both year 1 and year 4 are used as data sources. The initial survey data administered in 2015 consists of 671 responses across three universities. This survey included eight scales, including the short form (19 items) of the Ethical Climate Index (ECI; [4]). These nineteen items measure six climate factors: norms of moral awareness, norms of empathetic concern, focus on self (reverse scored), focus on others, collective moral motivation (reverse scored), and collective moral character. Each item is measured on a six-point Likert scale ranging from completely false (1 point) to completely true (6 points). The higher the score on the ECI, the more students perceive their university's climate as ethical.

Because the ECI was being to measure the ethical climate of a university rather than a workplace, the wording of some items was changed to refer specifically to a university context. For example, the ECI item "People in my *department* recognize a moral dilemma right away" was changed to "People at my *university* recognize a moral dilemma right away." The survey was sent out in spring 2019 to the same group that completed it in 2015. In 2019, 266 students completed the survey for a response rate of 38%. Of those, 257 completed the ECI in both surveys. These 257 paired responses are the data analysed here. Internal reliability (α) for the nineteen-item ECI scale was calculated to be 0.907 for the initial survey and 0.921 for the final survey.

For the qualitative part of this study, interview data from year 1 and year 4 are used as data sources. In year 1 a total of 111 interviews were conducted. The interview prompts included a primary question asking students to describe the ethical climate at their university. This was followed by additional prompts including:

a. What examples do you have that make you feel this way?
b. Did you participate in any orientations sessions where expected behaviour was discussed?
c. How were these expectations communicated to you?
d. Does your university have a code of conduct that all students sign?
e. How was this code of conduct presented to students?
f. Have you discussed this code of conduct in any of your classes?
g. Do you think students behave according to the code of conduct? Why or why not?
h. Do you feel there are certain situations where you feel students are more willing to bend the rules? If so, when? And what makes you feel this way?

The repeat interviews were conducted again in 2019 with 33 students. The year 4 protocol included the same prompts as year 1 with an additional prompt probing students' perceived shifts in ethical climate perceptions during the interim period. The recorded interviews were further transcribed and cleaned for quality purposes. And, all student names in the interview transcripts were anonymized and correspond to the university affiliation based on first letter.

4 QUANTITATIVE RESULTS

As noted above, data from the 257 respondents who completed the ECI in both surveys are reported here. A paired-sample *t*-test showed that for the students who completed the ECI in both surveys, their overall ECI scores decreased by 3.8 points from 76.4 (standard deviation = 11.4) in 2015 to 72.6 (standard deviation = 12.4) in 2019 ($t = 5.063$, $df = 256$, $p < 0.001$).

When a split-plot ANOVA was used to see if there were differences among students at the three universities, the results showed that students at all three universities scored differently from each other ($F(2,254) = 18.025$, $p < .0001$, partial eta squared = 0.124). Post-hoc analysis showed that students at Brigham Young University had ECI scores that were statistically significantly higher than students at Colorado School of Mines and Purdue University at both time points ($p < 0.001$). The scores of students at Colorado School of Mines and Purdue University were not significantly different from each other in either 2015 or 2019 ($p = 0.459$) (Table 1, Fig. 1). There was no statistically significant interaction effect ($F(2,254) = 0.824$, $p = 0.440$) which means that students at all three universities changed at the same rate over time.

Table 1. Total ECI scores (standard deviations)

	2015	2019
BYU (n = 42)	85.2 (12.2)	79.5 (11.8)
Mines (n = 115)	73.5 (11.0)	70.6 (11.7)
Purdue (n = 100)	76.0 (9.7)	71.9 (12.4)

When examining the six individual factors using paired-sample *t*-tests, scores on five factors (norms of empathetic concern, focus on self, focus on others, collective moral motivation, and collective moral character) significantly decreased from the first to final measure (Table 2, Fig. 2). The one remaining factor (moral awareness) did not show a statistically significant change over four years ($p = 0.327$).

Table 2. Changes on ECI subscale scores (standard deviations), 2015 to 2019

	2015	2019	Change (2015 to 2019)	p-value
Focus on Self	7.4 (2.8)	7.0 (2.8)	0.4	0.044
Moral Motivation	9.7 (2.8)	9.1 (3.2)	0.6	0.001
Moral Awareness	13.8 (2.2)	13.6 (2.3)	0.2	0.327
Empathetic Concern	19.4 (3.0)	18.5 (3.2)	0.9	0.000
Focus on Others	13.3 (2.3)	12.2 (2.4)	1.1	0.000
Moral Character	12.8 (2.3)	12.2 (2.5)	0.6	0.001

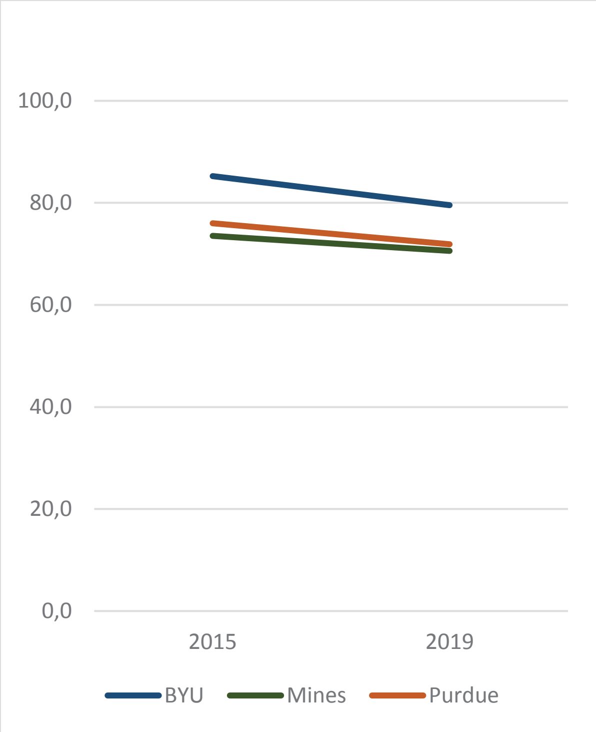

Fig. 1 ECI scores for each university

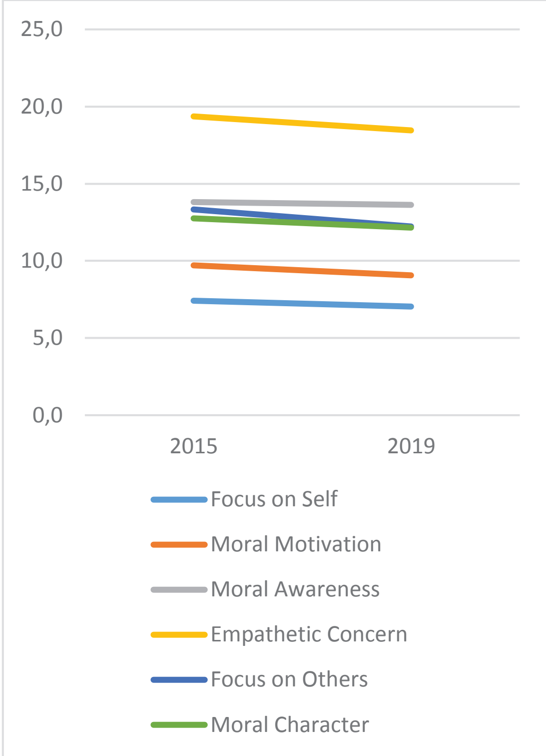

Fig. 2 ECI subscale scores (overall)

5 QUALITATIVE RESULTS

Further analysis of the survey data corresponding to the subset of respondents (n=33) who completed interviews during year 1 and year 4 reveals that 22 of these individuals showed a decrease in ECI scores, 4 showed no change, and 7 showed an increase. This is quite consistent and representative of the larger survey data sample. Of these 33 pairs of interview data, 7 pairs were identified for further exploratory analysis. The 7 pairs selected represent respondents who either had the most significant decrease (n=4) or significant increase (n=3) on the ECI scales.

In the qualitative phase, these 7 pairs of interview data were further analysed using thematic analysis techniques [8]. Preliminary analysis of the interview data indicated that most students did not perceive significant shifts in their perceptions of institutional ethical climate from year 1 to year 4. The few that did acknowledge changes in their perception of the ethical climate did not characterize the change as positive or negative. Specifically, in response to the year 4 interview prompt asking students if they viewed any shifts in their ethical perception of their respective universities, most students stated that they did not perceive any major shifts.

For instance, Bagheera, who had one of the most substantial increases in ECI scores, stated in response to a question about whether he had experienced any shifts in perceptions of ethical climate over the last few years: “I'm not sure that it has much.” Similarly, Cody who had one of the largest decreases in ECI scores expressed uncertainty in her shifts in ethical climate perceptions as she responds by saying “I mean, maybe a little bit.” In another account, Patricia, who also had a large decrease in ECI scores, states “I don't know if I would say more or less or if I could even pinpoint that. I just think it's changed.” Such responses indicate a lack of consistency between the ECI scores from the survey analysis and the interview data.

However, further review of the interview pairs suggests that although most students do not explicitly describe significant shifts in their perceptions of ethical climate or characterize it as negative or positive, their responses to ethical climate prompts in year 1 and year 4 reflect subtle changes in their views, which in turn could possibly explain the changes ECI survey scores. The following sections provide additional insights about how our subjects’ comments may reveal shifts in ethical climate perceptions (decrease and increase) from year 1 to year 4, along with some factors that may be associated with these changes.

5.1 Experiences of students with large decreases in ECI Scores

Our findings suggest that for students with a large decrease in the ECI scores, their experiences of their academic community and competitive environment stand out as critical themes impacting their shifts in perceptions of ethical climate from year 1 to 4.

Sense of Community

In this section, we present findings from our data that illustrate how students' experiences of a sense of community – or the lack of thereof – may impact their views on ethical climate. For instance, Carly attests that there was a much better sense of community in year 1 as compared to year 4. She further adds that such a decline in the sense of community negatively impacts collaborations with her peers. Reflecting on a specific example demonstrating this type of shift, she explains:

> I was living on a floor with 30 people, and everyone was so close together, like if you were working on something and you had a question you would just ask the person next to you. Versus like now, I live in a house with only six people, and none of them are civil engineers, so we're not taking any of the same classes. Yeah. There's not as much collaboration and stuff anymore like I do all my homework by myself.

As a further source of nuance, Carly further frames changes in ethical climate perceptions as she shifts from describing the ethical climate as being “very cooperative” in year 1 to “it's definitely cooperative like if you're already friends with someone” in year 4. Similar perceptions are also reflected in Cody's responses as he talks about a "cooperative" ethical climate in year 1 to "cooperative only among the people you know" in year 4. Such responses show how students' considerations of groups and experiences of community likely impact their views on ethical climate.

Competition

Our findings also suggest that students’ changing experiences of competition shift their perceptions of climate during their undergraduate years. Not surprisingly, students with a large decrease in ECI scores often alluded to experiences of increasing competition in classes, job searches, etc. For example, both Cody and

Carly talk about witnessing increased cases of cheating on campus from year 1 to year 4. Cody even attributes this change to taking more difficult classes in the final years, explaining: “I've definitely been into some much more difficult classes where people are more willing to cut corners.” Braxton adds another layer of complexity in his comments about how competition negatively impacts ethical climate. Specifically, in his year 1 responses, Braxton talks about experiencing more competition and less cooperation academically, but he also emphasizes that the competition is often limited to the "smarter people" in classes where grades are curved. Yet in year 4 he shows signs of disappointment in the climate when he states that “people are slowly helping each other up, but if they help the other person up to above where they are, they try and cut them down.”

5.2 Experiences of students with large increases in ECI Scores

In contrast to the above themes, our findings suggest that for students with a significant increase in ECI scores, their experiences of cooperation among peers stand out as a significant theme contributing to their shifts in perceptions of ethical climate over time.

Collaboration and/or Cooperation

For interviewee subjects with a significant increase in ECI scores, we observe that their experiences of cooperation in their schools far exceeds the expectations they come in with. This could potentially help explain the increase in ECI scores for this subgroup. For example, as Chad states, “I thought coming into this school it would be cutthroat. That's what I heard about this school just from high school in general. It's a cutthroat school, and it will be tough. Not the experience I've had whatsoever.” He further contends that the cooperation he has seen among his peers and colleagues changed his views on ethical climate for the better. It is also interesting to note that another student, Bosco, also demonstrates subtle shifts in his perceptions of ethical climate. In year 1, he describes the ethical climate to be cooperative for the “most part” and notes that people don't interact much in some classes, whereas in year 4 he talks about the ethical climate being “very cooperative.” He further states:

> I see all the time there's always students that are more than willing to help their friends or classmates with a difficult assignment that they understand. I think the proof of this is there's the … tutoring service where students volunteer to be tutors. There's nothing [pause] they're not getting paid or anything. They just want to tutor because they want to help other students out.

Other examples from all the three subgroup of interviewee subjects suggest that aspects of cooperation, as opposed to competition, are critical drivers of positive ethical climate perceptions among the participants in our study.

6 CONCLUSION

As noted above, our survey results suggest that a majority of our participants showed a decrease in ECI scores, meaning they had a less favourable view of ethical climate from year 1 to year 4. These results are also consistent with the views of authors such as Cech [2] who state that students’ sense of ethical responsibilities and social consciousness tend to decline over the course of their engineering education. While preliminary qualitative analysis of responses to questions probing student perceptions of climate did not initially align well with our survey findings, through further review we observed some patterned themes among the participants that highlight specific shifts in perceptions from year 1 to year 4. More specifically, we find that experiences of competition and a perceived lack of community may contribute to negative shifts in ethical climate perceptions, whereas exposure to experiences of cooperation and collaboration likely improve such perceptions. Interestingly, through qualitative analysis, we also observe that in some cases subjects talk about using the community as a defence mechanism for dealing with negative ethical climate perceptions. Particularly, interview participants allude to forming groups to collectively navigate the broader institutional climate challenges, such as competition and the lack of a strong sense of community. These findings emphasize the need for educational institutions to rethink what kinds of experiences and environments they can provide students to promote more positive ethical climates.

However, one of the significant limitations of the study is that the qualitative phase included only interview data for students with extreme increase or decrease in ECI scores. We plan to revisit all 33 pairs of interview transcripts to identify emerging patterns of shifts in ethical climate perceptions across the universities. We also plan to further analyse data on ethical climate perceptions and changes based on institution type. Through these kinds of analyses, we hope to provide more detailed insights about how students perceive ethical climate at different universities.

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Making Engineering students think about their study approaches

C. Oude Alink[1]
Educational Advisor
University of Twente
Enschede, the Netherlands
E-mail: c.oudealink@utwente.nl

J. Schretlen
Lecturer
University of Twente, Faculty of Engineering
Enschede, the Netherlands
E-mail: j.l.m.schretlen@utwente.nl

T. Thomas
Assistant Professor
University of Twente
Enschede, the Netherlands
E-mail: t.thomas@utwente.nl

T. Stobbelaar
Educational Advisor
Didactus advies & ontwikkeling
Enschede, the Netherlands
E-mail: thelma@didactus.nl

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ABSTRACT

At the University of Twente a longitudinal project was conducted about the mindset of engineering students on learning and their study behaviour. In the previous phases of this project the study approaches of first year students has been visualized. This showed a difference in study approaches between Mechanical Engineering (ME), Industrial Design (ID) and Civil Engineering (CE) students. The CE students applied surface approaches most frequently while studying, compared to the ME and ID students. During the second phase of this project an intervention was carried out with 47 CE students, focussing on deep study approaches and mindsets about learning. The rest of the CE students acted as a control group, which consisted of 22 students. The intervention was connected to the course of Structural Mechanics. Directly after the intervention students wrote a reflection, and a validated questionnaire was filled in by the students (mindsets and ASSIST) half a year after the intervention. In the short

term the students experienced a positive effect, they indicated that they adopted deep study strategy approach and several students mentioned that the deep study strategies helped them really understanding the content. Unfortunately there were no significant differences on the long term. For future research it would be interesting to investigate the effect of the teaching style on the study behaviour of the students.

1 INTRODUCTION

1.1 Deep and surface learning approaches

Over the years a gap has become visible between university and industry. Students know a lot about the content, but the lack of skills is a common reason for unemployment amongst new graduates [1]. This highlights the importance for students not to only learn disciplinary content but also the soft skills, which are a combination of academic and professional skills such as presenting, writing, teamwork, study skills, and time/project management [2].

In general engineering students love their own disciplinary content, so the problem does not lie with learning in general, but specifically soft skills [2]. However these soft skills remain important during their whole careers. Because when graduates find a job, it is likely they will not keep that same job for their entire career. Nowadays both senior and junior employees switch jobs more regularly then 20 year ago [1], so they have to be flexible and adaptive to learn the new skills and content necessary for their new jobs. Which makes the learning how to learn an important soft skill to have.

How to teach skills education is a highly researched topic, and it is widely accepted that it is an important aspect of a study programme. This does not automatically mean that the importance is also acknowledged by the students. For engineering students, it is shown that they dislike learning the soft skills [2].

When visualising the current study behaviour of engineering students, it shows that attention on the topic is important [3]. The learning approach can be categorised into three categories 1. a deep approach, 2. a strategic approach, and 3. a surface approach. A deep approach focusses on real understanding of the content, and gives meaning to the content. A strategic approach focusses the organisation of learning, the structure of the textbooks, management of time, and a focus on the expectations of the teacher. A surface approach focusses on passing the exam, memorizing the content with no or limited understanding of the content [4].

First year engineering students mostly apply a surface approach of learning, a strategic approach is applied second and lastly a deep approach. When looking at how they want to be taught a different image appears, they prefer to be taught by teachers using deep approaches [3]. The mismatch between their applied approaches and the way they want to be taught could indicate that students would like to apply deep approaches themselves as well, but don’t know how or don’t want to put the effort in themselves.

1.2 Mindsets

When linking effort to learning, a theory that comes to mind is the mindsets theory, by Carol Dweck. A meta-analysis published in 2012 found 113 studies conducted by many authors concluded that mindsets are a significant factor in people's self-regulation toward goals [5]. A person with a fixed mindset beliefs that intelligence is a fixed trait, a growth mindset is the understanding that abilities and intelligence can be developed. When students understand that they can get smarter they put more effort in their studies. Students can change their mindsets from fixed to growth, for example with proper guidance. But how can this mindset be influenced? The Dutch Brain Centred Learning (BCL) institute studied the mindset theory of Carol Dweck [6] and came to the following approach to influence the mindset [7].

1. Give concrete feedback on approach, effort and perseverance (development-oriented feedback), students that were praised for their effort outperformed students that were told they were smart.
2. Show appreciation and stimulate pride on progress and development.
3. Make students aware and proud of mistakes made and that they are part of learning.
4. Stimulate the use of own examples (learning, mistakes, perseverance).
5. Explain the plasticity of the brain; if you believe your brain can grow, you behave differently.

1.3 Study strategies

The aspects listed above are aspects that teachers can take into account when designing their course and communicating with students. But in the end it comes down to the behaviour of the students themselves. Even if students have a growth mindset, they need to know which study strategies work and how to apply them. A surface approach requires less effort than deep approach, but the long term effect is lower [7]. For short term the effect might be more positive result as in passing the exam, but it is questionable if the students would really learn the content. Whether deep- or surface learning occurs also has to do with how they think about learning and their actual behaviour, so the study strategies applied by the students. Therefore it is important to make students aware of the effectiveness of their study strategies.

There are a lot of misconceptions and myths concerning study strategies [9]. Students think they are studying well but often use strategies with little effect, such as rereading. Study strategies that showed a positive result are spaced practice, elaboration, self-explaining, and practice testing [9]. Weinstein and Sumeracki [10] added two more strategies, and wrote about six effective study strategies: 1. Spaced practice, 2. Interleaved practice, 3. Elaboration, 4. Concrete examples, 5. Dual coding, 6. Retrieval practice.

1.4 Intervene

At the University of Twente first year engineering students mostly apply a surface learning approach [3]. Of the three engineering programmes within the faculty of

Engineering Technology, the students of Civil Engineering (CE) apply the most surface approaches. What is seen is that a lot of these students have difficulties with the more fundamental engineering focused courses, such as structural mechanics. Could an academic skills course with a focus on learning, mindsets and study strategies help the students in applying more deep approaches to learning, to facilitate a short term and long term effect?

2 METHODOLOGY

2.1 Setting

This paper describes the second phase of a longitudinal study. During the first phase the starting situation has been visualized, in which 378 students filled in a combination of two validated questionnaires. The result showed that the CE students applied the most surface approaches during studying (in comparison with the ME students and ID students [3]). In the fourth quartile the CE students could choose between 4 different academic skills activities: improving writing skills, research skills, time management or study skills. Each topic was shortly explained during an introduction lecture, after which the students could notify their decision. 47 students chose to participate in the study skills activities.

2.2 Intervention

At the end of their first year, 47 students joined the intervention, consisting of 8 (weekly) workshops related to study skills and strategy. The workshops consisted of a combination of theory to create more awareness of study skills and strategy, and exercises to practise these techniques. Subjects addressed during these workshops are i) study strategy per individual, ii) how do people learn, iii) motivation iv) efficiency, v) concentration & focus, vi) dealing with set-backs, vii) time management and viii) exam preparation. All with a relation to the course of Structural Mechanics, realizing that the student could simultaneously apply the knowledge and exercises in a real course. When discussing relevant study strategies, the six strategies of Weinstein and Sumeracki [10] were given.

2.3 Instruments

To collect data, two different types of instruments have been used: questionnaires and reflections written by the students.

Validated questionnaires

For data about the long term effect two validated questionnaires have been combined into one, namely the mindset questionnaire and the ASSIST questionnaire. The mindset questionnaire is based on the theory from Carol Dweck [6]. The questionnaire consist of 16 multiple choice questions, about views on intelligence and talent. Students had to answer the questions on a 6 point Likert scale. The ASSIST questionnaire [8] consists of 60 multiple choice questions. Students had to answer the questions on a 5 point Likert scale. 52 questions were about the study approached applied by the students and 8 questions about the preferred teaching style.

Reflections

At the end of the quartile the students finished an assignment in which they reflected on whether their knowledge on the theory behind the subjects has increased, they became more aware of their own study strategy and skills (strengths and weaknesses) and whether they experienced and increase in their capability of applying this in their studying.

2.4 Analysis

The pre- and post-questionnaire were the same questionnaire, which made it possible to do a good comparison. The results of the pre- and post-tests have been statistically analysed. For this analysis the averages, standard deviations and/or correlations have been visualised for the following questions:

- Is there a change in the mindsets and study approached applied?
- Is there a correlation between the applied study approaches and the preferred teaching style?

These results are then linked to the reflections written by the students were possible. In the analysis of the reflection the focus was on their mindset, applied study strategies, and the experienced effect of their study behaviour.

3 RESULTS

At the moment of the pre-test survey, 80 students were in the Civil Engineering programme. Those 80 students received the pre-test survey of which 56 completely filled in the survey. This is a response rate of 70%, which is quite high and suggests the sample (56 out of 80) is representative. Quite some of them dropped out after the first year. For students who filled in the survey, 29% (16 out of 56) dropped out. From the remaining 40 students, 50% (20 out of 40) also completely filled in the post-test survey. This response rate is still significant, although somewhat lower than expected. Of the 20 students that filled in the pre- and post-test 14 participated in the intervention and 6 students were in the control group.

3.1 Changes in study approach

To indicate changes in study approaches we looked at the paired scores of the post and pre-test. As expected, the paired scores show a positive correlation (between 0.5 and 0.8, except for the deep preference for which the correlation is less strong). The variation in the differences of the scores are generally smaller than in the scores themselves. The distribution of the differences basically peak around the average difference with a few large negative and positive differences. In any case, due to the limited range of possible outcomes, the distribution of sample means quickly converges to a normal distribution when the sample size increases. In Figure 1, the variation of the differences between the pre-and post-test are visualised for the whole sample, where light grey represents the differences of the deep study approach, dark grey of the strategic study approach and black of the surface study approach. It can be seen that the differences between the pre-and post-test are small, mostly between

-1,99 and 2 points. As a result, sample means and standard deviations (of the mean) are good indicators to represent the distributions. There was no significant difference between the group who participated in the intervention and the group who did not. The control group of 6 students is simply too small for any meaningful comparison.

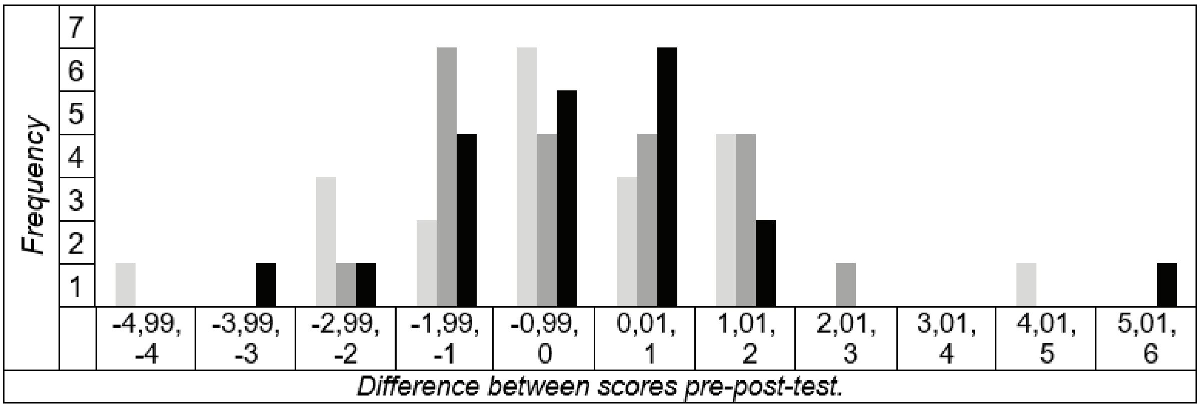

Figure 1. The variation of the difference between the pre- and -post test for the study approaches.

Table 1. shows the results of the paired differences. The first two rows (without and with intervention) shows the sample means and standard deviations of the mean. The lower two rows show the respective standard deviations of the differences. On average the result appear to show the opposite effect of what was strived for, students started applying less of the deep approach and more of the surface approach. However, the results are not statistically significant. In short, we cannot conclude that there is any difference between intervention and non-intervention. Moreover, there is no statistical evidence that students changed their preference or strategy over time.

Table 1. Averages and standard deviation of the differences (pre-post)

	Study approach			Preference	
	Surface	Strategic	Deep	Surface	Deep
Average no intervention	-0,71±0.44	0,67±0.46	0,71±0.48	-0,50±0.34	-1,00±0.63
Average intervention	0,32±0.52	-0,37±0.37	-0,50±0.57	0,64±0.86	0,21±1.18

The correlation between the study approach applied and the preference to be taught using a deep approach appears to have become stronger, see Table 2. For the group who did the intervention the correlation went from 0,45 to 0,86. The correlation for applying a surface approach and preferring a surface approach of teaching became less, it went from -0,64 to -0,30. Although results from Table 2 suggest that approach and preference for deep learning are better aligned after the intervention, the sample size is too small to conclude this with enough confidence. The only conclusion we can draw, is that after the intervention the correlation is significant for deep learning (i.e., significantly different from 0 with a significance level of 0.05), while this is not the case for the pre-test situation.

Table 2. Correlations between preference and study approach

	Deep approach – deep preference		Surface approach – surface preference	
	Pre-test	Post-test	Pre-test	Post-test
Total	0,37	0,61	0,03	0,11
No intervention	0,49	0,57	0,36	0,32
With intervention	0,45	0,86	-0,64	-0,30

3.2 Mindsets

No correlations was found between the scores of the pre- and post-test of the mindset with the approaches they applied. When solely comparing the averages of the group that participated in the intervention with the control group, it is shown that before the intervention both groups were almost equal (with intervention 4,7, without 4,6). After the intervention the group that participated in the intervention moved one category up towards a growth mindset (see Table 3). Category 1 is a completely growth mindset and category 8 is a completely fixed mindset.

Figure 2. shows the scores in the pre-test (in grey) and the scores of the post-test (in black) of the group that participated in the intervention. The distribution over the categories grew, and on average they scored a bit more towards the growth mindset. However, again this result is not statistically significant. In the reflections, all but one student indicated that they had a growth mindset. The one student said that he was in the mix of both a growth and fixed mindset. The mismatch between the scores of the post-test and the reflections could mean that they can't categorize themselves properly, or not all students could not retain their growth mindset over time.

Table 3. Averages of mindset categories

	Pre	Post
Whole group	4,6	4,4
Did not participate in intervention	4,7	5,0
Did participate in intervention	4,6	4,1

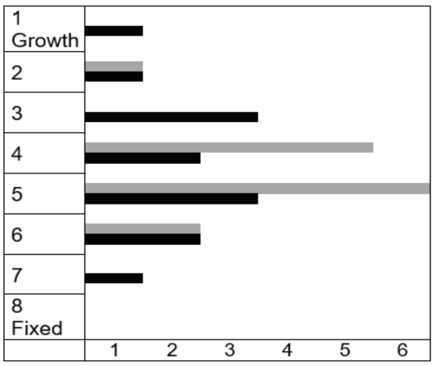

Figure 2. distribution of scores on growth and fixed mindset.

3.3 Study strategies

Of the fourteen students who participated in the intervention and filled in both the pre- and post-test, thirteen wrote a reflection. In this section the results of those thirteen reflections are presented. In these reflections most students indicated that they applied mostly a strategic approach (see Figure 3). Three students indicated that they combined two approached. In the reflections three students wrote that they did not change their study strategies while participating in the intervention. The other students did change something in their studying. During the intervention six study strategies were discussed. Figure 4 shows how many students used these strategies. Five students commented that applying these study strategies helped them in really understanding what they were doing. One student explicitly added that it gave him more confidence. There was a big variation in which strategy they found most useful. Eight students experienced a positive effect of changing their study strategies, three were neutral and one student experienced a negative effect. The student who experienced a negative effect indicated that he did not put in as much effort as he normally would put in, because he did not need to pass the course before summer to continue with his studies.

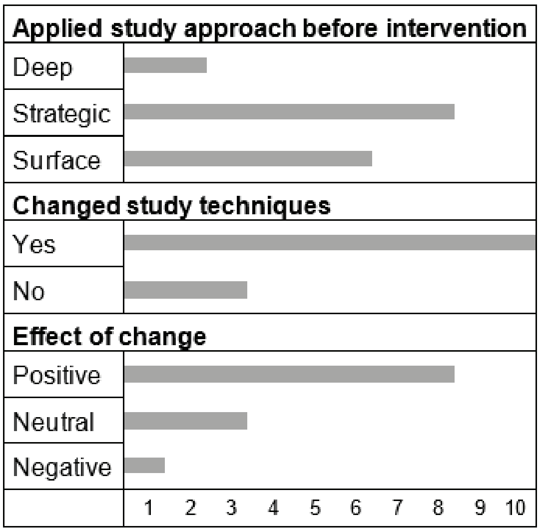

Figure 3. Summary students' behaviour

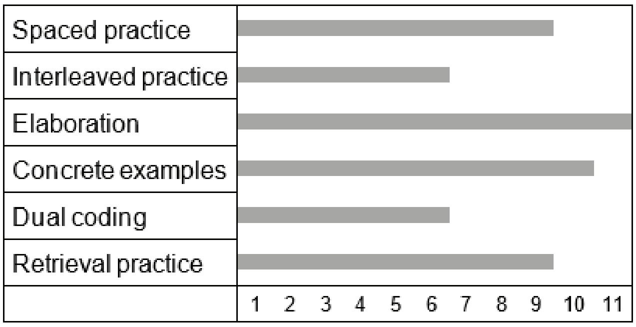

Figure 4. Frequency of applied study techniques

4 CONCLUSION AND DISCUSSION

4.1 Conclusion

The question that was asked was: could an academic skills course with a focus on learning, mindsets and study strategies help the students in applying more deep approaches to learning, to facilitate a short term and long term effect? The answer to this question is not one sided.

When looking at the short term effect, visualised in the reflections the intervention can be seen as a success. The intervention was intensive, eight meetings in a period of ten weeks. Most students said they experienced a positive effect, and that they changed their study approach towards a deep study approach. They wrote that they saw the relevance of the learning strategies. A comment written often was that the change in applied study strategies helped them to really understand the content instead of just applying the tricks, which was exactly the goal of the study. When asking the students about their mindsets, they all said that they had more of a growth mindset then before the intervention.

Half a year after the intervention, the questionnaires were distributed to test the long term effect of the intervention. Unfortunately no significant changes were visible on the long term, so no hard conclusions can be drawn about the long term effects. The intervention did not succeed in letting students apply more deep learning approaches and fewer surface approaches in the long run.

When looking at the mindsets, a small long term effect is visible. The students who participated in the intervention on average moved one category towards a growth mindset. Whereas students in the control group remained the same as in their first year, but these changes are not significant.

The effect that was seen and experienced by the students on the short term did not stay for the long term, which is a pity. Providing a onetime course is not the solution for the problems students (and teachers) experience about the study behaviour of the students. If the topic of study strategies is integrated into the curriculum in a more prominent manner, and repeated several times maybe this could have a positive effect on long term effect. So a recommendation would be to make study strategies a permeant topic in Engineering curricula.

4.2 Discussion

When interpreting the results, some aspects have to be taken into consideration. One of the things that limits the generalization of the results is the small amount of respondents that filled in both the pre- and the post-test. It was proven difficult to let students fill in the questionnaire, even when reminding them during lectures. For stronger conclusions, a larger sample size would be necessary.

Another discussion point that the focus was on the students, but as indicated in the introduction the way of teaching has an effect as well [7]. The variable of how is being taught has not been taken into account. It would be interesting for future research to investigate the effect of the teaching style on the study behaviour of the students.

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Rural Locations Modify Socioeconomic Status Differences in Spatial Visualisation

G. Panther
University of Nebraska Lincoln
Lincoln, United States

S.A. Sorby[1]
University of Cincinnati
Cincinnati, United States

N. W. Loney
University of Cincinnati
Cincinnati, United States

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ABSTRACT

To create an engineering-capable workforce, the talent from people of all demographic backgrounds must be sought. One method of identifying this talent is by measuring their spatial skills. Spatial skills have been shown to be a better predictor of success in engineering degree attainment compared to other testing measures, including mathematics. Additionally, success in engineering has been linked to a students' spatial skills. But most work has focused on students from urban settings. Through exploring the spatial skills of rural students from low social economic backgrounds, we aim to leverage the skills of these students that are often underrepresented in the engineering workforce.

[1] Corresponding Author
S.A. Sorby
Sheryl.sorby@uc.edu

1 BACKGROUND

Creating an engineering-capable workforce requires the talent of people from all demographic backgrounds to be represented [1]. Increasing participation in engineering relies upon attracting and retaining students from varying backgrounds that more accurately reflect the population. Attracting and retaining a diverse population to engineering is important not only for social justice reasons but also to solve the grand challenges of today and in the future. One promising method for improving retention rates of women engineering students is by helping students improve their 3D spatial visualisation skills [e.g. 2 - 4]. Spatial visualisation is a common practice in engineering and is the ability to conceptualise real and imagined spatial relationships including being able to mentally manipulate, organise, and reason about these relationships [e.g. 5]. Engineering students with well-developed 3D spatial visualisation skills have been shown to persist and do better in engineering courses compared to their lower skilled counterparts [6,7].

Spatial Cognition has been an area of research in psychology for more than 100 years and significant gender differences (favouring males) have been found throughout that time [e.g. 6-9]. Research has also shown differences in spatial ability between students from low Socio-Economic Status (SES) groups and their more affluent peers (favouring affluence) [10]. Since spatial skills are known to be critical to success in engineering, this means that women and students from low SES groups are at a disadvantage when pursuing engineering studies. Poorly developed spatial skills for these populations could be a hindrance to our ability to diversify engineering.

Most spatial skills research has focused on urban populations when studying students from different SES backgrounds. However, no studies (to our knowledge) have examined if locale modifies SES differences. Additionally, students from rural areas are 32.2% less likely to pursue post-secondary education compared to non-rural youth, which provides an opportunity to determine ways in which this often underserved demographic group can be supported and encouraged as we strive to create a diverse engineering-capable workforce [11]. Therefore, this paper aims to gain a better understanding of how locale interacts with SES status relevant to spatial skills.

2 PURPOSE

The purpose of this paper is to explore if differences in spatial skills exist in urban and rural children of differing SES levels. The following two hypothesis will be tested:

Hypothesis 1: There will be a significant difference in the spatial skills of students in rural locations compared to the spatial skills of students in urban locations.

Hypothesis 2: There will be a significant difference in the spatial skills of low SES students in rural locations compared to the spatial skills of low SES students in urban locations.

3 METHODS

3.1 Sample

The data used in the analysis presented here was collected in middle schools from seven states (Texas, Michigan, Georgia, Colorado, Ohio, Tennessee, and Alabama) in rural and urban areas within the United States. To be considered rural, the school had to be located in an area with a population of less than 25,000 residents. A majority of the students were of white/non-Hispanic race. The data were collected from grade 7 and grade 8 (ages 12-13) science and mathematics classrooms. Approximately 3,000 students participated and were evenly split between low and medium/high SES (1490 vs. 1489). A student was categorised as low SES if they qualified for free or reduced-price lunch (a federal program in the United States that requires near poverty level income).

3.2 Testing Instruments

A total of four tests were administered during grade 7 (PSVT:R, DAT, LAP & MCT) and two tests during grade 8 (PSVT & DAT). The tests are explained in greater detail in the following section.

The Purdue Spatial Visualization Test: Visualization of Rotation (PSVT:R) was used to measure students' 3D mental rotation skills [12]. An example of a PSVT:R question can be found in Figure 1. The Differential Aptitude Test (DAT) assesses students' abilities to take a 2D pattern and predict what would be formed in 3D after it was folded [13]. An example of the DAT task can also be found in Figure 1. Each correct response was given 1 point when scoring the tests.

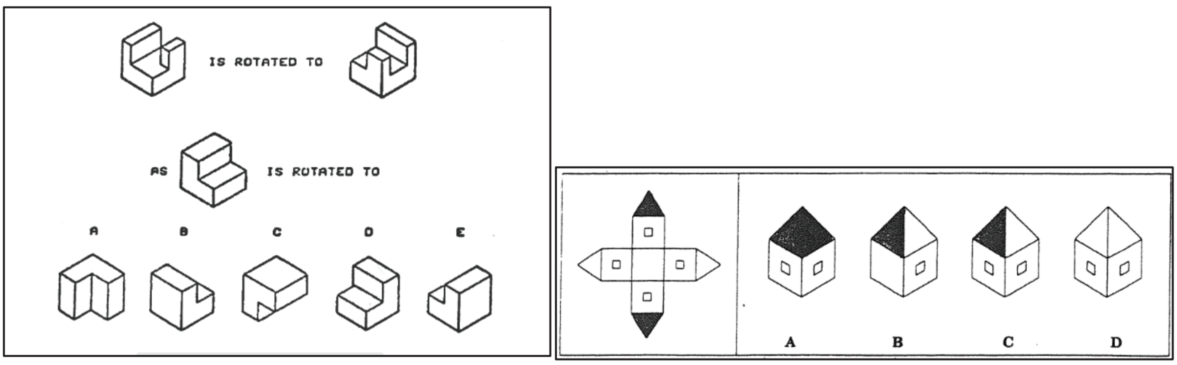

Figure 1. Example of a PSVT:R (left) and DAT (right) problem that students were asked to solve

The Mental Cutting Task (MCT) focuses on the ability of a person to imagine what a cross section of an object would look like if sliced by an imaginary plane [14]. The Modified Lappan Test (LAP) tests students' ability to dissect orthogonal views and relate them to coded plans [15]. An example of a MCT (top) and LAP (bottom) test question can be found in Figure 2. Each correct response was given 1 point when scoring the tests.

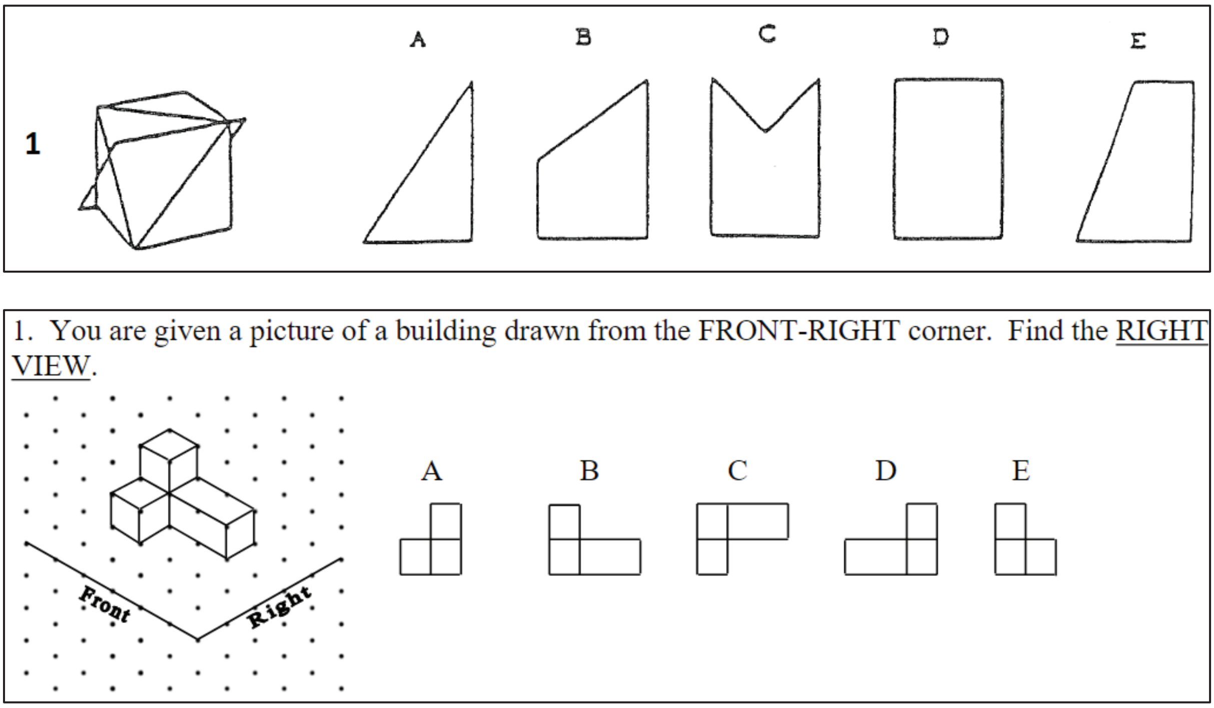

Figure 2. Example of a MCT (top) and LAP (bottom) question presented to students

3.3 Data Collection

Data collection occurred sometime in the second semester (~March) of both grade 7 and grade 8. Testing was spread out over at least two class periods and was conducted by the math or science teacher at each respective school. Testing included the PSVT:R, DAT, LAP, and MCT in grade 7. The LAP and MCT were eliminated for grade 8 testing due to time limitation concerns expressed by the teachers and therefore only DAT and PSVT:R data is presented for grade 8.

3.4 Data Analysis

Responses were analysed using IBM SPSS where both descriptive statistics and an independent sample t-test were used to test the differences between locations (urban/rural) and SES to students' performance on the spatial skills tests.

4 RESULTS

Hypothesis 1: There will be a significant difference in the spatial skills of students in rural locations compared to the spatial skills of students in urban locations.

Means for urban and rural students were dissimilar on all six spatial skills tests, ranging from 2.30 to 4.68 for urban students and 2.76 to 5.12 for rural students (Table 1). Hypothesis 1 was accepted (2.67 < t < 6.32, p < .008). Effect sizes were small or minimal (.05 < r_{pb} < .13)[16-17]. Overall, rural students statistically scored higher on the spatial skills tests than the urban students.

Table 1. Rural and urban Students' Spatial Skills Tests Scores[1]

	Urban	Rural	Independent sample t-value	p-value	Effect size (r_{pb})
7DAT	4.23	4.45	2.67	.008	.05**
7PSVT	3.44	3.93	5.63	< .001	.11**
7LAP	2.41	2.99	6.32	< .001	.13**
7MCT	2.30	2.76	5.62	< .001	.12**
8DAT	4.68	5.12	3.44	.001	.09**
8PSVT	4.05	4.69	4.76	< .001	.12**

**Correlation is significant at the 0.01 level (2-tailed)
[1] Means are on a 10-point scale with 1 point being awarded for each correct answer.

Hypothesis 2: There will be a significant difference in the spatial skills of low SES students in rural locations compared to the spatial skills of low SES students in urban locations.

Means for Low SES students in urban and rural locations were dissimilar on all six spatial skills tests, ranging from 2.13 to 4.18 for urban students and 2.72 to 4.87 for rural students (Table 2). Hypothesis 2 was accepted (3.48 < t < 6.81, p < .001). Effect sizes were between small or minimal and medium or typical (.10 < r_{pb} < .19) [16-17]. Overall, Low SES students in rural locations statistically scored higher on the spatial skills tests than low SES students in urban locations.

Table 2. Low SES Students in rural and urban Locations Spatial Skills Test Scores[1]

	Low SES		Independent sample t-value	p-value	Effect size (r_{pb})
	Urban	Rural			
7DAT	3.83	4.23	3.48	.001	.10**
7PSVT	2.89	3.70	6.81	< .001	.19**
7LAP	2.14	2.80	5.73	< .001	.17**
7MCT	2.13	2.72	5.48	< .001	.17**
8DAT	4.18	4.87	3.96	< .001	.15**
8PSVT	3.68	4.44	4.19	< .001	.16**

**Correlation is significant at the 0.01 level (2-tailed)
[1] Means are on a 10-point scale with 1 point being awarded for each correct answer.

5 DISCUSSION

Spatial visualisation skills have consistently and statistically been found to be an independent predictor of engineering career selection and attainment of an advanced engineering degree [18]. Multiple studies have also shown a link between spatial skills and introductory engineering courses [7, 19, 20]. Additionally, research has found that spatial skills are linked to creativity and technical innovation [21]. Thus, it is evident the importance of well-developed spatial skills for success in engineering.

Ensuring success of students in grade 7 mathematics is one way to assist in increasing the number of students from a range of demographic backgrounds who pursue engineering. Further developing students' spatial skills through training and support may lead students to take higher-level mathematics courses in high school, which would put the students in a better position to ultimately pursue engineering in post-secondary education.

Most current efforts aimed at diversifying engineering provide students with engaging interventions to combat the stubborn problem of a lack of diversity. *Science is fun! Women can be engineers! Engineers and scientists solve interesting societal problems!* All of these efforts are engaging and rewarding for the young women who participate in them, but they are missing a key component. Working on *affective* issues without solving underlying *cognitive* issues will likely not solve the problem of a lack of diversity in engineering. Spatial skills show some of the most robust and persistent gender and SES differences in cognition. Since spatial skills are important to success in engineering, students with poor spatial skills will be at a disadvantage if they do eventually overcome the stereotypes and pursue an engineering career. Efforts to improve engineering diversity that are aimed at only the affective while ignoring the cognitive do so at their peril. A holistic approach is needed if we are to be successful in our efforts to increase diversity in engineering.

Understanding which students would benefit the most from spatial skills training (e.g., urban low SES, women, etc.) will allow us to target resources and effort where it is needed most. Further, since it appears that spatial skills of rural low SES students do not appear to be significantly lower than those of their more affluent peers, perhaps spatial skills training for this group is not as critical and resources could be focused on affective issues in these locales.

6 CONCULSION

In summary, the results show that students from rural settings score higher on spatial tests compared to their urban counterparts. More specifically, when looking at SES status, we see that low SES students in rural locations outperform low SES students in urban settings.

Our findings indicate the need to create recruitment strategies specific to rural students to help boost their participation rates in university. Additionally, the findings here support further inquiry into determining the aspects of rural life that contribute to developing better spatial skills compared to urban settings. While some research has already found differences in the type of language used to describe spatial relations (rural use geocentric and urban use egocentric), future research can consider additional factors such as parental involvement and activity type [22].

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Preparing Technicians for the 4th Industrial Revolution

S. J. Peters[1]
Research Group Strategic HRM
Saxion University of Applied Sciences
Enschede, The Netherlands

M. R. Wolffgramm, MSc
Research Group Smart Industry & Human Capital
Saxion University of Applied Sciences
Enschede, The Netherlands

K. E. G. McGovern
Research Group Strategic HRM
Saxion University of Applied Sciences
Enschede, The Netherlands

S. Corporaal, PhD
Research Group Strategic HRM
Saxion University of Applied Sciences
Enschede, The Netherlands

Conference Key Areas: 4th Industrial Revolution; Lifelong learning

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ABSTRACT

The fourth industrial revolution is rapidly and drastically changing work in the tech sector. This requires tech workers to embody new competencies. So far, previous research efforts resulted in competency sets that were insufficiently capable at addressing the new requirements tech works should meet. Therefore, we conducted two scientific studies to specify these. In the first study, semi-structured interviews (n=54) were conducted involving CEOs and HR directors from tech companies. Based on these data, we found five major technological developments and their implications for tech workers' jobs. In the second study, we asked the same CEOs and HR directors to indicate which competences they expect to be the most important for tech workers in line with the five technological developments. This resulted in a questionnaire that was handed to a larger sample of tech companies' CEOs and HR directors (n=236).

Our research shows that the fourth industrial revolution will fundamentally change the work activities and job complexity of tech workers. Different technological developments in automation, optics, and big data start interacting with each other, reinforcing their impact on the tech workers' jobs. According to respondents, this requires a tech worker with an outstanding and up-to-date knowledge base regarding his profession, as well as the ability and mind-set to closely collaborate with tech

[1] Corresponding Author
S J Peters
s.j.peters@saxion.nl

workers from other professions. Our practical implications reveal how Engineering Education, tech companies, and their tech workers can collectively establish these new requirements, helping tech workers to become and remain futureproof.

1 INTRODUCTION

The fourth industrial revolution, also known as ‘Smart Manufacturing’ (Kang et al., 2016), ‘Industrie 4.0 (BRD)”, and ‘Smart Industry’ (NL), can be described as the digitization of the (high-)tech industry and focusses on the merger of three technological developments (Smart Industry, 2017). Firstly, new production technologies emerge, such as 3D printing and robotics. These are expected to further automate the production process. Secondly, in addition to the production technologies, information and sensor technology develop rapidly and become more intuitive too. For instance, technologies regarding big data and the internet of things increasingly digitize the management of production process and enable machines to make autonomous decisions. Thirdly, technology creates room for new business concepts as it increasingly integrates people with each other. Resulting in shorter supply chains and shifts from product-oriented business models towards service-oriented business models (servitization).

Different from previous industrial revolutions, ignited by discoveries such as the steam engine and computer technology, the fourth industrial revolution is believed to be accompanied by an impact and the pace of change mankind has not encountered yet. Where previous industrial revolutions were concentrated on one major technological breakthrough, the fourth industry comes with a combination three radical developments. This combination of new, powerful and flexible technologies, combined with cheap data storage, strong analytical software, fast internet-of-things technology, and innovative business models, generate fruitful opportunities for new developments to emerge, such as: virtual reality, complex production process simulations, and autonomous production machinery. The increasing pace of change has to do with both as the life cycle for technological innovations will shorten and urge for a faster time-to-market. Meaning that new technologies will enter the market faster than ever before and come with a broader and more disruptive, rather than an incremental, character.

It is anything but surprising that these predications on the fourth industrial revolution launched various research agendas devoted the impact of technological developments on the future of work. However, most of these research efforts were focused on the question which jobs will disappear due to an increasing use of technology (Went, Kremer, & Knotternerus, 2015; Frey & Osborne, 2017). By exclusively focussing on these disappearing jobs, researches have overlooked an important question, namely how these technological developments impact the actual work activities of employees. This question does merit much more attention than it currently receives (e.g. Ras et al., 2017). Because, as recent studies showcase, new technologies are expected to make work more complex and require a highly-skilled workforce that is capable of designing, implementing and using innovative technologies in their daily operations (Usanov & Chivot, 2013). Furthermore, businesses are discovering new ways of organizing as a result of these technological developments and are working towards new business models, leading to a demand for new skills and competences too.

These new work demands are expected to lead to a growing urge for new competencies: a total of required knowledge, skills, and attitudes. These are often described as '21st century skills', 'lifelong competences' or 'key skills' (Voogt & Roblin, 2012). To illustrate, as a result of aforementioned technological developments, employees should be capable of: (1) working closely together with the newest technology; (2) having the ability to manage one's personal development and proactively respond to organizational change; (3) coping with constantly changing work demands due to an increasing customization of products and services. In order to cope with these developments, and remain employable, employees should master competencies focussed on adaptability and multidisciplinary collaboration (Van Est & Kool, 2015). Despite the strong line of research regarding employees' future competencies, these publications often include vague descriptions of the actual knowledge, skills, and abilities required.

Before addressing this paper’s aim, we would like to underline why it is necessary to focus this paper on the tech sector. Of course, one could argue that technological developments will have an impact on all sectors. However, we do have serious reasons to believe that work and competency requirements in the tech sector will dramatically change on a relatively short term. This could be ascribed to the technologies’ decreasing purchase prices and rising amount of applications. Providing large companies new, sophisticated solutions and, more important, lowering the financial burden for small and medium-sized tech companies to acquire these technologies as well. This already results in situations where parts of tech workers’ jobs are being robotized, smart software are used to micro manage the product streams, and new steps are made towards fully automated, customer-driven production lines (lights out factory or smart factory).

Furthermore, some tech companies already allow customers to operate their manufacturing technology over the internet, enabling same-day delivery of orders. In such fully automated systems, there is hardly any need for operator intervention. The tech workers that still work there are now in constant contact with the customer. They help customers through the (digital) production process, translate customer demands into final production, understand machine planning, have an excellent grasp of the supply chain, and are apt at using methods of data analysis. Goos (2013) infers that such innovative ways of organizing will go hand in hand with developments such as self-managing teams, staff rotation, and ongoing training of competences, like co-operation and information sharing.

In line with the highlighted knowledge gaps and dynamics in the tech sector, the goal of this paper is to specify how technological developments are affecting the tech workers’ jobs (study 1) and what this means for the competencies they should master to cope with these (study 2). Filling the knowledge gaps would result in a valuable contribution to Engineering Educational programmes as these studies’ findings provide the yardstick on how to futureproof tech workers, both students and those working on the factory floor, for working in tomorrow’s tech sector.

2 STUDY 1: HOW DOES WORK IN THE TECH SECTOR CHANGE DUE TO RECENT TECHNOLOGICAL DEVELOPMENTS?

2.1 Methodology

In order to thoroughly understand and describe how technological developments will change work in the tech sector, a qualitative research approach was taken. 54 semi structured interviews were conducted involving Dutch tech companies' CEOs and HR directors. In total, 141 CEOs/HR directors of 141 companies were approached, resulting in an 38% response rate. Twenty respondents were from larger companies (employing >250 employees) operating in the high-tech industry. The remaining respondents (N=34) were from small (<50 employees) and medium-sized enterprises active in the following sectors: installation, mechatronics, construction, electronics, and IT. Companies were selected based on their work floor technology. We included companies that were praised for their technological innovations or used the newest technologies on a daily base. These selection criteria were used for two reasons. Firstly, we assumed that these interviewees would be well-informed about the current technical status quo and, therefore, best capable of predicting future developments. Secondly, by selecting technology-driven companies, we expected more room for practical examples during the interviews. These would help us to better frame and understand the interviewees' predictions.

During the semi-structured interviews, respondents were asked to describe the technological developments they expect to have an impact on work in their tech company for the upcoming five to ten years. The semi structured character of the interviews allowed the researchers to ask the respondents to clarify their pictured technological developments, increasing both our understanding and the validity of results. By clarifying these developments with examples, respondents were challenged to describe the impact of technological developments on work in the (high-)tech sector as precisely as possible. Additionally, the respondents were also asked to describe how future work in the tech sector will differ from their current jobs.

The interviews were translated into verbatim transcripts. These were imported into the Atlast.ti coding program and inductively coded by two independent researchers. In order to increase the results' validity, inter-rater reliably was established as both researchers compared their coding structures to agree upon the final codes to use. Next, four researchers used the final codes to determine how technological developments change work in the tech sector. Through a group discussion, the researchers agreed upon five overarching developments that would clarify how the future of work in the tech sector is being influenced by technological developments.

2.2 Results

Based on the analysed interview data and coding process, five developments were found that shed light on how the future of work in the tech sector will be influenced by technological developments. These findings exceed the boundaries of the tech workers' workplace as the interviewees mentioned how the business, as a whole, will be affected by the newest technologies too. In this paper, the term 'tech worker' will be used in its broadest sense to refer to all technical employees (high and low educated) working in the tech sector.

Development 1: Tech jobs will become more diverse and demanding. The integration of smart software, big data, smart machinery, and robotics means that a tech worker's job will become more diverse and demanding. We found three explanations. First, the fast-growing increase in 'customized' products, services, and innovations require the tech workers to rethink their job on a daily, or even an hourly, base. In order to properly do this, tech workers should be capable of: rapidly and effortlessly switching between different work demands, deploying a variety of knowledge and skills, and coping with constantly changing customer demands. Second, in order to stay competitive, tech workers should work closely together with highly-complex robots and systems (e.g., programming, tooling, fixing errors). This will increase the tech workers' job complexity as most respondents did not perceive these technologies as user-friendly. However, most of the respondents reported a weak trend regarding the simplification of user interface design and the introduction of helpful tools (e.g., tables or augmented reality). These should make the complex technologies easier to use and, thus, mitigate the accompanied job complexity. Third, the tech workers' constant development will become increasingly important for two reasons. On the one hand, tech workers should remain capable at using the newest technologies. These are expected to be introduced at a higher speed than accustomed to, especially for tech workers in SMEs. On the other hand, tech workers should have the required competencies for coping with situations that, due the technological acceleration and mass-customization, become unpredictable and unstructured. These three explanations come with an important practical implication according to the respondents: approximately half of the respondents claim that tech jobs require employees with a higher level of education. In contrast to the other half of the companies, who state that more intense, long-term, and company-specific educational programs and workplace learning should prepare tech workers for future job demands.

Development 2: Team dynamics and work places will face radical change. Technological developments are expected to drastically impact the tech workers' team composition and work environment. More specific, tech workers working in teams that involve colleagues, customers, and suppliers, is expected to become the norm. Respondents provided two explanations for this. First, advanced systems and smart machines will integrate the processes that run throughout the value chain with each other. This brings those involved in the value chain, from first to end tier, closer together and fosters intense, direct collaboration. Second, respondents expect an increase in the demand for Just-In-Time customization. This requires effective, short-cycled projects where members from various departments (e.g., product development, finance) and the value chain work closely together to timely deliver. These projects are expected to affect the tech workers' work place as they will spend an increasing amount of time at other departments, companies, and online (e.g., virtual teams).

Development 3: Work will become increasingly automated and robotized. Respondents from larger companies stated that robots and automation tools are already taking over simple, routine tasks from their tech workers. A scenario almost half of the SME respondents expect to happen soon. They predict that prices for robotics and automation tools will lower due to an increasing competition among suppliers and economies of scale benefits. Lowering the financial burden for SMEs to purchase these technologies. Additionally, the expectations and demands from business-to-business partners and suppliers are expected to reinforce the automation and robotization of the SME work floor. Next to the routine tasks, respondents from both company sizes expect robotics and automation tools to take over more complex routine tasks and even non-routine tasks as these technologies are becoming: more advanced, highly interconnected with each other, self-learning and -correcting, flexible, and, on the long term, easy to (re)program. Requiring tech workers to transition from manual labour to: programming, analysing large amounts of system data, checking machine statuses, fixing errors, and optimizing production processes, products, and services.

Development 4: The use of augmented and virtual reality will intensify. Virtual and augmented reality systems and accompanied cloud-techniques are expected to provide various efficiency benefits to both larger companies and SMEs. By receiving augmented reality work instruction from distant machine builders, tech companies are being enabled to build and maintain their own machines and quickly resolve errors themselves. Virtual reality could be used for step by step training of tech workers and help them when executing advanced work activities. In addition, respondents from larger companies expect that they will soon be capable of using virtual reality to simulate process designs (digital twinning) and, based on the analysis of the simulations, generate opportunities for radical process optimizations, at a fraction of the costs involved in building a real production line.

Development 5: New product-market combinations will demand for adaptive tech companies. According to the larger companies, technological developments will lead to new product-market combinations, unexplored business models, and different ways of organizing. One of these developments point towards the fully automated factory where customers login on the machines, operate them, and receive their customized product the same day. Another would be the turnaround from traditional production towards service provision (so called servitization), which is being sparked by leveraging large amounts of (machine) data in a smart way. Both developments demand for the tech companies' organizational adaptability. Implying that tech workers should be better capable at functioning in switching teams that can timely and autonomously respond to such market developments.

3 STUDY 2: WHAT DO THESE CHANGES IN WORK MEAN FOR THE REQUIRED COMPETENCES OF TECH WORKERS?

3.1 Methodology

Based on the outcomes of study 1, the same tech companies' CEOs and HR practitioners were asked to provide a description of the new knowledge, skills and attitudes tech workers should possess for successfully coping with the five technological developments. We did this through different types of interviews. The first ten interviews had an open character. We asked tech companies to describe for each of the five technological developments what competencies tech workers should possess to properly cope with these for the upcoming five years. In order to thoroughly understand these competencies, we asked respondents what they meant with their competencies and asked for practical examples. The remaining 44 interviews were conducted in a semi-structured manner. We asked these respondents to determine whether the competencies found in open interviews were applicable for their tech workers too. When considered applicable, we asked the respondents to illustrate this through practical examples. At the end of these interviews, we provided respondents the possibility to list new, unmentioned competencies and elaborate on these.

The transcripts of the interviews were imported into the Atlas.ti software program and were coded by three independent researchers. The three coding structures were compared with each other and, through discussion, agreement was found on the final codes. These provided us with an overview of knowledge, skills and attitudes that tech workers should master. Subsequently, we converted these codes into a questionnaire. The items were based on the themes that were found in final codes. We tested our questionnaire through four additional interviews with tech companies' CEOs and HR practitioners. The questionnaire was tested for overall clarity and item formulation. These interviews resulted in various linguistic changes, making the questionnaire easier to understand and complete.

In total, the questionnaire captured twelve competencies: three knowledge aspects (expert knowledge, multidisciplinary knowledge and business knowledge), six skill aspects (adaptability, commercial skills, accuracy, analytical skills, communication skills and collaboration), and three attitude aspects (proactivity, creativity / innovation and dealing with uncertainty). We shared the questionnaire with 331 tech employers'. The response was 72%: 236 employers completed the questionnaire. Among these companies, 91 were small companies (<50 employees), 113 medium-sized companies (50 to 250 employees) and 32 large companies (250+ employees). A wide range of companies in the tech sector has been included: from metal and electrical companies to more high-tech process technology and ICT companies. Appendix A captures an overview of the competencies and related questions. For each competency, respondents were asked how important these are for future tech workers to possess (five-point Likert scale: 1 = very unimportant; 5 = very important). As the technological developments from study 1 were expected to become a reality within five to ten years, we used a five-year time frame for the questionnaire.

The scales from the questionnaire were tested for reliability, using Cronbach's Alpha with a test criterion of $\alpha > .70$. Based on this criterion, four questions were omitted from the data analysis for the following competences: business knowledge, creativity/innovation, commercial skills, and adaptability. Table 1 provides an overview of the number of questions, after omission, per competence and the associated reliability. Despite the insufficient reliability for the creativity/innovation competency ($\alpha = .68$), the decision has been made to include the competency as the test criterion of $\alpha > .70$ was almost met. For each competency, we aggregated the underlying scores and analyzed its importance compared to other competencies. We did this by comparing the average scores between competencies and looking for significant differences, using independent sample T-tests. Additionally, we use the same statistical test for comparing the average scores within each company size. We did this as we wanted to know if company size placed a different emphasis on certain competencies. For instance, larger companies could be interested in rather specialist competencies, while small and medium-sized companies might place more emphasis on generalist competencies. As each company size comes with its distinct agenda and available resources, or the lack of it, we have not looked at the differences between companies.

Table 1. Overview Cronbach's Alpha after omission

Domain	Competencies of the tech worker of the future	Number of questions	α
Knowledge	Expert knowledge	6	.91
	Multidisciplinary knowledge	4	.76
	Business knowledge	4	.70
Skills	Analytical skills	5	.83
	Accuracy	6	.72
	Communication skills	6	.74
	Collaboration	5	.90
	Creativity/Innovation	5	.68
	Commercial skills	4	.78
Attitude	Proactivity	3	.78
	Dealing with uncertainty	4	.72
	Adaptability	4	.77

3.2 Results

Based on the findings represented in table 2, we found all tech companies agreed that business knowledge and expert knowledge are the most important knowledge-related competencies for their future tech workers to master. They considered these competencies significantly more important than multidisciplinary knowledge. It is notable that this finding applies to all companies, regardless of the size. However, by looking, per company size, at the amount of significant differences between high- and lower-ranked competencies, we found that small-sized companies placed most emphasis on business knowledge. While other company sizes did this for both business knowledge and expert knowledge.

Accuracy and creativity/innovation were found to be most important skill-related competences, However, in this domain, we found that each company size placed a different emphasis on the skill-related competencies. To illustrate this, we found that large organizations considered collaboration, accuracy, and creativity/innovation most important. Which differs in comparison to, small companies, which underlined the importance of accuracy, creativity/innovation, and collaboration, and medium-sized companies emphasized accuracy, creativity/innovation, and commercial skills. Again, by looking at the significant differences per company size, we found that larger companies require their tech workers of the future to master more skill-related competencies, compared to the smaller and medium-sized companies.

When looking at the attitude domain, we discovered that the companies consider adaptability to be the most important attitude-related competency, followed by a proactivity and dealing with uncertainty. Comparable to the previous domain, differences between company sizes are visible. For tech workers in larger companies, dealing with uncertainty was considered key. While other company sizes underlined the absolute importance of adaptability. For this domain, the significant differences per company size reveal that large companies address more attitude-related competencies to their tech workers of the future, compared to the other companies.

Table 2. Comparison of Importance Scores for the Competencies

Domain	Competencies of the tech worker of the future[1]	Total Importance (N=236)[1]	Small companies (<50) (N=91)[3]	Medium-sized companies (<250) (N=113)[3]	Large companies (>250) (N=32)[3]
Knowledge	Expert knowledge	3.97^{b}	3.86^{y}	4.02^{x}	4,10^{x}
	Multidisciplinary knowledge	3.50^{c}	3.50^{z}	3.43^{y}	3,73^{y}
	Business knowledge	4.11^{a}	4.14^{x}	4.07^{x}	4,11^{x}
Skills	Analytical skills	3.48^{b}	3.44^{yz}	3.41^{y}	3.88^{xy}
	Accuracy	3.83^{a}	3.86^{x}	3.77^{x}	4.00^{xy}
	Communication skills	3.45^{b}	3.35^{z}	3.49^{y}	3.66^{y}
	Collaboration	3.55^{b}	3.47^{yz}	3.48^{y}	4.04^{x}
	Creativity/innovation	3.76^{a}	3.68^{xy}	3.79^{x}	3.91^{xy}
	Commercial skills	3.50^{b}	3.41^{yz}	3.63^{xy}	3.27^{z}
Attitude	Proactivity	3.62^{b}	3.63^{xy}	3,53^{y}	3,93^{x}
	Dealing with uncertainty	3.49^{c}	3.47^{y}	3,37^{z}	4,01^{x}
	Adaptability	3.86^{a}	3.75^{x}	3,93^{x}	3,92^{x}

1 – Appendix B contains the descriptions of the competencies of the tech worker of the future
2 - all averages within the same domain (Knowledge, Skills, or Attitude) and having different superscripts (a, b, c) indicate statistical difference (p < .05).
3 – all averages within the same domain (Knowledge, Skills, or Attitude), same company size (Small, Medium-sized, or Large), and having different superscripts (x, y, z) indicate statistical difference (p < .05). Differences between company sizes have not been administered.

4 BUILDING BRIDGES: LEARNING COMMUNITIES AND SKILLS LABS

The effects of technology on work that companies describe are innovative compared to the discussion about the effects of automation on work as it has been going on for several decades (see, for example, Scheele, 1999). It is about a difference in both the nature and the degree of change. As far as the nature is concerned, it has already been pointed out that various technical changes come together at the same time and combine with cheap data storage, strong analysis software and fast internet technology. This makes developments possible that were previously impossible, such as virtual reality, complex production process simulation and autonomous production machines or vehicles. The extent of the change is mainly due to the speed of change and the penetration of the new technology. The speed of technological developments in the fourth industrial revolution is greater than ever before, the impact is wider, and the changes are also more disruptive. According to the companies, this is because technologies such as smart machines, big data and sensor technology have now developed to a level that is applicable and affordable for many more, even smaller companies. As soon as a company responds to technological developments, the consequences for those lagging behind are often so large and radical that the pioneering initiator removes all its market threat. In addition, the technologies are merging into new concepts such as "smart factories" and highly advanced (software) systems that transcend individual business boundaries. According to companies, this amalgamation also ensures that technology penetrates quickly and massively within all domains a company. According to them, this leads to adjustments in (production) processes, ways of organizing or even in revenue models, and as a result the work and the working environments of tech workers are changing drastically and quickly.

If we examine the competencies that are needed in the new industrial reality, a picture quickly arises, one that presents employers looking for a five-legged sheep; tech workers who have excellent professional knowledge, are capable of work well-together and have a proactive attitude. This demand has been the case for year several years now. Furthermore, with regard to knowledge aspects, it was noticeable that the tech companies are fairly clear about the increasing importance of expert knowledge: a "broad" education is not enough. According to the tech companies, it is essential that a tech worker is socially competent, can collaborate and negotiate with employees, customers or suppliers from other disciplines or ones with a different background. In addition, respondents emphasized the increasing importance of new knowledge areas such as sensor technology, robotics and nano technology.

Regarding the skill aspects, it was noticeable that a large number of respondents, certainly in the large companies, made it clear that the boundaries between a tech worker and a business administrator are blurring. A tech worker in these companies will increasingly have to possess a far-reaching insight into the processes, the supply chain and business models. One must be able to continuously place the work or project in relation to the company or even the entire chain and must be actively involved with internal and external developments. They also see the ideal tech worker as a kind of marketer; someone who can make connections between people quickly, knows how to sell themselves and has a keen eye for new opportunities. Concerning skills aspects, tech companies mainly emphasize the flexibility and development capacity of employees. They find it difficult to put those aspects into practice, while at the same time they often have an acute need to further develop that capacity among their tech worker. It is striking that aspects related to creativity and innovation were mentioned less, while it is generally expected that these are precisely the aspects with which an employee can survive in the rapidly changing labor market (Meel, 2015).

However, relating back to our earlier description, the tech worker of the future is not a five-legged sheep. Tech employers realize that the tech worker of the future cannot have all the competencies if they start their career. A distinction can be made between "*qualifiers*"; skills that everyone must possess in order to function in the new industrial reality and "*order winners*"; skills that distinguish a tech worker on the labor market. The following can be identified as *qualifiers*: (1) being an expert in one's own field and (2) constantly looking for new knowledge. Concluding that current and in-depth knowledge is still the essential characteristic for a tech worker: a broad education is not enough. Order winners on the other hand can be referred to as: (1) business knowledge (understanding having an overview of what is going on in the company and then acting) and (2) renewing by collaborating with other disciplines and thereby renewing their own knowledge and convert them into practical applications for the organization.

Respondents see Engineering Education and companies playing an essential role in training tech workers for the future. Companies emphasize that they want to contribute to the training of tech workers, in particular, the areas of business knowledge, communication and commercial skills and collaboration. However, the basic dimensions of work in the new industrial reality, and the competencies that result from it, require more than vocational training. Instead, it demands tech companies who train their tech workers at the workplace. To assure (young) tech workers have the ability to cope with new technological developments, being able to function in unstructured and unpredictable situations and being able to work with new teams, Engineering Education and the business community will have to work together to a greater extent. The competencies that emerge from this research require not only a training program and work content that challenges the learning of the necessary competences, but a permanent development path that tech workers thoroughly, with long-term focus and step-by-step can transform for the ever-changing, unpredictable and unstructured work environments. Welten (2013) describes this as training in smart missiles: "people who can adapt at lightning speed because they are able to change course completely, and that requires that they forget what they had originally learned".

It is not only up to tech companies to facilitate this, but also up to Engineering Education. Engineering Education will have to build learning environments that prepare tech workers for the technological developments described in this paper. From that perspective, the various Dutch, regional partnerships between Engineering Educational Institutions, business and government that are currently being built in the form of "field labs", "learning communities" and "skills labs" are promising. Within these initiatives, a practice-oriented learning environment is being built, full of modern technology that is being introduced by companies. These environments offer tech companies, students and Engineering Education the opportunity to work together in a powerful way to develop the skills of the tech worker of the future.

We have developed a first concrete guide for training the tech workers of the future with five companies in the Smart Industry. Via mooc.saxion.nl students, employers and employees have access to five publicly accessible practical cases with which tech workers learn what the most important technological developments are and what that means for their work and the competencies required for this.

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APPENDIX A: QUESTIONNAIRE TECH WORKER OF THE FUTURE

Questionnaire: Competencies for the tech workers of the future

The tech worker of the future …

Expert Knowledge (in his/her own field)

1 ... is constantly looking for new knowledge within his/her field of expertise.

2 ... has in-depth knowledge within his/her field of expertise.

3 ... is an expert in his/her own field.

Multidisciplinary knowledge

1 ... is a generalist: has broad knowledge about various disciplines.

2 ... has knowledge of related fields of expertise of fellow technical colleagues.

3 ... has knowledge of the market and its customers.

4 ... has knowledge of the disciplines that he/she closely cooperates with.

Business knowledge

1 ... understands the impact of work on the profitability of the company

2 … understands how his/her work contributes to the product being made.

3 ... knows what to do in the event of a change or error in the process.

4 ... knows all the steps within the production process.

Analytical skills

1 ... is able to interprets complex information and convert this into concrete behaviour.

2 ... is able to discover and recognise connections in information and / or data streams.

3 ... is able to solve problems in a structured manner and distinguishes between main and minor issues.

4 ... is able to understand the essence of customers' demands and can act accordingly.

5 ... is able to translate complex information and/or data streams into manageable steps.

Accuracy

1 ... constantly examines the quality of his/her own results.

2 ... seeks feedback from others on the quality of his/her own work.

3 ... strictly adheres to working instructions and procedures.

4 ... is meticulous in every act he/she performs.

5 ... realises the importance of accuracy in his/her actions and the consequences of errors.

6 ... continuously examines and challenges the quality of the results delivered by others.

Communication skills

1 ... communicates easily with different levels.

2 ... is able to empathize with others when transferring discipline-specific knowledge.

3 ... is able to accurately express his/her opinion.

4 ... is adept at communicating with others in the organization.

5 ... is able to maintain contacts with customers and support them in an approachable manner.

6 ... is able to provide the customer with technical details in an understandable manner.

Collaboration

1 … provides input to the work of other professional disciplines.

2 ... works closely together with other disciplines towards a common goal or result.

3 ... solves complex problems in collaboration with other disciplines.

4 ... supports colleagues in their work.

5 ... is open to criticism and questions when cooperating with colleagues.

Creativity and innovation

1 ... thinks out-of-the-box and goes beyond the existing framework.

2 ... sees errors as learning opportunities and focuses on solutions.

3 ... explores and broadens the limits of the technical possibilities.

4 ... deliberates and reflects about how products can be improved.

5 ... designs innovative products together with the customer.

Commercial skills

1 ... advises customers on purchasing products.

2 ... negotiates and convinces customers about buying products.

3 ... understands the needs and wishes of the customer and can adjust products accordingly.

4… considers the customer perspective and customer experience in order to better understand the customer needs.

Pro-activity

1 ...is able to expresses his/her opinion within the group.

2 …is constantly seeking opportunities and takes the initiative to seize all within reach.

3 ... takes initiative to search for improvements for products and works to execute these.

Dealing with uncertainty

1 ... handles conflicts of interests well.

2 ... continues to function optimally regardless of tight deadlines.

3 ... manages the constant update of products and/or work procedures smoothly.

4 ... handles changing expectations well.

Adaptability

1 ... easily switches between different working environments

2 ... adjusts easily to changing team configuration.

3 ... switches quickly and often between work and machine work.

4 ... adjusts easily to setbacks and/or resistance.

APPENDIX B: DESCRIPTIONS OF THE COMPETENCIES OF THE TECH WORKER OF THE FUTRUE

Competencies of the tech worker of the future Tech Worker	Description
Expert knowledge	Expert in own field, in-depth knowledge, constantly looking for new knowledge
Multidisciplinary knowledge	Broad knowledge, knowledge of adjacent areas, multidisciplinary knowledge
Business knowledge	Understands and works in line with the production process, and understands the impact of work on profitability.
Analytical skills	Interprets complex information, sees through relationships, solves structured problems, brings out essence of customer wishes
Accuracy	Continuously questions quality, acts in accordance with work rules and process, is precise.
Communication skills	Communicates easily with other levels, makes easy contact, can maintain contacts with customers
Collaboration	Can work with other disciples and solve problems. Supports colleagues.
Creativity/innovation	Thinking out of the box, broadens the boundaries of technical possibilities, can improve products
Commercial skills	Advises and convinces customers, can adapt products to customer needs
Proactivity	Voices own opinion, takes initiative, continuously seeks opportunities, takes action towards own development
Dealing with uncertainty	Can cope with conflicting interests and tight deadlines. Is able to switch quickly between changing expectations.
Adaptability	Adapts easily in the event of a setback or resistance, and can switch quickly and often between activities

Engineering Graduates' Development of Competencies – Views from Academic Stakeholders

V.-P. Pyrhonen[1]
University Teacher, Tampere University
Tampere, Finland

S. Niiranen
University Lecturer, Tampere University
Tampere, Finland

E. Pajarre
Planning Officer, Tampere University
Tampere, Finland

Conference Key Areas: Lifelong learning, Sustainability reflecting the complexity of modern society

Keywords: Competency development, Accreditation, Engineering education research

ABSTRACT

This paper investigates importance and development of expertise and personal competencies of newly graduated engineers from the standpoint of academic stakeholders; namely, academic staff members, industrial employers and graduated engineers themselves. The aim was to discover which competencies are the most important ones in working life and in engineering curricula. It was also investigated which competencies have satisfactorily developed and which have not during university studies relative to their current importance. For such purposes, a national-wide graduate survey measuring the importance and development of 26 expertise and personal competencies on the scale 1–7 was used as a basis for research. Then, 69 academic staff members used FINEEC's (The Finnish Education Evaluation Centre) reference programme learning outcomes to evaluate the importance of competencies in their curricula. Finally, 24 industry representatives gave their evaluations on the importance of the 26 competencies of newly graduates.

The results from the study indicate that all stakeholders share similar opinions regarding to the importance of several competencies. However, engineering curricula puts more emphasis on theoretical foundation rather than in generic competencies, whereas industrial employers favour attitudinal factors and generic

[1] Corresponding Author
V.-P. Pyrhonen
veli-pekka.pyrhonen@tuni.fi, https://orcid.org/0000-0003-3313-127X

competencies. Furthermore, according to graduates' ratings, several competencies have been developed more than seems to be needed in working life. The same competencies are the most valued in engineering curricula. Similarly, competencies that are least valued in curricula are related to the competencies that are least developed in studies. Interestingly, several competencies that are least developed are also the most important ones for newly graduates.

1 INTRODUCTION

Inclusion of generic competencies into university graduates' curriculua has become increasingly important during the past 20 years [1]. For newly graduates' employment, possessing substance knowledge that are taught on students' study field is not enough. Instead, employers are putting increasingly more emphasis on graduates' generic competencies such as communication skills and team work skills [2]. In the engineering field, it has been argued that engineers are "not only expected to be technically proficient in the field but also to know how to behave and operate within an organization" [3]. It has been stated that overall, social skills such as persuasion, emotional intelligence and strong social and collaboration skills will be in higher demand across industries than narrow technical skills [4]. In spring 2018, the academic board of Tampere University community, in Finland, outlined a set of common learning outcomes for all its degree programmes. The common learning outcomes entail descriptions of generic competencies that every student should master by the time of graduation. These common learning outcomes and generic competencies should be integrated into all degrees by considering the perspective of the competency needs in the degree programmes. However, even though the importance of generic competencies has been largely recognized, there are differences in how universities have adopted them into their curricula and how professors and faculty value them [2–3; 5].

In the field of engineering, educators are called upon to help learners to develop analytic, communication, and teamwork skills, while meeting ever increasing content demands and cultivating independent learners [6–7]. As the professional knowledge about teaching and learning processes expands, also new type of expertise is required. In order to develop engineering education and pedagogical approaches in engineering education practices, it is important to get an overview of the current state of students' competency development. Thus, this study is aimed to discover, which competencies are currently the most important ones in working life of Finnish engineering field, engineering curricula, and as regards to newly graduate engineers. It is also investigated how various competencies of newly graduates have developed in studies and in working life relative to their current importance. In this study, the importance and development of various competencies of graduated engineers from the standpoint of academic stakeholders was investigated during 2016–2018 using well-known surveys and questionnaires. Next, the results from a national-wide graduate survey, academic staff members' ratings and employers' ratings are presented along with some analysis and interpretation of the obtained results.

2 IMPORTANCE AND DEVELOPMENT OF COMPETENCIES ACCORDING TO GRADUATE SURVEY

In this section, the results of the TEK (Tekniikan akateemiset) graduate survey[1] [8] are displayed. First, newly graduated engineers[2] evaluated the importance of each competency relative to their current need in working life using integers on the scale between 1 ["Not at all (important)"] and 6 ("Very much") with an option 7 ("Cannot answer"). Then, the graduates evaluated how each competency has been developed in studies and in work, respectively, using the above scale. Hence, each engineering graduate gave each competency three numerical values in the range 1–6(7), which were then averaged and displayed in a single figure. This allows reader to quickly see the importance of each competency relative to their current need in working life, and how well each competency have been developed in studies and in work. The figure also displays if importance and development meet each other, or if differences between importance and actual development exists. In case of differences, the amount of mismatch and its orientation are also easily seen.

2.1 Results of the graduate survey

The results of the TEK graduate survey are depicted in *Fig. 1*. In total, 12 competencies have been more developed in studies than in work. Most of these competencies are related to traditional university study activities, and hence, the development profile is not surprising. In turn, 14 competencies have been more developed in work than in studies. Many of these competencies are outside the scope of traditional university study activities, and they are more related to the generic competencies rather than subject specific engineering activities.

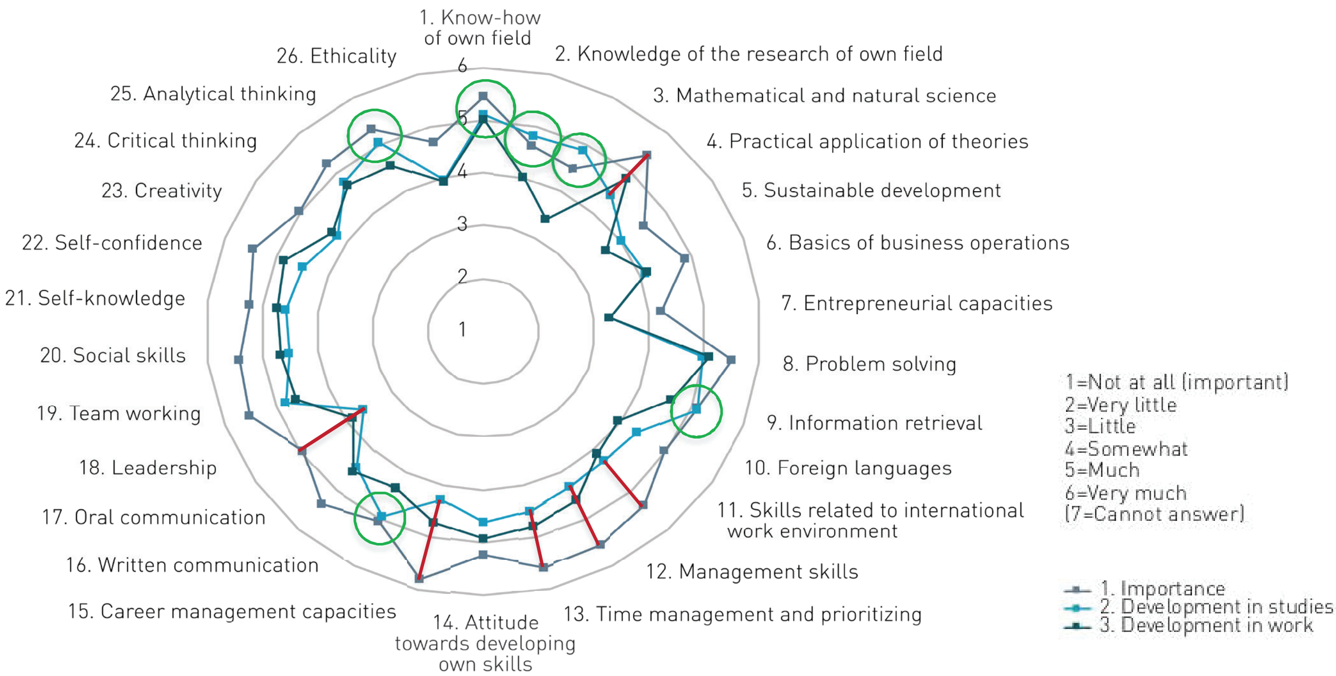

Fig. 1. Development of competencies in studies and in work relative to their current importance. Green circles = most developed, red lines = least developed [8].

[1] In the graduate survey, expertise and personal competencies are termed as 'skills and expertise'.
[2] A newly graduate engineer has just completed Master's degree in engineering and is required to participate in the survey.

According to graduates' opinions, the six most important competencies, in the *absolute sense*, are: 15. Career management capacities, 1. Know-how of own field, 19. Team working, 13. Time management and prioritizing, 8. Problem solving, and 4. Practical application of theories. The six least important competencies, in the *absolute sense*, are: 7. Entrepreneurial capacities, 5. Sustainable development, 3. Mathematical and natural science, 2. Knowledge of the research of own field, 26. Ethicality, and 6. Basics of business operations.

Furthermore, in *Fig. 1*, those competencies that have developed most, in studies, *relative* to their current importance in working life have been marked using green circles, whereas competencies that have developed least, in studies, *relative* to their current importance have been marked using red lines. According to *Fig. 1*, the six most developed competencies, in the *relative sense*, are: 3. Mathematical and natural science, 2. Knowledge of the research of own field, 9. Information retrieval, 16. Written communication, 25. Analytical thinking, and 1. Know-how of own field. Note that according to graduates' evaluations, the *absolute* developments of items 3, 2 and 9 in studies have been rated higher than their *absolute* importance in working life. Actually, no other competency has been rated such that their development in studies or in work shows larger values than their importance. Moreover, the *absolute* importance of 3 and 2 belong to the four least important competencies according to the graduates' ratings, while the development of 3 and 2 in work display very low ratings. These observations indicate that scientific fundamentals and theoretical foundations are learned during university studies, as they should be. More difficult issue is to argue, whether items 3 and 2 are nowadays too much emphasized in engineering education. After all, theoretical and scientific research is still one of the main functions of universities, and universities should educate researches as well.

The six least developed competencies, in the *relative sense*, are: 15. Career management capacities, 18. Leadership, 11. Skills related to international work environment, 12. Management skills, 13. Time management and prioritizing, and 4. Practical application of theories. It is quite interesting to note that theoretically oriented competencies like Mathematical and natural science, and Knowledge of the research of own field are the most developed, but Practical application of theories is one of the least developed. One possible explanation for such observation might be that engineering education in parts of former TUT (Tampere University of Technology)[3], including teaching and learning activities, assessment as well as intended learning outcomes, was practiced such that knowledge and understanding of science and theoretical matters were more favoured compared with engineering practice and applications.

However, it should be noted that the results in *Fig. 1* represents viewpoints of newly graduate engineers only. At the time of answering the survey, competencies that may seem unimportant to them, or with respect to their current job description, may well become important in future, say, five years later. These could e.g., be 5. Sustainable development, 7. Entrepreneurial capacities, 26. Ethicality, and 18.

[3] Tampere University of Technology no longer exists. It is now part of the new Tampere University.

Leadership, which are, *relatively*, the most unimportant skills and expertise regarding to newly graduates' opinions. Ethics, sustainable development and entrepreneurial capacities have just recently been included in planning of higher engineering education of Tampere University, and hence, they may also seem unimportant to newly graduates only because they have been explicitly missing from curricula.

Nonetheless, the most developed competencies are traditionally promoted in higher engineering education, and hence, it is reasonable that their development display large values among newly graduates. In the next subsection, it will be evident that these competencies were the most valued by the staff members of Faculty of Engineering Sciences of former TUT, and hence, these skills were fostered in their curricula.

2.2 Results from academic staff members ratings

In this section, the results from academic staff members' ratings are displayed. The data were collected during a teaching development event at Tampere University of Technology in 2017. In total, 69 staff members[4] participated in the event. The purpose of the ratings was to find out how various competencies are valued in faculty's engineering programmes. For such a purpose, FINEEC's (The Finnish Education Evaluation Centre) reference programme learning outcomes were adopted, which describe the knowledge, skills and competencies[5] that the learning process should enable engineering graduates to demonstrate *after graduation* [9].

The reference programme learning outcomes are based on EUR-ACE (European Accredited Engineer) framework standards of the ENAEE (European Network for Accreditation of Engineering Education). The reference programme learning outcomes are divided into the following five categories: 1) Investigations and information retrieval, 2) Engineering practice, 3) Multidisciplinary competencies, 4) Knowledge and understanding, and 5) Communication and team-working. Each category has their own set of competencies, which can be found in [9] along with their descriptions. Nonetheless, staff members were divided into the field-specific groups, and each group rated the importance of each competency in their curriculum using options: 3 ("must have"), 2 ("should have") and 1 ("nice to have"). Group work method was chosen to ensure that each member shared mutual understanding of each rated item. Then, the results of each field-specific group were gathered together and averaged. Finally, the results of all groups were gathered together and averaged for easy reference. As a result, the maximum score a competency could achieve was 18 points, whereas the minimum score was 6 points.

It turned out that those competencies that received most points were related to the graduate survey's following items: 1) Information retrieval (18p), 2) Know-how of own field (18p), 3) Written and oral communication (18p), 4) Problem solving (17p), 5) Ability for life-long learning (17p), and 6) Mathematical and natural sciences (17p). In contrast, the least valued competencies were related to the following items: 1) Management skills (10p), 2) Leadership (10p), 3) Creativity (11p), and 4) Sustainable development (12p), 5) Ethicality (12p), and 6) Practical application of theories (12p).

[4] Staff members of this study consisted of faculty's teaching staff, researchers, Ph.D. students and professors.
[5] Knowledge, skills and competencies of FINEEC's learning outcomes are hereafter referred as competencies.

It is quite interesting to observe that most of the items that received the highest score belong to the competencies that newly graduates have rated, *relatively*, as the most well developed in studies. It is also interesting that many of the items that received the lowest score belong to the competencies that newly graduates have rated, *relatively*, as the least developed in studies. However, items related to “self” i.e., the psychological factors were missing from [9], and hence, also from the staff members’ ratings. That is, [9] mostly considers expertise competencies.

2.3 Results from industrial employers ratings

In this study, 24 industrial employers ranging from small and medium enterprises to large enterprises were interviewed in 2018 on the importance of the same competency set as in the graduate survey. The most important competencies according to industrial employers were: 14. Attitude towards developing own skills, 8. Problem solving, 19. Team working, 1. Know-how of own field, 16. Written communication, and 13. Time management and prioritizing. The least important competencies were: 7. Entrepreneurial capacities, 18. Leadership, 2. Knowledge of the research of own field, 5. Sustainable development, 15. Career management capacities, and 6. Basics of business operations.

The industrial employers were also asked to list competencies that newly graduates lack most. These were: 19. Team working, 20. Social skills, 13. Time management and prioritizing, 6. Basics of business operations, 22. Self-confidence, and 21. Self-knowledge. Moreover, many employers highlighted several other competencies, which newly graduated lack but which were not captured by the survey’s items. The most commonly mentioned competencies were: 1) humility, 2) motivation, 3) respect towards other people, 4) manners, 5) adaptability to change, and 6) flexibility. Lastly, industrial employers were asked to list competencies, which they expect to be important in future. The six most frequently occurred competencies were: 19. Team working, 20. Social skills, 5. Sustainable development, 23. Creativity, 11. Skills related to international work environment, and 13. Time management and prioritizing. Note that items 5 and 23 were two of the least valued competencies in the engineering curricula of the Faculty of Engineering Sciences of former TUT.

Nonetheless, the absolute importance (most and least) of various competencies according to all stakeholders as well as the relative development of graduates has been collected into *Fig. 2*. Several interesting observations can be made from *Fig. 2*: Items 1 and 8 seem to be the most important attributes to all stakeholders, but none of them exist in the most developed attributes of graduates. Item 3 seems to be one of the most important in curricula, but at the same time, it is one of the least important for graduates and relatively most developed. Item 4 seems to be one of the least important in curricula, but it is also one of the most important for graduates, and relatively, one of the least developed.

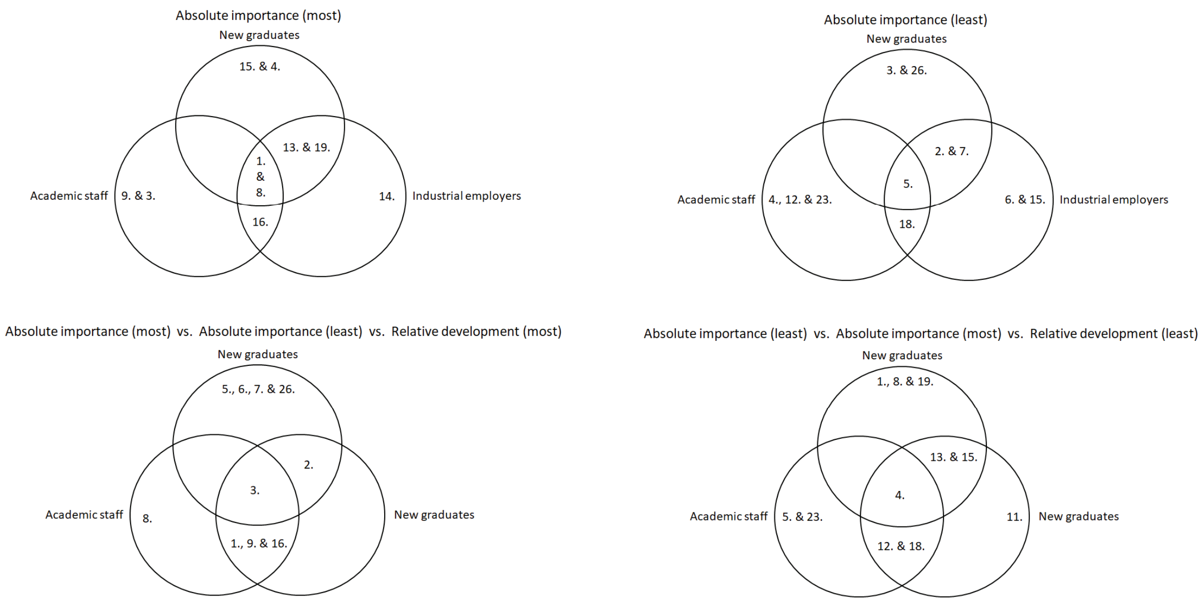

Fig. 2. Set diagrams of absolute importance and relative development.

Furthermore, items 1, 3, 9 and 16 belong to the set of most important items for staff members, and they also are, *relatively*, the most developed competencies of graduates. Also, items 4, 12 and 18 belong to the set of least important items for staff members, and they also are, *relatively*, the least developed competencies of graduates. Finally, it seems that industrial employers favor generic competencies and attitudinal attributes over subject specific competencies. In particular, items 13, 14 and 19 are the most important from their perspective. In what follows, research-based suggestions for developing higher engineering education is presented that are aimed to partly meet the desired needs for newly graduates.

3 DEVELOPING HIGHER ENGINEERING EDUCATION

Many of the major drivers of transformation currently affecting global industries are expected to have a significant impact on jobs, ranging from significant job creation to job displacement, and from heightened labour productivity to widening skills gaps [4, 10]. The findings of this study revealed that stakeholders of higher engineering education share similar viewpoints regarding to the importance of expertise and personal competencies. However, academia puts more emphasis on engineering specific technical knowledge, science and theoretical matters rather than on generic competencies. Industrial employers on the other hand highlight the importance of attitudinal factors, self-concepts and generic competencies, whereas graduates' views seem to overlap with those of academia and industrial employers. Furthermore, it seems that competencies that are most valued by engineering curricula are the ones that have relatively developed most according to graduates' ratings. Also, it can be observed that competencies that are least valued by curricula are related to the competencies that have relatively developed least in studies. Thus, the results seem to partly validate the outcome of educational efforts in higher engineering education in the former TUT.

When investigating the results in more detail, the industrial employers rated that competencies, which newly graduates lack most are e.g., team working, social skills, self-confidence and self-knowledge. In addition to those, they presented some competencies, which newly graduated lack but which were not captured by the graduate survey (e.g. motivation, adaptability to change, flexibility) and suggested several competencies, which they expect to be important in future working life (e.g. team working, social skills, creativity, time management and prioritizing). In order to provide students' education that would help them to achieve these skills, new type of educational strategies should be adopted into higher engineering education. Students should be seen more and more as learning agents of their own learning, who engage in a continual process of 'retooling' their knowledge and skill base by taking more responsibility for their own learning [10]. Teacher can support this in many ways e.g., by activating students during teaching and moving towards student-centered teaching and learning practices.

It has been argued in previous studies that a deep approach to learning has stronger relations with academic competencies than the other approaches [11]. Students with a growth mindset embrace challenges, persist when facing some setbacks, see challenges and effort as a way to the mastery, learn from criticism and find inspiration in the successes of others [12]. Also, improving the level of student motivation and engagement by active learning can be seen resulting in deep learning. Pedagogical strategies of active learning are answering to changing economic demands and patterns of work, which underpin the ubiquitous discourse of the 'learning society' and 'lifelong learning' [10; 13]. In engineering discipline, it has been argued that situativity should be seen as a dominant perspective by emphasising the role of the environments that require extensive content knowledge and analytical skills to engage in learning [6; 14]. There has also been an increased concern about the need to develop a better understanding of how people learn engineering [15] and how they build engineering identity.

Teachers are those who are constructing bridges between the contents and actions during courses. Thus, a course designer must have the ability to understand the situational and contextual constrains and also analyse practical learning problems i.e. to understand the position of the learner [16]. During the past 15 years, universities have begun to provide pedagogical training that is aimed to improve the teaching practises and skills of university teachers. Thus, the university pedagogical training in engineering pedagogy aims to strengthen the participants' pedagogical expertise through self-reflection and collegial collaboration. The courses foster research- and development-oriented approach to teaching among the participants by exploring their personal experiences and theoretical perspectives. The aim is to enhance teachers' ability to engage in pedagogical discussions and promote actions that support students' deep-level learning. In summary, these are the main methods for developing higher engineering education and for trying to fill the observed skill gaps of newly graduates' engineers.

4 SUMMARY

This paper investigated the development of personal and expertise competencies of newly graduate engineers according to academic staff members', industrial employers' and graduated engineers' evaluations. The development profile of each competency was investigated relative to the competency's current need in working life. The results indicated that the most developed competencies of newly graduate engineers were strongly related to the competencies that are most valued by academic staff members. Similarly, the least developed competencies were related to the competencies that are least valued by academic staff members. Interestingly, some of the least developed competencies are the most important ones in working life, whereas some of the most developed competencies are the least important, according to newly graduates' evaluations. Moreover, it seems that industrial employers are looking for graduates having good generic competencies and personal attributes, while academia is emphasizing knowledge and subject specific engineering competencies. Undoubtedly, other possible implications can easily been drawn from the obtained data that can raise fruitful debates regarding higher engineering education and its development.

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Retaining students at Aalborg University

How are we successfully retaining students?
Case: Interaction Design (IxD) 2014–2019.

Pia Bøgelund
Institut for Planlægning
Aalborg, Denmark

Henrik Worm Routhe[1]
Institut for Planlægning
Aalborg, Denmark

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KEYWORDS: retention, engineering education, interaction design, professional and social integration

ABSTRACT

Dropouts from higher educations have been high for several years. As increasingly within the research field, the focus in this project is the positive angle of the problem – 'retention'. The study case is the Interaction Design (IxD) program, a study doing well regarding retention. The research question is: *What is it that the IxD program does well regarding retention?*

We have used an explanatory mixed methods approach, as we have used both qualitative and quantitative research methods. Qualitative data was used to design the questionnaire, and to substantiate the quantitative results. The questionnaire was send out to all students from first until 7th semester. Alongside this, we also interviewed staff.

In terms of state of the art within the research area of retention, this piece of work highlights the importance of expectation reconciliation amongst different stakeholders.

INTRODUCTION – RESEARCH QUESTION AND METHODOLOGY

Dropout rates from higher education have been high for several years. The dropout percentage has been 16% for the last 10 years for first-year students; this indicates a problem (1). Previously Aalborg University had a low dropout rate compared with other universities. However, during the last few years an increased dropout rate among first-year students at Aalborg University has given rise to concern. There are great differences in rates for dropouts when one compares different programmes. Knowledge about the causes of the problem is essential. Another perspective which can shed light on why there are differences between the different programmes and why some programmes are clearly better than others is just as essential. During the

[1] Corresponding Author
routhe@plan.aau.dk

last few decades, focus on the problem has changed from a negative approach – ‘dropout’ – to a positive approach – ‘retention’ (2, 3). The focus of this study is on the positive angle of the problem: ‘retention’. The case study used is the Interaction Design (IxD) programme, which has been performing well with regard to retention. The research question is:

What does the IxD programme do well regarding retention?

As a starting point for qualifying our research, questions, and establishing a focus in relation to our empirical collection and data analysis, the theory of a ‘sense of belonging’ was used (2, 3). This research shows that successful retention is linked to the student's experience of belonging (‘sense of belonging’) to the education, professionally as well as socially. In other words, the students' perception of being academically accepted, appreciated, and included, and their experience of being an important part of social life and social activities, is important to the retention of students. Other research (1, 4) points out that the start-up phase and the first year are particularly critical for retention. We have chosen, however, to involve students from the first semester up to and including the seventh semester, because we know from the outset that the older students have a great influence on the academic and social environment of the entire programme. Based on this and the above comments on the importance of the context, the following three sub-questions were identified:

What type of students attends the education programme and how do they experience the programme’s start-up phase?

How does professional and social integration look at each four-year stage: i.e., the first, third, fifth, and seventh semesters?

In what institutional context does the IxD programme unfold, especially with regard to the infrastructure implemented by the supervisor (IT, group rooms, secretaries, etc.) and student organizations?

1.1 Method for data collection

We used an explanatory mixed methods approach (5), because we used both qualitative and quantitative research methods. In our quantitative approach, a questionnaire was sent to all students in the first to seventh semesters. The qualitative data were used to design the questionnaire and to support the quantitative results. The qualitative data consist of three focus group interviews with, respectively, five students from the first semester, seven students from semesters three to seven, and two teachers and supervisors who helped to found the programme. In addition, the student counsellor for the programme was interviewed. Data on dropout rates were collected for the individual semesters. Data from the questionnaire and interviews were subsequently analysed according to the three sub-questions. In the following paragraphs, the results of the analysis are first reviewed in a number of sections, after which the main question of the study is discussed.

The questionnaire was sent to 129 students from semesters one through seven. Responses were received from 55 students: 22 women and 33 men. Thirty-six students answered all the questions. Replies were received from 19 students in the first semester, 13 students in the third semester, 9 students from the fifth semester, and 11 students from the seventh semester (see Table 1). We consider the answer rate satisfactory and have no reason to assume that the responses are biased.

Table 1. Response rate for questionnaire survey

Semester	Number of questionnaires	Number of answers	Answer Rate
1st semester	37	19	51.4%
3rd semester	37	13	35.1%
5th semester	39	9	23.1%
7th semester	16	11	68.8%
Total	129	55	42.6%

2 BASIC DATA, EXPECTATIONS, AND START-UP

2.1 Satisfaction with the programme

The study results show that 33% of the students are very satisfied with the programme and 53% are satisfied with the programme. No student is very dissatisfied with the programme.

On the question of satisfaction, there is a difference in the answers between the first to third semesters and fifth to seventh semesters. The first to third semesters answered that 47% are very satisfied and 47% are satisfied. For the students in the fifth to seventh semesters, 7% are very satisfied and 67% are satisfied. There are relatively more very satisfied students in the earlier semesters.

2.2 Motivation for choosing study and start-up

A number of questions about what influenced the students' choice of programme reveals that design and creativity, problem-solving, construction of new solutions, and technology have great influence or some influence on their decisions, whereas the expectations of others and tradition have no influence or limited influence.

If we look specifically at how the students experienced starting at Aalborg University, there is great satisfaction with their experience of the introduction period. The students were asked how they were received at Aalborg University, how the tutor scheme worked, and how the introductory period progressed. Everyone replied that these were very good or that they were well received. For first to third semester students, 43% were very satisfied, while for fifth to seventh semester students, 33% were very satisfied. Regarding the question of the tutor scheme, 92% of first to third semester students responded that it works very well or well. Eighty-four percent of fifth to seventh semester students answered that it works very well or well. With regard to the introductory course, 93% of first to third semester students answered that it works very well or well. Eighty-four percent of fifth to seventh semester students answered that it works very well or well. A comparison of the answers for the different semesters – first to third semesters and fifth to seventh semesters – shows that the first to third semester students are generally the most positive. The students generally agree that the tutors make a fantastic effort. It was also mentioned that the professional start-up is quiet and calm. The students also commented on what topics could be improved in the on-boarding. In particular, they mentioned that more information before the start is desired.

3 PROFESSIONAL INTEGRATION

Professional integration is very important for the students' ability to retain the knowledge of the subject they have chosen. We asked the students what aspects of study are important to them. They responded broadly that the subject's interest, relevance, usability, quality, and learning environment and balance between study and leisure are the most important parameters, together with a good social environment and the capability to finish their studies. A few quotes from first to third semester students illustrate some of these points:

> *…that I can see a relevance in what I am taught and can use it now in the semester project, but also in the future. In addition, it is also important to have a good study environment, both among one's fellow students on the programme, but also from other study programmes.*

> *An educational environment where there is also the opportunity to be with my fellow students socially, a good education that interests me, good teachers, good literature, a group room for the project group.*

Similar comments were recorded from the students in semesters five to seven; however, they added parameters such as a correspondence between expectations and realities, student involvement, a connection between projects and courses, and good facilities. They also pay attention to the importance of the size of the classes. In relation to professional integration, it was emphasized that it is important that the classes do not become too small (i.e., under 30 students) for the sake of the possibility of entering into different types of academic relations with fellow students and in terms of providing a better opportunity to adapt courses specifically to their professional skills. On the other hand, the classes should not be too big because, in this scenario, social integration is compromised. Students from the later semesters also emphasized the importance of the projects being realistic and the existence of a professional challenge.

3.1 Workload, project work, and coherence of courses

With regard to the workload, 75% of both the younger and older students experienced it as comfortable, while for 20% it was too much. Seventy percent of the students in semesters one to three found the degree of difficulty comfortable, while 26% found it difficult or very difficult. In the fifth to seventh semesters, 50% of students found the degree of difficulty comfortable and 33% found it difficult. The students experienced an increase in the level of difficulty in the later semesters.

We asked the students to list good aspects about studying at Aalborg University. The common answer across all semesters was group work and Aalborg University's basic PBL model. A few examples are as follows:

> *I really like the group work that I know helps me to prepare for my future in the labour market.*

> *Group work, PBL, Aalborg as a study city, the people.*

This fits well with the feedback on how important it is for the individual student to work in project groups, which was 89% and 92% for first to third semesters and fifth to seventh semesters, respectively. This is also reflected in how important it is for the individual student that projects are perceived to be relevant. For 100% of the students in the fifth to seventh semesters, this is of great importance, while it is of great importance to 78% of students in the first to third semesters.

Respectively, 74% and 67% of first to third semester students and fifth to seventh semester students found that the relevance of the project work they are participating in is great. Thus, there is better correspondence between expectation and reality in the first to third semesters than there is in the fifth to seventh semesters. The focus group interviews with the students also show the importance of the projects. The following quotation is from students in the fifth to seventh semesters:

> *Projects work well!*

A relationship that traditionally has an impact on academic integration at Aalborg University is the coherence between courses and projects. Ninety-seven percent of students in the first to third semesters think there is coherence or a very large coherence. The tendency is for a downward trend in the fifth to seventh semesters, where 67% think there is coherence or a very large coherence and 33% see only a little coherence.

3.2 The professional environment and the students' own initiatives

The big picture shows that 88% of the students surveyed think that there is a good to very good academic environment for their education, 80% believe that they are part of the academic environment, and over half of the students in both groups believe they have an influence on their professional environment. At IxD, a student-driven professional club called FixD has been established, which has been a driving force in establishing professional and social activities. This group has had a significant influence on the academic environment. FixD and its activities are more pronounced in the fifth to seventh semesters.

4 SOCIAL INTEGRATION

Social integration, together with professional integration, is important for retaining students. The issues related to social integration are the social environment, a sense of belonging, and the students' own initiatives.

4.1 Social environment

Regarding the overall question of how the social environment works, 92% of first to third semester students answered that it works very well or well. For fifth to seventh semester students, 75% responded that it works very well or well.

The student initiative FixD is of great importance to the social field, and it has a little more importance for the older students than for students in the initial semesters. For the first to third semesters, the student initiative is of great importance to the social environment for 46% and has little importance for 31%. Twenty-three percent indicated that they did not know. For fifth to seventh semester students, the student initiative has a great importance for 67%, a little significance for 17%, and no significance for 17%.

The experience of being part of the social environment is greatest among fifth to seventh semester students. Here, 66% experience being part of the social environment to a great extent and to some extent. For first to third semester students, just 47% experience being part of the social environment to a great extent or to some extent. Forty-six percent of first to third semester students feel to a lesser extent part of the social environment; the corresponding group of fifth to seventh semester students account for 25%.

5 PROFESSIONAL AND SOCIAL INTEGRATION – SENSE OF BELONGING

5.1 On a scale of one to ten, how much do you feel that you belong here?

The students have been asked to indicate, on a scale from one to ten, how much they feel that they belong to the programme. There is a big difference in the experiences of belonging between the different semesters. First semester students experience a very high degree of belonging, compared with other semesters. The lowest affiliation is that of third semester students.
We asked about students' identity in both interviews and, already in the first semester, they have a clear and simple feeling of who they are and what their role will be in a professional context:

> *I have to learn to make a computer easier to use.* (First semester student)
>
> *We are natural born problem solvers.* (Fifth to seventh semester students)

6 INSTITUTIONAL FACTORS

The institutional factors deal with the supervisory body, collaboration with the study secretary, IT structure, IT support, scheduling, teaching platform, and premises, etc. We began by looking at the programme's establishment and development before moving on to other institutional factors.

6.1 The establishment and development of the programme

IxD is a new programme that started in 2014. The first candidates will complete the programme in the summer of 2019. The programme is small with an admission in 2018 of 38 students. According to interviews with two of the leading forces in the establishment of the programme, the background for its creation was both a need in the industry and a recognition of the importance of further developing the students' academic expertise in the field:

> *There are a lot of jobs that are about working with users…. There is a demand for someone who can build something… who can be constructive and not just creative. This is a design-oriented education,… a technical education.... That's what the industry demands.*
>
> *We designed the education programme in the way that we thought was the right way to approach this type of education.*

There is a clear and meaningful outside demand. The composition and content, and the relationship between projects and courses, are also elements the supervisor group worked on diligently and intensely. The supervisors have been very careful to integrate well individual elements of each semester and then focus on explaining the programme to the students.

During the first few years, there were some adjustments. In order to be able to develop the education, it was important for the teachers to have 'a finger on the pulse' with regard to the students; in particular, the first year students' progress was followed closely. The teachers have been very responsive towards the wishes of the students and they have had a crucial role in initiating social activities:

> *Some of them [the social activities] we pushed and started, and then the students took over. And that's actually a dream situation.*

From the focus group interviews with the older students, it is clear that there is great initiative and ownership among the students in the later semesters. They are very committed to their education and very dedicated to each other. When there is something that does not work according to the students' wishes, they have a great drive to change things. This drive is coupled with a great deal of scepticism towards the university, the teachers, and the structures they are part of.

6.2 Nature and composition of the supervisor group

There is an internationally recognized research group at IxD. As mentioned, they have been very much involved in the establishment of the programme. There is great enthusiasm among the teachers and the education is their 'lifeblood', which means that they often 'run 10% longer':

> *It is very much driven by the fact that it has been very important for us to get this education both accredited and up and running.*

It also means a lot to the teachers' international reputations to have a programme in their own field of research that is very successful. Many resources from the teachers' side have been used to progress the programme to the level it is at now. Thus, two of the challenges of the programme are its success and its scalability. It is, for example, difficult to acquire newly qualified staff, so there are vacancies that are not occupied.

6.3 Education structure: scheduling

Eighty-two percent of the students in the first to third semesters answered that the education structure and scheduling work very well or well. For fifth to seventh semester students, the corresponding figure is 58%. One of the challenges that has emerged from the focus group interview with the older students is the merged classes they have with other programmes. The students feel overlooked when, for example, they study with Architecture & Design students.

> *It has happened several times that lecturers have forgotten that we are present. …[They have] not prepared anything for us.*

The teachers are aware of the problem and say:

> *I think that the merging… has had some challenges. We have changed a lot of this, but still have not quite found the right solution.*

The challenge is that there is a difference in the structure of the programmes. The idea of mixing programmes in courses is liked by the supervisors but, in practice, it can be challenging. It may look ‘good on a slide’, but the reality is more complicated.

6.4 Teaching platform and group rooms

Twenty-two percent of the students in the first to third semesters answered that the teaching platform works well. For fifth to seventh semester students, the corresponding figures are 58%. Of the students in the first to third semesters, 48% answered that the teaching platform works less well. For fifth to seventh semester students, 25% responded that the teaching platform works less well. Thirty percent of first and third semester students and 17% of fifth to seventh semester students responded that the teaching platform works poorly.

Own group rooms are of great importance to the students. Eighty-seven percent of all students state that it is very important to have their own group room. The same percentage of all students thinks that the group rooms work well or very well. When asked for a reason why it is important to have one’s own group room, one of the student answers was:

> *You can do more concentrated group work and work without disturbances from others or alarms from other students. You can also have your own things there, especially if you are doing some sketches or other things that can be difficult to take back and forth; it is nice that it can be locked and no one can come and take it.*

7 DISCUSSION

In accordance with the initial identification of the design of the study, we will first answer the three sub-questions and then answer the main question of the study: what does the IxD programme do well in relation to retaining students? In conclusion, we will present the results of the analysis in order to transfer the experiences to other programmes at Aalborg University.

7.1 What type of students attend the programme and how did they experience the start-up phase?

When looking at the results of the analysis, it is clear that there is generally a great satisfaction with the IxD programme. This applies to all students. Even at the beginning, the students feel well received. They especially emphasize the tutors, who do a great job in connection at the start-up. An area that could be improved in connection with the start-up is the information that students receive before the start of their studies. Approximately half of the students state that they did not get enough information. In connection with the students' motivation for choosing the programme, it is clear that parameters such as design and creativity, problem-solving, construction of new solutions, and technology are important for the choice of the IxD programme. When interviewed, it became clear that the students have a very clear idea of what their study entails in terms of subject and identity, and they have a very clear understanding of their role as interaction designers. They identify themselves as interactions designers, even though it is a new education programme and they have a clear understanding that there is a need for precisely their qualifications in industry. The reason for this understanding and sense of identity may be due to a great deal of clarity from supervisors and teachers in terms of what is taught and what it can be used for.

7.2 How does professional and social integration look at the programme's first, third, fifth, and seventh semesters?

In relation to professional integration, the students at IxD mainly experience having an appropriate workload and an appropriate level of difficulty in courses and projects. Something that is widely agreed among the students is the importance of project work. Project work is the cornerstone of their education. It is one of the best things about going to Aalborg University. When project work is combined with great relevance and appropriate academic challenges, this is of great importance for professional integration. Another factor that has a great influence on professional integration is the coherence between courses and projects. There is a good coherence between the courses and the projects on the IxD program. The students also mention the students' own initiatives at FixD as an important part of professional integration. The efforts of the older students to help the younger students academically have great importance for professional integration. This, combined with a large satisfaction with supervisors and teachers, gives the students of the IxD programme good professional integration.

The social environment works well in the IxD program. Something that is very important to this is the students' FixD initiative, which organizes several social activities across the semesters. Many of the students consider themselves to be an important part of the social environment. All of these factors contribute to good social integration. The affiliation of the students with the IxD programme is considered to be relatively high. This is not least based on good professional and good social integration, but also based on the students' own assessments. The character of the students' affiliation is worth paying attention to. It seems as if the students in later semesters feel affiliated to the other students in the programme and hardly any affiliation with Aalborg University or the teachers. There seems to be a certain contradiction between the perspective of older students and Aalborg University as an institution, which is related to a large discrepancy between the students' visions and dreams of a very special education, where not only professionalism and the social environment are above average, but also the framework of the education. Overall the satisfaction from the 1st-3rd semester students are higher compared to the 5th-7th semester, which is evidence of a growing satisfaction with the education.

This development has been enhanced by the teachers being particularly responsive to what might not be working, as well as perhaps a lack of dissemination/recognition among the students about what claims a well-established university can generally meet and function. However, it is still the professional and social quality that is crucial for student retention.

7.3 In what institutional context does the IxD programme unfold?

In the institutional context in which the IxD programme unfolds, group rooms are essential. Other institutional factors, such as IT structure and IT support, collaboration with the study secretary, and lecture rooms work well. A challenge exists with merged courses, especially in the later semesters. Here, there are many cross courses with other programmes and this presents the challenge that IxD students often feel overlooked. This relationship is, among other things, because there is a structural difference between how the education is organized. Various solutions have been tried, but no optimal solution has yet been found. At the IxD programme, there is an internationally recognized research group. The mainstay of the IxD programme has been involved from the beginning. There is a great spirit among the teachers, which rubs off on the students. This, however, is also the seed of a future challenge: to scale the education to the educational resources that are available for the programme. The supporting forces have been very involved in the development of the programme and with the growth of the programme it is necessary to recruit new teachers. This has so far been difficult; thus, there are several vacant positions among teachers and supervisors.

7.4 What does the IxD programme do well in terms of retaining students?

A summary of what the IxD programme does well is presented in Table 2 in a number of bullet points.

Table 2. What does the IxD programme do well, regarding retention?

The start-up	Motivation for choosing education
-Good reception -Good tutors -Good intro week	-Clarity on content and usability -Clear identity in relation to choice of programme
Professional integration	**Social integration**
-Appropriate workload and difficulty -Relevant projects -Good coherence between courses and projects -Good academic environment -Good guidance and good teachers -Student organization	-Good cohesion in the programme across the semesters -Student organization -The social environment
Institutional context	**Areas that could be improved**
-Own groups -Opportunity for collaboration across design spaces	-Information before start of study -Cross courses between programmes -The students' knowledge of and recognition of AAU's internal development logic

7.5 Perspectives on previous studies and transfer of experience

Previous studies at Aalborg University (6, 7) made it clear that, in other programmes, the expectation reconciliation with the students has not been sufficient, both in terms of rationale for the education in general and the rationality of the individual educational programme contents. The IxD programme directors are aware of the expectation reconciliation between students and university. When they organized the programme, it was based on a clear job-market-related rationale with a focus on high quality and well-founded progression. In addition, they were very attentive to communicating the idea and structure of the overall education and individual semester. This gives meaning and transparency to the students. In relation to what can be transferred to other programmes, we want to point out the following:

1. Expectation reconciliation with students is central. This is the key to a good collaboration between students and university.

2. The rationale behind the programme is important. Ensuring our programmes are in line with the demand of our students and the labour market is crucial for creating immediate logic and meaning.

3. The internal structure of the programme is of great importance. A focal point is to ensure an internal logic and trade-off between the different elements of a programme and a clear rationale behind which activities are placed when. In addition, it is important to at the same time take into account that the total workload does not become too large.

4. Agency and enthusiasts are crucial. The leading teachers who established the course have delivered an effort out of the ordinary and the motivation has come from within the programme. The same can be said about the students, even though the push towards collaboration has been largely due to the teaching staff's influence. Enthusiasts must take care not to be taken advantage of in order that they are able to both support their initiatives and ensure that they do not work over their abilities and run out of energy.

Of course, it is easier to apply points two and three in a new education programme. Similarly, it is probably easier to support the enthusiasts of a well-established programme, because it gives a lesser load to the same people.

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Adaptation of teaching and assessment to students' ambition levels

Kjell Staffas
Uppsala University
Uppsala, Sweden

Steffi Knorn
Uppsala University
Uppsala, Sweden

Keywords: Student-centered learning (SCL), small group teaching, ambition, selfconscious learning

ABSTRACT

Three different groups of engineering students took the course Signals & systems in a teaching approach, which they perceived as radically new and different. In the course, their only physical contact with the teacher was one weekly hour at their disposal. Apart from this, students were encouraged to use provided material for self study. When taught in a more traditional way, students used to have trouble fulfilling all learning goals for the course. The study's aim was to investigate students' capability to adapt to this model and their experiences from a motivational and performative view. A mixed methods approach was used with interviews, a written questionnaire and a comparison of the grades from previous years. The students' performed considerably better on the exam, but experienced difficulties in adapting to the newer format, and many fell back in a more common passive role, despite taking part in the new activities. Only a small group changed their study routine according to the intention from the teachers. The main criticism concerned the absence of traditional lecturing. The study clearly shows that students can change and perform better but are also stuck in a teaching tradition that they are used to. They perform better in groups, and can adapt from fellow students that change their study routine. This paper gives valuable insights in what students fostered in "traditional teaching" experience from a format where they are responsible for these parts of the teaching, and how they use their time with the teacher. Future investigations should include motivation from lectures, improvement of metacognitive skills and degrees of self-regulation.

1 INTRODUCTION

The planning and development of most university courses is still heavily based on a traditional format including informative lectures, presenting problems solutions on the board and fill in the blanks laboratory work. Of course, there exist initiatives on engaging the students in communicating during lectures and lessons, and other inputs to make the laboratory work more investigative. Nevertheless, apart from potential issues in implementing alternative teaching methods, teachers also face resistance from students as many of them express that they are perfectly happy with a course in the traditional format. Thus, courses often contain no surprises and the lectures include what students can expect from the exam [1].

Efforts on transforming education to a more student-centered approach is far more than applying a model that proved to be engaging and motivating. From experience on tutoring teachers in higher education, efforts tend to bring the teachers to a frustrating moment in their course where they realize that people are lazy by nature. Fostered in a traditional format of teaching student become insecure on what to expect from a newer model and what is expected from them. It is far from obvious that they become more active just because the teachers have learned some new tricks up their sleeve.

Therefore, a change towards more student-centered learning activities requires a transformation in the teacher's own approach as an expert and facilitator to deep knowledge. This transformation is perhaps the most difficult part of the new format: How to take part in the learning process? Generally, there are fewer relations between study success and methods and habits, than between study results and attitudes and motivation [2]. Therefore, the key role for the teacher, besides being the expert, is to create an engaging and motivating environment for the students. I.e. the presence of the teacher is not very important but instead the process among the students and the motivation and drive of the students is what counts and should be strived for.

2 RESEARCH QUESTION

In this study, we aim to test and evaluate how different teaching activities are suitable or can be adapted to students' abilities and ambition levels. The course goals and required levels for passing the course and achieving higher grades were communicated to the students in a clear and efficient fashion. Given those goals and requirements, we investigate the students' ability to take responsibility for their learning as well as efficiently plan their time and study activities.

3 METHODOLOGICAL APPROACH

This inquiry is based on

- quantitative comparison of exam results;
- a questionnaire investigating students' experience of learning, adaptation and alignment to the different teaching approach and learning activities from their ambition and abilities; and
- fourteen interviews with selected students,

a mixed methods approach is preferred [3]. The collected data mainly covers students' own actions and reactions to the new format, which gives the survey a narrative view from experience [4].

4 STUDENT-CENTERED LEARNING (SCL)

The main difference between a "passive learning environment" and a more active is, instead of transferring knowledge to students, to engage them in a collaborate process of continuously building and reshaping their understanding naturally connected to their experiences and interactions with the world [5]. All learning is of course active so the meaning is more of the difference between activities that promote surface learning compared to deep learning. To prevent students from surface learning one must remove the factors that guide them not to learn in depth [6]. For good teaching to promote effective learning, [7] summarize four shared focus-areas from a constructivist approach:

1) Focus on who is doing the learning
2) Focus on the context
3) Focus on the kind of learning task being undertaken
4) Focus on the processes involved

To become a constructivist teacher in higher education, [8] suggests the following guiding principles:

1) Posing problems of emerging relevance to students
2) Structuring learning around primary concepts
3) Seeking and valuing students' points of view
4) Adapting curriculum to address students' suppositions
5) Assessing student learning in the context of teaching

There are several frameworks for SCL. Keller's ARCS model aims at enhance attention, relevance, confidence and satisfaction (hence the abbreviation ARCS) through a motivational design approach [9]. [10] suggests that learner-centered approaches focus on the unique individuality of varying interests, capacities, backgrounds and perspectives, and how to support it. In order to increase ownership for the students, [5] proposed the REAL (Rich environments for active learning) model. Focusing on the social aspect of SCL, [11] capitalized on active learning and facilitation via social media. There are also proposed models that assume students to perform independently without external guidance [12]. This is similar to different problem- and project based learning approaches (PBL).

The approach underlying the model used in the framework for this paper is more like the proposed model from [13]: To encompass motivational, cognitive, social and affective aspects of learning, the following constructs of SCL are keys:

a) Autonomy from self-determination theory
b) Scaffolding from constructivism
c) Authentic audience from constructionism

This is the Own it, Learn it, and Share it (OLSit) framework.

5 THE COGNITIVE AND MOTIVATIONAL DIMENSIONS OF (SELFDIRECTED) LEARNING

Already Dewey presented in his early work that the ultimate challenge in designing an educational experience is the integration and coordination of cognitive and social concerns [14]. From the constructivist approach, the focus is on the learning process itself, not the teacher or teaching. A model of self-directed learning is proposed by [15]:

- External management (contextual control)
- Internal monitoring (cognitive responsibility)
- Motivational (entering and task) issues associated with learning in an educational context

The learners shall "…assume personal responsibility and collaborative control of the cognitive (self-monitoring) and contextual (self-management) processes in constructing and confirming meaningful and worthwhile learning outcomes." (ibid. p. 18). To create a motivating and inspiring learning environment the following content was presented:

- A course compendium written for the course, including dedicated exercises;
- Worked out solutions for all exercises of the course compendium;
- Conceptual questions with solutions for each course week's material;
- Video recordings of lectures covering most of the material in the course compendium;
- A summary for each course week including a list of recommended reading material, video lectures and exercises to be solved;
- An explanation of each course goal, including a break down into which subparts are required for passing the course or receiving higher grades and related, relevant material such as parts in the compendium, video lectures and exercises.

This was a 5 credits course given at 1/3 speed which means eight weeks in total. Students were divided into small groups of up to 8 students of their choice, i.e., students were asked to join a group freely. Then, each student group got one hour of scheduled time (referred to as "lesson" or "meeting") with the head teacher of the course per teaching week, which could be used according to the students' choice. Options included explanations of some material, solving examples, answering questions, giving feedback on students' work or free discussions. The remaining time was intended to be used for self-organized study activities for the course but no specific times were formally scheduled for the students for such activities. Students were encouraged to follow the week plans, organize their time as well as study the material according to their ambition (wishing to achieve a higher mark or just passing) and ability (allowing for less time to be spent in case of good prior knowledge and providing extra material for students with insufficient prior knowledge) and prepare for the weekly meetings with the teacher. However, teachers did not check whether students followed these recommendations. The course planning was also adapted by a fellow teacher on the same course in another program (the control group) without further influence from the other two courses/teachers. None of the teachers was specially trained for this teaching approach. Rather, they have experience using both traditional and other SCL approaches. Both teachers also taught the courses before and are well familiar with the contents.

6 RESULTS AND DISCUSSION

In this study, we followed a mixed method approach using answers to a written questionnaire, semi-structured interviews and a comparison of the grades from previous years. We included students from two engineering programs taking very similar courses, which were taught with the novel teaching approach by the same teacher and of which we interviewed nine students (five from one program and four from the other). For comparison, we also considered students of a third engineering program (control group) taking the same course, with the same teaching approach but another, experienced teacher. We interviewed five students of the control group.

6.1 Results from interviews and course survey

It became apparent that it is far from easy to implement methods that should nurture SCL: it can backfire and make the students passive, i.e. they use the non-scheduled time studying other parallel courses instead. In addition, it is hard to let go of the lecturing part of sessions and meeting students in smaller groups need to be focusing on what the group actually asks for. This is both a challenge for students, who reported that they needed time to adapt to the new approach and reflect about their needs and preferences, as well as teachers, who were tempted to fall back into the traditional lecturing role. Specially, when groups were merged (in the control group) to give each group more time, i.e., then 2 hours per larger group instead of one hour per small group, the lessons more often became mini lectures. Therefore, the teacher's role is utterly important and he/she needs to leave the lecture suit in the office. It is about being perceptive to what the students are there for. Then it becomes even more important to give them instructions on what to work on to prepare for the meetings with the teacher. As [13] puts it:"…SCL is a complex learning process that students must be thoroughly supported in the motivational, cognitive and social aspects.". Hence, instead of converting the sessions into lectures, teachers must instead challenge the students into taking responsibility for their learning, explore the material and prepare questions or at least form an opinion about how the lesson should best be used.

In fact, comparing answers from the two programs and the control group revealed that a mayor distinguishing factor between students, that benefited and appreciated the teaching approach, and others, who did not, was the insight that the courses' teaching approach required students to take responsibility for their learning. Out of the five students interviewed from the control group, who all disliked the teaching approach, only one mentioned the need to take responsibility for organizing and planning the learning activities. The remaining students instead expressed a strong wish to be taught in the traditional lecture format, which they are used to. A loss of interest in the course and difficulties in learning the material was hence mainly blamed on the absence of lectures. The only positive aspect of not having lectures for them was the freedom to use the time for other activities such as studying for other courses. However, they also admitted that using the time for studying for the other courses worsened the situation as it became even harder to follow the course in the new teaching format, which led some of them to give up on the course all together (at least for some time).

In contrast, the majority of students from the first two programs, brought up the need to take responsibility for their learning, including to organize their time and motivate themselves to study the material as well as prepare for the lessons, in the interviews. While they agreed with the control group, that this aspect was challenging (especially at first), they acknowledged its necessity in order to prompt students to become active learners. Further, some reflected that they felt more "in phase" with the course in the new teaching program compared to the parallel courses in the traditional format, as they became more active in learning and preparing for the lessons.

Students in the two programs reported a high level of deep learning and expect to remember the course material longer. In contrast, when asking the same question to students in the control group, they indicated that their learning was more superficial and focused on learning in order to pass the exam, which they started to prepare for admittedly late. Indeed, some detailed that they did not grasp how different parts of the material connected and were missing the overall picture in the course. This partly contradicts the common believe (especially among students) that lectures allow to give a comprehensive overview of the material and facilitate general understanding of the material since the control group also reported to have perceived the lessons as predominantly lectures.

Several students from the two courses admitted that they did not like the teaching approach at the beginning of the course mostly because it was perceived as unusual, uncomfortable and partly scary. However, after getting over initial deprecative responses, students reported that they changed their attitude and appreciate the benefits of being forced to grapple with the material. Hence, even in a relatively short period of time (6-7 weeks of teaching) students can adapt and change their attitude towards teaching approaches, their study routine and sense of responsibility. However, whether they do, seems to depend to a large degree on the teacher, since students in the control group did not report such change of mind.

Another aspect to facilitate students to take responsibility for their learning and change their study routine towards an active role might be the group size. Despite some students complaining about shortage of time, groups were kept as small as intended (with up to eight students) in the two courses, which allowed for only one hour per group per week. An additional lunch meeting, open for all students, and prompt responses to requests sent via email offered some relief of the time problem. This seemed to have been a worthwhile decision as students expressed feelings of confidence and safety when being able to ask questions in front of only a few fellow students.

In contrast, in the control group, the teacher decided to join two groups at a time in order to allow for more time per group with now up to 16 students. This led to a greater tendency of converting the lessons into lectures, as discussed above. Also, 16 appears to be too large of a group to feel confident about asking questions openly. Students in the control group instead indicated that they perceived no difference in asking a question in the groups of 16 students comparted to their entire class of around 90 students. Hence, there seems to be a critical group size below 16 to ensure students feel confident and secure to be honest and open to ask questions and seek help. Another factor might be that students in the control group chose who to form a (small) group with but were then combined with another group solely by convenience of the teaching schedule but not allowing students to choose how groups should be joined. Both aspects are important to guide students and build up their confidence such that they are able to then take an active role in their learning.

6.2 Exam results

The exam was graded on the scale “Fail/3/4/5 (highest mark)” and included one part per each of the 5 course goals. For each course goal, students needed to pass one basic part in order to pass the exam, i.e. receive mark 3. The basic parts were only marked as pass or fail. Further, in order to receive a higher mark, students could choose to answer additional questions (clearly marked as “for higher grades”). Marks 4 and 5 were then awarded depending on points earned for the more advanced parts. Which kind of knowledge was expected for each course goal, both for passing / basic as well as for higher grades, was clearly communicated to the students at the beginning of the course. Hence, students could adapt their study activities during the course and which questions to answer during the exam depending on their ambition level.

The following table shows an overview of the exam results for all three courses (abbreviated by “C” and C3 being the third course given to the control group) for the autumn semester 2017 and the autumn semester 2018. Note that the exam structure was the same in both academic years but in autumn 2017, all three courses were given with flipped lectures (for the entire class) and tutorials (in large groups of up to 50 students).

Table 1. Exam results

	C1 (2017)	C2 (2017)	C3 (2017)	C1 (2018)	C2 (2018)	C3 (2018)
Pass (tot, %)	21, 36.8%	23, 41.1%	56, 61.5%	22, 45.8%	38, 77.6%	62, 78.5%
Fail (tot, %)	36, 63.2%	36, 58.9%	35, 38.5%	26, 54.2%	11, 22.4%	17, 21.5%
Ave. mark	3.29	3.35	3.7	3.41	3.53	3.22

It is interesting to see that in all three courses (including the control group C3), the pass rate increased. In fact, in course 2 it increased so significantly that further investigation is needed to understand potential other factors, that might have contributed to the result. However, only in C1 and C2 the average mark (only calculated from the pass grades, so excluding the “fail”) increased, which means that not only students grasped the basic concepts better (leading to a higher pass rate) but also did better in the harder parts of the exam, which required higher taxonomy levels (leading to an increase in average grade). This is particularly interesting, as it indicates that the teaching method benefited strong students (getting better marks) and weaker students (helping them to pass). In case the teaching method would have only helped weak students to pass, the average mark should have dropped. Likewise, in case the teaching method would only benefit higher achieving students, the pass rate might even have fallen or remained the same with a higher average mark.

Note that the control group (C3) clearly also benefited in terms of achieving a higher pass rate. However, in contrast to C1 and C2, the average grade dropped from 3.7 to 3.22, i.e. much more than the increase in C1 and C2. This hints on that the method mainly benefited weak students (that only achieved grade 3) or that students achieved less deep knowledge and hence got less points in the more difficult parts for higher grades, which required higher taxonomy levels. Another aspect might be that students in the control group might have been less interested in learning for the course and hence chose to only try to pass the exam. This is particularly interesting as the students in the control group (taking C3) are considered as very ambitious and very knowledgeable (see for example their average pass rate and mark in 2017 in contrast to C1 and C2).

7 SUMMARY

It should be noted that despite the majority of the students in the two programs appreciated the course structure towards the end of the course and acknowledged that they learned a lot, their initial rejection or at least distrust had to be dealt with and overcome. Students complained about the teaching method in different forms and expressed strong discomfort, especially at the beginning of the course. Also, despite the pass rates and average grade improving in both programs, the student rating in the final survey did not improve much. Hence, one conclusion might be that effective SCL and teaching does not guarantee that students appreciate it or feel comfortable.

8 FUTURE QUESTIONS TO INVESTIGATE

- Can students' content be improved by adding some lectures (as requested) without compromising the positive effects of the group teaching mode (such as increased passing grade)?
- Are students in some programs more or less prone to benefit from the small group teaching?
- Will students retain their knowledge achieved through the small group teaching longer?
- Do students improve their metacognitive skills by being forced to be more self-steered and self-organized when using small group teaching?
- Would students respond more positively when being taught with this method in first year, i.e., before being overly used to classical lectures?
- Would students' opinions on this teaching method change when being more used to it, e.g. by being taught in this form also in a subsequent course?

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Expert views on interdisciplinarity in engineering education for design of a new modern University.

T. Stanko
Kazan National Research Technical University named after A.N.Tupolev
Kazan, Russia

E. Chernyshkova
University of Navarra
Pamplona, Spain
Ural State University
Elaterinburg, Russia

O. Zhirosh
Innopolis University
Innopolis, Russia

Conference Key Areas: New Notions of Interdisciplinarity in Engineering Education

Keywords: STEM, engineering education, trends in higher education

ABSTRACT
University education, and particularly engineering education, is currently undergoing intensive change. A number of new universities have been established in recent years to fulfil modern educational model in STEM. Current research effort reports the finding of a recent study commissioned by a private foundation with a goal to establish a new engineering university in Europe. The experts converged on several important components for a new university to be successful: (a) highly personalized educational plan, with an ability to combine completely different modules from STEM, art, history, real-life projects etc.; (b) return to the origin of liberal arts envisioning a university as a bearer of the European humanistic tradition; (c) multidisciplinary education program in complex socio-technical systems with strong emphasis on data science; (d) distributed and cross-border campus and individual adaptive educational scenarios. The findings of this study highlight global trends in higher education affecting most university models and STEM education as a whole.

1. INTRODUCTION

University education, and engineering education in particular, is currently going through the period of intensive change. A number of new universities have been established in recent years to fulfil modern educational model in STEM [1, 2, 3]. Often such new universities are privately funded initiatives. Current research effort reports the finding of a recent study commissioned by a private foundation with a goal to establish a new engineering university in Europe. The purpose of the study was to identify significant global trends in education and to develop recommendations for setting up a model for a next generation university capable of creating an environment sufficiently fertile for the development of an intellectual elite suitable to the modern world. Preference was given to the recommendations relevant to the Minimal Viable Product (MVP) concept.

2. METHODS

The data for the study was collected between November 2017 and March 2018. Three qualitative research methods were utilized in the study: twenty semi structured in-depth interviews were conducted with international experts from academia, business, art and policymakers from EU, USA and Russia.

In this paper we report on the fraction of the study related to the experts' perspective on local and global trends in higher education.

Expert interviews provided an opportunity to get acquainted with the respondents' opinions on three topics: first, to discuss economic and social processes that influence the education system and how the education system in general and higher educational institutions in particular respond to these processes; second, to understand what innovations are developing in modern universities and what new projects and models of activity within these the universities have been successful and why; third, to find out what the respondents think about launching a new, next generation university, what features they consider necessary for success and what key risks they see in this project
During the study, 20 expert interviews were conducted, and a list of experts is provided in Appendix 1.

3. RESULTS AND DISCUSSSION

Current chapter will report the research finding in terms of the expert views on current situation in Higher education, mission of a contemporary university and a vision of a successful university of the nearest 10-15 years.

3.1. Current Situation in Higher Education

The experts believe, that current higher education situation is characterized by intensive competition between universities and between universities and business, massification of higher education with the risk of quality decrease, and a boom of online education as one of the solutions to address the problem of quality maintenance while meeting the increased need of higher education graduates. Other trends, i.e. internationalization, implementation of quality assurance procedures, and life-long learning described as existing trends in e.g. *Trends 2010: A decade of change in European Higher Education* [4], by the respondent of this research were reported as desirable, and as the features of a "future" university, rather than currently observed trends.

3.1.1. Competition escalation

The experts noticed that, globalization of economy, massification of higher education and growing mobility of students and professors all over the world have led to fiercer competition for talent and resources, increases in the level of necessary investment.

The increase in university education costs due to the growth of its scale and increased price of material factors of conducting scientific research puts a lot of pressure on national budgets [5].

«I think that there is a stratification dilemma here, as in the whole world. What will happen — on the one hand, large universities will still exist –elite universities that will respond to certain needs, either intellectual or practical. But here the role of the middle ones, as if becoming the case all over the world (in other spheres), disappears; the middle class — it goes away everywhere. The same thing happens with universities. (…) Polarization and stratification, this is a slightly different topic… Big and small will remain, and the middle-sized ones will go away».

Besides, the respondents of this research report that contemporary universities are forced to compete with large corporations for researchers:

"Many corporations — Facebook, Amazon, Google and other companies of the new economy — are recruiting large groups of researchers who will be involved in exactly the same kind of work they would be doing at universities. Working for these corporations is prestigious, and this work is well paid".

In the experts' view, currently applied tenure system is out of date:

«Some approaches — like the tenure system, for example, in the United States — have been effective before, but have already fulfilled their role and in the current situation hold everyone back»

3.1.2. Massification of higher education and risks for quality

Another characteristic of higher education situation pointed out by the experts, is increased need for higher education degrees for successful performance in jobs. The increasing complexity of production technologies, the rapid development of information technology, the pace of growth in the development and implementation of new products and services in production and daily life all combine to demand recognition of a pressing need for higher education on a global scale than ever existed before [6]. The rapid growth in the number of universities and students has led to a significant variety in the quality of education and the types of university models than those which sufficed in the past.

«In India about 3000 new engineering schools were created in the last 5 years. Proceeding from the fact that the effectiveness of teaching depends directly on the quality of the teaching staff, one can only guess at what this current level of effectiveness is. But nevertheless it speaks about the scale of demand».

3.1.3. Online Boom

Finally, the respondents notice that online technology has increasingly become part of the routine process at universities. Now students can master standard courses online, and time in a classroom can be used more efficiently for discussion and verification of the knowledge obtained.

On the other hand, according to the experts, the development of online technologies raises a serious challenge for traditional «mass» universities:

«Online — for mass universities this means a loss of monopoly on the storage and
transfer of knowledge. And taking into account the fact that a lot of people come to the university for a certain set of competences, and not because they want to become part of the system, the question arises: why should these people continue to go to university? »

Some experts also noted that, as a possible consequence of the diversification of forms of education and the development of online opportunities, the trend of reducing the brand's importance to employers has gained momentum and this trend can become a threat to the most famous universities:

«Education in terms of which university you graduated from begins to play a really small role both for employers and for those projects that you have done, in comparison to what you have really learned. On the one hand, the university as a best owner of a set of received information decreases in its importance, as it has become more or less clear with the development of online education and with the opportunity to receive different knowledge in different locations. On the other hand, the university as a place where you immerse yourself in some community of people, where you are equally inundated amid in all social connections, this does not go away, but overall, I think we are already seeing the diminishing role of the
university as a brand. This is happening in the technological world, probably during the course of the last two years. Resumes of those applicants for high-level positions without a classical education from a leading university, but who rather have a set of on-line and off-line courses (confirmed ones, that's important, they should have some certificates or something like that), are perceived quite receptively… Most likely, if it says that the certificate is from Harvard, it's even better, but difference between brand and non-brand is going away».

Several aspects of positive impact of online learning development are pointed out by the experts. First, I their opinion, the development of mass online education the emergence of quality MOOC (Mass Open Online Courses) provides public a chance to get quality education:

«What I'm witnessing is that there is an increasing development of education based on computers and what is available online. I suppose [this trend] will lead to a serious increase in competition [among universities] Bad education will leave the market. People will prefer to receive an average quality online education rather than a poor quality offline».

Moreover, the availability of MOOCs developed by the world's leading universities has had a significant impact on teaching technologies, and these solutions continue to improve, some experts point out.

«MOOC has a great future that has not been realized yet and it is connected with custom - tailored courses, as when, for instance, a computer can look at you, analyze your facial expression and on that basis offer something slower or faster, or suggest other exercises and tests»

However, among many experts the opinion prevails that MOOCs as such cannot give the student the same versatile training as good universities — first of all, because the personality of the graduate as a researcher or engineer, the bearer of «analytical, practical and creative intelligence» is formed to a decisive degree as the result of intensive interpersonal communication between the student and the professor both in the process of training, and in the process of carrying out research and applied projects. Thus the 'human' aspect is retained, the natural interaction between a mentor and a student maintained as a sort of 'sacred' trust.

«It's not enough just to teach people methods and facts. Students should learn to cover the entire problem mentally, and this cannot be learned without interacting with the person [the teacher]. I do not think that you can teach this — to teach to think — through the computer. It is also important to teach people to ask the right questions [that computers cannot do] ».

«The University still exists because it is sanctified by its formal title, and also because it gathers people into a dense space where they can get acquainted, get into the right environment. But this is all typical for leading universities, relatively speaking, Harvard in the US, the Higher School of Economics in Russia and so on. Therefore, leading universities won't ever have to compete with on-line technology. Because people do not go to Harvard for this».

To summarize, the most noticeable features of current Higher education system according to the respondents of this research are "growing importance of knowledge-led economies" which resulted in higher rate of population participation in Higher Education, increased global competition and online learning boom with its potential risks for the 'mass" universities and potential benefits in terms of quality education accessibility and teaching methods improvement.

3.2. Mission

Describing a university of the future, the experts envision its purpose as being an independent intellectual power body, which provides life-long learning options thus ensuring employability for the population in a long-term prospective.

3.2.1. Independent intellectual power

Independence from the state and involvement in the network is a promising trend to be regarded as essential. Many experts noted that such autonomy represents a vital criterion for the success of the university in the future. Therefore, the University of the Future must be able be an independent center of intellectual power (although at the moment very many strong universities directly depend on the state and its funding, and therefore have no choice but to tolerate its intervention at the management level).

«The university is not merely an institution for training, it is not only a research institute, there should be a broader way of thinking, augmented by the capacity

to entertain and reflect on ideas from any scale, absolutely any scale — it is a very big ambition, and, unfortunately, this kind of thinking is intercepted by corporations, governments, many of whom deny that universities should have ideas, so it is already a struggle for intellectual power.»

In order to ensure a quick start and optimal positioning, it is crucial for any future university with similar missions to what is under discussion here to join, at an early stage, the necessary networks and partner programs with other, preferably well-established and even famous, universities. They must also form strategic alliances with employers that are household names to the public (UN, EU, large companies), as well as establishing cooperation and integration with international organizations such as UNICEF, Habitat, UNESCO.

Experts unanimously recommend avoiding the participation of government officials in the university governance. At the head of a successful university there should be a strong academician with excellent managerial qualities. According to experts, a hierarchical management system often becomes overloaded with levels and boards; a sufficient minimum set is as follows: supervisory board, president, provost (dean) and committees of professors (and students).

Speaking of the mission of universities, experts pay special attention to the importance of the role of leading independent intellectual centers capable of interpreting the global processes of any transformations occurring in society and formulating a «high-level» intellectual agenda for governments and social outcomes.

3.2.2. Life-long learning and employability

The dynamics of the processes taking place in the economy and in society leads to the necessity for a growing number of people to enter (and be adequately qualified for) several professions during the course of their lives. There is a growing need for a variety of forms of education for professionals who have a high level of basic training and considerable professional experience.

«People and students can choose relatively freely among modules and how they want to build their own curriculum and this works especially for guest students who would be accommodated for a year or a year and a half by foundations or organizations within the university when they are there and can pick up whatever they want provided that they have a project. This is the sort of ideal, universal education for the future and it works especially for people who already have 10-15 years of professional experience. It's much more difficult to accomplish in existing universities or in any existing curriculum because they are much more structured».

The experts believe, that university should provide access to advanced-quality higher education not only to a high-school graduate with no or very little professional experience, but also offer everyone concerned the opportunity to improve the skills and obtain the required knowledge of a specialist with many years of experience.

3.3. Vision of a *University of the Future*

Several essential features of “a university of the future” were listed by the respondents of this research. It is worth noting that some features e.g. internationalization, quality assurance that are being recognized by other research as exiting well established trends are reported by the experts as developing and desirable.

3.3.1. Ecosystem

The volume of applied research in the field of innovations carried out by the forces of distributed teams whose members interact through networks is growing in the world. The success of research universities — the elite among higher education — will in future depend on whether they can be important or central links in innovation ecosystems [7].

> *«The leading group of 300-400 universities in the world will be trying their best to build up and retain leadership competencies in research, with regard to their practical application; so they will attempt to occupy and represent the center of ecosystems (innovations). For example, KU Leuven, MIT, Stanford — these are universities that do not exist separately but are an important part of [such] ecosystems. I believe Cornell University in this sense is doomed. Cambridge built an ecosystem around itself, and Oxford most likely did not»*

The «ecosystem» principle of organizing and conducting research and applied developments provides a chance to join the league of research universities successfully even for small institutions of higher education. For them it is important to occupy a certain niche in the ecosystem of innovations, to secure a leading place in any of the links. The rest of necessary knowledge and educational opportunities can be obtained from other elements of the system in the process of «symbiotic exchange» between the elements of the ecosystem.

> «*Nowadays, knowledge and competence can be at the intersection of field A and field B. It is possible and absolutely real, even if these fields A and B do not exist in one university — it can be in a distributed structure. This is a huge trend that I see»*

Because of the dynamic nature of the processes in universities, which reflects the growing pace of changes in the economy and public life, an increasing number of professors and researchers start work on temporary contracts. This is in contrast to the almost lifelong guaranteed employment for university academics.

3.3.2. Balancing research and teaching and quality management

Experts point out the risk that the excessive focus of attention of the faculty on research may reduce their inclination to work with the students and therefore lead to a decrease in the quality of education [8].

> *«The public wants to know that their primary concern is opening doors, creating opportunities for their children. This is primary. Research is important but it’s not a fundamental mission of what education should be about. Higher education is full of elite academics who have tenure, who don’t care about their students and*

who care about only publishing ideas in journals. They are all about the money and they're not doing a good job with our kids. There's a quote from a Senator in the US who says it very succinctly, he says: 'Higher education costs too much and delivers too little, it has to change'. That's the sentiment».

3.3.3. Internationalization

The globalization of economic life requires successful universities to be international in terms of the composition of university professors, students, and governing bodies. To succeed in competition for resources and international students (a source of income and prestige), a university must build an international community, attract strong professors and experts from all over the world, and be the focus of international intellectual life on the territory of their country.

«They (leading universities) understand that they need to be, not national, but global, in terms of both the student body and the body of professors serving them, and, further, in the system of management directing the process. This is because if you are not international, you cannot master certain types of knowledge — humanitarian and political, for example, and so you should have such a structure intrinsically. This is not an easy trend considering nationalism, Trump, etc. …. the Chinese are taking steps in this direction, but this remains a problematic trend, this is not just black and white»

3.3.4. Interdisciplinarity

Many experts draw attention to the fact that it is difficult for traditional universities with a conservative structure to overcome the inertia of the traditions of the last century, when the training was much more specialized and included a fairly rigid set of interrelated courses on specific topics.

«Most universities are a loose association of departments and chairs. Even the chairs within the department are very autonomous and interact with each other poorly. Interfaculty interaction basically comes down to administrative issues coordination, and not on teaching goals and strategies. In most universities, there is little real interdisciplinary education»

An example of a successful interdisciplinary program that is popular with students is the joint Bachelor of Science (hard sciences) and social sciences combination in Paris Sciences Po and UPMC.

«Students spend their 1st and 2nd years studying in Paris, and they take courses simultaneously at Sciences Po and UPMC. That is, they alternately enroll in the social sciences and humanities and in natural sciences. They literally, run between the two buildings. Sciences Po offers economics, modern history, political science and sociology, UPMC — biology, chemistry, computer science, mathematics and physics. During the second year of study, they choose minor — math — computer science, chemistry — biology or math — physics, while continuing to study the humanities and to work towards a social science major».

The experts noted the growing demand for higher education generalism — the formation among students of a broad and deep view of modern world problems, which will allow them to engage later on in private aspects of research and applied projects, thus preserving the vision of the overall perspective and global context of these projects

«The goal is to teach students to simultaneously understand and speak two languages —natural sciences (addressing various topics and issues) and social sciences. According to the organizers of the program, it is acquaintance with both that will allow students to adapt to the complex world of modern society. The program will give them skills that are useful for working in many industries: 1) they will learn the basic concepts of social sciences and the humanities; 2) they will be able to evaluate the arguments critically, being familiar their historical, economic, cultural and political context; 3) they will be able to combine arguments from two radically different paradigms — natural and social sciences; 4) build a system of argumentation, using knowledge from different disciplines.»

«I believe that in our time it is very important to reaffirm the traditional goal — that the university is the bearer of the European humanistic tradition, to recognize the importance of the breadth of education along with the specialization and focus on the global intellectual progress of society».

«The concept of universality is even more important today than it was in the past, and the first two decades of the 21st century has witnessed a change in our understanding of the world we inhabit. We have come to see the fundamental pervasive importance of networks — of people, communities, devices, organisms, physical processes — where the elements of the network not only influence the dynamic of the network, but the network dynamics influence at a very deep level the behavior of the elements. This shift in understanding contrasts conventional control and hierarchical organization with self-organizing system dynamics. Specialization is still essential to understand and model the subject of interest, but system complexity matters more, especially when we go beyond pure science, engineering, and technology».

3.3.5. Personalization and accessibility of education

Almost all experts believe that personalization of education is the leading trend in the development of higher education and in the future will become an important criterion for the success of any educational project. The expert opinion correlates well with Gallup research Group [9], where the main criterion for the success of higher education from the standpoint of graduates is the level of attention paid by professors to the students as individuals. On the one hand, online technologies have expanded the possibilities for universities, especially for small ones, allowing the creation of diverse educational programs. It is sufficient for the university to have specialists only in some subjects of the curriculum, and for other subjects to teach students online.

«They [ASU, Arizona State University, the largest university in the US, and NTU, Nanyang University of Technology in Singapore, a young university that is growing very fast in rankings] pay close attention to distance learning opportunities in online programs, the opportunity to deliver knowledge to a

person no matter where he is located. I think this is a very important trend. In this respect, a successful university of the future must be able to provide such an opportunity, for example — if we take the educational trajectory of a person that includes some knowledge of X, Y and Z, and only the field of knowledge X is taught at this university, it is necessary to help him to acquire knowledge in areas Y and Z».

3.3.6. Distributed campus

For launching international programs, the experts recommend using the distributed campus at the beginning of the project, where there is a physical building downtown with all the advantages of city life, and in addition a country pavilion, then possibly campuses in other cities of the world (thus a cross-border campus). Experts recommend not buying / constructing a campus but renting facilities. In a city where the main campus is located, there should be a high concentration of intellectual capital and a vibrant economy that provides job opportunities for graduates.

3.3.7. IT and Big Data

The spread of information technologies has led to a huge demand for training specialists, carrying out a large volume of applied research and implementing a growing number of applied projects on this topic.

«So without a doubt, the thing that will be most in demand for next 5 years is going to be data science and knowledge about how to develop new applications, creating value or innovations in all areas, not only in technical but also in the improvement of customer service to the citizens of the city. Banks are using it, so now big bankers massively downsize people, replacing them with computers instead. It is the biggest trend»

Working with «big data» has become an integral part of an increasing number of research and business areas. Knowledge and skills in this area are now virtually prerequisite for a specialist of any profile, they have gradually become an obligatory component of all educational programs.

«Big data for the foreseeable future is going to be very important in every field, given the massive amount of computer capacity that is now available. Humanities, social science, all areas of medicine, law, you name it, they all are using big data and of course marketing, banks — everybody out there is using big data, trying to figure out who their customers are, how best to get at them. Or looking back as a proactive exercise and, just to give a random example, doing analysis of some 19th century author and saying: «Oh, here is the phrase he used over and over again, this must have been important to him».

3.3.8. Humanities

Many experts agreed that in a world that is getting more and more complicated, university education should shape thinking in a broad sense, orient people towards the solution of the global issues that humanity faces. Extensive basic knowledge in different disciplines should be combined naturally with a deep expertise in concrete

subjects. A professional of the future should possess balanced knowledge and skills both in humanities and technical fields.
A number of experts believe that in the foreseeable future (albeit without an exact indication of when this may happen) the university system can expect a kind of «humanitarian renaissance» — an increase in demand for programs in social sciences and humanities. This is due to the need to study and manage complex systems that are socio-technical by their nature and a growing demand for soft skills and critical thinking, along with the increasing need of people to find their place in a world of robots and virtual reality.

> *«To continue teaching as actively as before in the fields where a human being can be replaced completely or for the most part by a computer, is senseless enough. We cannot fight with artificial intelligence and its computing power, it will be an ineffective investment of our energy, whereas it will, by contrast, be more effective to invest in areas where machines cannot replace us yet. That sphere is really more connected with liberal arts, with various soft skills and patterns of academic endeavor, and this is more connected with the humanitarian part».*

> *«Without qualitative humanitarian knowledge, it will be impossible to live meaningfully in the future, because, on the one hand, these soft skills which employers are talking about are precisely those which graduates are lacking, and so future graduates must emerge from the universities having been brought up in the field of humanitarian education and joint project activities. On the other hand, there are growing problems of self-awareness in the domain of robots, in a world where professions that were well-known to human beings have radically changed over the past 10-15 years; therefore, people will need deeper social and psychological awareness, as well as various other insights into the grand scope of humanitarian knowledge.»*

Hence a niche research university as an MVP-model, based on the experts' recommendations: With limited resources to launch the university, experts lean towards a model of a small university with a pronounced individual approach and a healthy, fruitful interdisciplinary environment for the work of researchers. The number of professors is small enough for sustainable life and development of the university (60-80 people), with no more than a 10 students per professor ratio. Education and research are concentrated around 4-5 majors, which work well at the junction with each other. For example, sociology / economics / IT, sociology / mathematics / IT. Practically all experts unanimously advise to include methods of working with big data both into the research agenda and in the academic program for all fields.

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Appendix 1. The list of respondents of in-depth interviews.

MATS NORDLUND has a background of executive positions in academia and industry in Europe, USA, and Russia. He spent 15 years in industry, first as director of corporate technology strategy and acquisition at Saab AB, a major aerospace company, and later as Director of Research and Development for Emerson Process Management — Level and Marine. In his academic career, Dr. Nordlund recently served three years as Vice President of Research Programs at Skoltech, a new university being established in Moscow in partnership with MIT. In the 1990s, he launched and managed the System Design and Management (SDM) program at MIT. Dr. Nordlund has also served on several national and international (EU) panels in innovation and research and as an industry member on Chalmers' Mechanical Engineering Program's Advisory board.

MAURIZIO SOBRERO is Full Professor of Innovation Management at the University of Bologna. He is a member of the Production and Operations Management Society. From 2000 to 2007 he was the Coordinator of the PhD program in Business Administration at the University. He has published 5 books and over 20 articles on the economy and international innovation management. He has taught in many programs for executives in South America, China and several European countries. In 2005 he was invited to contribute to the United Nations World Investment Report. He has done consulting for various companies and institutions. He is a member of the Board of Directors of the Zignago Vetro SpA where he oversees the Committee for Internal Control. He received his PhD in Management of Technology and Innovation at MIT (Massachusetts, USA).

DR. RUSSELL C. JONES has been a leader in several organizations; he has served as the Dean of Engineering at the University of Massachusetts, the Chairman of Civil Engineering at Ohio State University, Academic Vice President at Boston University, and President of the University of Delaware. He also published the International Engineering Education Digest for several years, with a distribution of 70,000 readers worldwide. In addition to his accomplishments within higher education, Dr. Jones has a long history within various engineering societies. He was the president of the American Society of Civil Engineers (ASCE), president of the Accreditation Board for Engineering and Technology, as well as the Executive Director of the National Society of Professional Engineers. In 1998, Dr. Jones founded World Expertise LLC, a focused consulting company serving clients in higher education as they developed new programs and institutions.

DAVID VERNON is a Professor of cognitive robotics and computer vision at Carnegie Mellon University, Rwanda. Over the past 35+ years, he has held positions at Westinghouse Electric, Trinity College Dublin, European Commission, National University of Ireland, Maynooth, Science Foundation Ireland, Khalifa University, University of Genoa, Technical University of Munich, and University of Skoevde. He is a Senior Member of the IEEE, a Chartered Engineer of the Institution of Engineers of Ireland, and a past Fellow of Trinity College Dublin. He is co-chair of the IEEE Robotics and Automation Technical Committee for Cognitive Robotics. BA, BAI Engineering, Trinity College Dublin PhD Computer Science, Trinity College Dublin

RICHARD K. MILLER has been President and first employee of Olin College of Engineering since 1999. Previously, he served as Dean of Engineering at the University of Iowa, Associate Dean of Engineering at USC in Los Angeles, and assistant professor of engineering at UCSB in Santa Barbara. With a background in applied mechanics and current interests in innovation in higher education, Miller is the author of more than 100 reviewed journal articles and other technical publications. He received the 2017 Brock International Prize in Education for his many contributions to the reinvention of engineering education in the 21st century. Together with two Olin colleagues, he received the 2013 Bernard M. Gordon Prize from the U. S. National Academy of Engineering (NAE) for Innovation in Engineering and Technology Education. Recently elected to the American Academy of Arts and Sciences, he is a member of both the NAE and the National Academy of Inventors. In 2011, he received the Marlowe Award for creative and distinguished administrative leadership from the American Society for Engineering Education. Miller currently serves as Chair of the National Academies Board on Higher Education and Workforce (BHEW). He has served as Chair of the Engineering Advisory

Committee of the U. S. National Science Foundation and has also served on advisory boards and committees for Harvard University, Stanford University, the NAE, NAS, and the U. S. Military Academy at West Point in addition to others. Furthermore, he has served as a consultant to the World Bank in the establishment of new universities in developing countries. A frequent speaker on engineering education, he received the 2002 Distinguished Engineering Alumnus Award from the University of California at Davis, where he earned his B. S. He earned his M. S. from MIT and Ph.D. from the California Institute of Technology, where he received the 2014 Caltech Distinguished Alumni Award.

JENS CHRISTIAN GODSKESEN is a Provost at IT University of Copenhagen, the youngest University in Denmark.

ANDREAS FRIJDAL is an ex head of the European University Institute, having 29 years of service. He has been head of Academic Services for the last 25 of those years. Frijdal came to the EUI from Brussels in 1985 as a research officer. The Academic Service calculates that under his watch, more than 3000 researchers have passed through the Institute.

OLEG KHARKHORDIN was a rector of the European University in St. Petersburg (EUSP) from 2009 to June 2017. He worked as a research fellow at the Center for International Studies at Harvard University (1996-1998), a visiting professor at the Political Science Department of Yale (2002) and Harvard (2002-2003),and at the Institute for Political Studies in Paris (2005, 2006, 2008). Being the dean of the Faculty of Political Science and Sociology of the EUSP (1998-2001), he founded the International Master's Program in Russian Studies (IMARS). He is the founder of the Inter-Department Research Center Res Publica. Thanks to his efforts, the first endowment fund in St. Petersburg (and the second in Russia) was registered in the EUSP.

JONATHAN FANTON has been President of the American Academy of Arts and Sciences since 2014. Previously, he served as the president of the John D. and Catherine T. MacArthur Foundation from 1999 to 2009 and as the president of The New School for Social Research from 1982 to 1999. In addition to his leadership of these organizations, he has served as board chair for several organizations, including Human Rights Watch, the Security Council Report, and the New York State Commission on Independent Colleges and Universities. He currently serves on the boards of Scholars At Risk, the Asian Cultural Council, and the Benjamin Franklin House, and he chairs the advisory board of the Newman's Own Foundation. Dr. Fanton was elected a fellow of the American Academy in 1999.

NICOLAS BUCHOUD is a leading French urban development and sustainable metropolitan systems expert. He has recently been involved in large scale metropolitan projects such as Le Grand Paris or the Greater Moscow, working on contemporary urban challenges from Vancouver to Vladivostok, Paris to Bandun. He has a long standing and high level European and international experience in complex urban development strategies and negotiations, crossing urban regeneration and urban innovation, including civil society involvement in complex decision making processes. He graduated in public law and political science (MA), planning and urban development (MA), and Chinese history (MA), from Sciences Po and La Sorbonne.

SERGEY GURIEV is a chief economist at the European Bank for Reconstruction and Development. He is a professor of economics at the Instituts d'études politiques in Paris (Sciences Po). He was a Morgan Stanley Professor of Economics and a Rector at the New Economic School (NES) in Moscow until he resigned on 30 April 2013 andmoved to France. He joined NES in 1998 and became the school's Rector in 2004. He graduated Summa Cum Laude from Moscow Institute of Physics and Technologyand received his PhD in Applied Mathematics from The Russian Academy of Sciences. In 1997-98, he visited the Department of Economics at MIT for a one-year post-doctoral placement. In 2002 he received a degree of Doctor of Science in Economics. In 2003-2004 he was a Visiting Assistant Professor at the Department of Economics at Princeton University.

HENRY ROSOVSKY is an economic historian and Harvard University administrator. In 1973-84 and 1990-91 he served as the Dean of the Faculty of Arts and Sciences at Harvard, where he was previously a Professor of Economics and chair of its Department

of Economics. He also served as Acting President of Harvard in 1984-87 and holds the Geyser University Professorship Emeritus. After stepping down from the dean's position, in 1985, he became a member of Harvard's governing body, the Harvard Corporation, until 1997, the first Harvard faculty member to do so in a century. In 1981, he received the Encyclopædia Britannica Achievement in Life Award for Achievement in Education and, in 1992, the Clark Kerr Medal for service to Higher Education from the University of
California at Berkeley. in 1984 the French government made him a Chevalier of the Legion of Honor; in 1988 he was awarded the Order of the Sacred Treasure (Star) by the Government of Japan.

MARK SHMULEVICH has been the Chief Strategy & Operations Officer of Acronis, Inc. since 2014 and served as its Chief Strategy Officer. Mr. Shmulevich is responsible for strategic and technical development, improving management of the R&D segment and
strengthening ties with universities and research centers. He is simultaneously becoming a partner in the QWave Capital venture fund. Previously he was deputy communications and mass media minister. He was in charge of the IT sector at the Communications and Mass Media Ministry.

VELJKO VUJAčIć is Provost of the European University at St. Petersburg and Professor of Sociology at Oberlin College. Professor Vujačić's fields of specialization include sociological theory, political sociology and comparative-historical sociology, with a special focus on communism and nationalism in the Soviet Union and Yugoslavia. PhD'95, UC Berkley

DENIS KONANCHUK is an Associate Dean for Academic Affairs, Moscow School of Management Skolkovo. He was directly involvedin the development of the roadmap for the North (Arctic) Federal University in Arkhangelsk. He developed a concept and launching and development program for Ural Federal University, Yekaterinburg; Concept of the International Olympic University, Sochi.

MARIA YUDKEVICH — Vice-Rector, Director of the Center of Institutional studies, Associate Professor of the Applied Economics Chair, Economics department; Laboratory Head of the International Laboratory of Institutional Analysis of Economic Reforms; Member of the Research board. She is the author of articles at such magazines as Issues of Education, Issues of Economics, Research in Higher Education, Studies in Higher Education.» European Educational Research Journal», «International Journal of Educational Development».

ANDREI VOLKOV, Academic Policy Advisor, Moscow School of Management Skolkovo. Vice-Chairman of the International Council of the Academic Excellence Project. He graduated from Moscow State Institute of Engineering and Physics. From 1984 to 1991
was a research fellow at the Scientific-research institute of Nuclear reactors.

RUBEN VARDANYAN is a Russian social entrepreneur, manager and philanthropist, cofounder of the Aurora Humanitarian Initiative, founding partner of Moscow School of Management SKOLKOVO and its first president (2006–2011), founder of UWC DilijanCollege in Armenia, founder and chairman of the board of directors of PHILIN (Philanthropy Infrastructure), founder and partner of Phoenix Advisors, former CEO and controlling shareholder of Troika Dialog, an investment bank (1992–2012).

SVETLANA VELIKANOVA is a co-founder and CEO of Harbour. Space, private university in Barcelona, Spain.

SHLOMO WEBER is an economics professor and Rector, New Economic School in Moscow, Russia; Academic Director, Center for Study of Diversity and Social Interactions, New Economic School Moscow; Robert H. and Nancy Dedman Trustee Professor of Economics Department of Economics, Southern Methodist University.

Laboratory learning:

Influence of the perceived laboratory mode on learning outcomes

Fabian Steger[1,a,b]
Alexander Arbesmeier[c]
Alexander Nitsche[b]
Katja Brade[b]
Hans-Georg Schweiger[b]
Iouri Belski[a]
[a] Royal Melbourne Institute of Technology, Melbourne, Australia
[b] Technische Hochschule Ingolstadt, Ingolstadt, Germany
[c] University of Vienna, Vienna, Austria

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ABSTRACT

This paper presents the results of the second phase of a study that investigated differences in learning outcomes of university students who conducted laboratory experiments in two different modes in the local domain: hands-on and simulated. In order to keep constant as many variables as possible (such as experimental approach, learning objectives and tests, supervision, teaching materials), a crossover study approach was deployed. During the first phase of the study, it was found that there were statistically significant differences in learning outcomes of 102 study participants, favouring the hands-on mode. Since laboratory experiments in both modes were created to be very similar, the reason for this difference needed clarification. It was hypothesised that the difference in learning outcomes originated from different perceptions on the efficacy of hands-on and simulated experiments. In order to check this hypothesis, a modified second phase of the study with 113 subjects was conducted. This time, in order to ensure that the mode of a laboratory experiment will not be an influencing factor, all participants used hands-on equipment for laboratory experiments. Subjects from one group actually used hands-on equipment. Subject from the other group only thought that they are conducting hands-on experiments. In fact, their equipment was ‘modified’ to display the results of simulated experiments. The outcomes of the second phase of the study supported the ‘perception’ hypothesis. No statistically significant differences in learning outcomes of the subjects from the second phase of the experiment were discovered.

[1] Corresponding Author: F. Steger, sefi_pub@fabian-steger.de

1 INTRODUCTION

To optimise outcomes of student learning and to develop valuable skills for future employment, engineering courses often complement lectures with laboratory classes [1]-[4]. A combination of theoretical learning with laboratory experiments is of particular importance at German universities of applied sciences that aim for practice-guided learning [5].

The goal of implementing laboratories is to meet various learning objectives (such as instrumentation, experimental approaches, data analysis, safety and teamwork). Sometimes these objectives are not clearly formulated at the early stages of laboratory development [6]. Over the years, the efficacy of laboratory modes and advantages of different laboratory modes for teaching in general and for teaching engineering students in particular was discussed broadly [4], [7]. However, many studies in this field did not use strong methodological approaches, and therefore, it is difficult to attribute results of these studies to the influence of laboratory modes alone [4]. The goal of this study was therefore to compare laboratory modes of a battery basics course while keeping constant as many influencing factors as possible.

The present research focused on two modes in the local domain. In-person *hands-on* laboratories allow students to directly interact with the subject at hand and check the equipment even though this interaction might be mediated through technology or a user interface. In an in-person *simulated* laboratory, on the other hand, all of the students' interactions are moderated through a user interface, including procedures by which they create their understanding of the experimental hardware. Properties of the investigated effect or sample are simulated by computer software. Commonly, students work in a classroom equipped with computers on which simulations are running. With increasing complexity in teaching practical engineering skills via laboratories, borders between these modes often become blurry. Therefore, the perceived laboratory condition is also of interest when comparing laboratory modes.

In 2005, Euan D. Lindsay published results on perceived laboratory learning. Experiments were conducted in three perceived modes. Firstly, hands-on experiments in the local domain. Secondly, simulated experiments in the local domain. And thirdly, remote experiments (physically present experiments in the next room). The user interface was the same as for remote and simulated experiments. Technically, students calibrated a piezoelectric accelerometer using a laser-Doppler and a spectrum analyser. It was attempted to make the remote and simulated laboratory conditions as similar as possible. For example, in one of the experiments, the simulation group heard recorded sound from a real experiment, while the remote group heard sound from the actual experiment. Both the remote and the simulation group conducted the experiment from the same room. While checking the lab reports, Lindsay observed that the laboratory mode (hands-on, remote or simulated) influenced learning outcomes. The distance between students and equipment made the remote and the simulation groups more reflective since the two groups did better at noticing and adapting to unexpected results than the hands-on group. The learning outcomes from the remote group and the simulation group, which had almost identical experiences, were not equal either. The simulation group paid more attention to the theory behind the experiment, and less attention to hardware and how it influenced the experiment. Lindsay noticed that the focus of students changed, because they knew that they were not using real hardware. He concluded that the students' attitude towards the laboratory was the deciding factor that affected the learning outcomes. [8]

While simulated experiments have become popular for conducting laboratory exercises in tertiary education due to obvious reasons (among others, repeatability and cost efficiency) [7], this study focuses on differences in learning outcomes of students by comparing hands-on and simulated laboratories. Moreover, simulations, which were framed as hands-on experiments, were used. This so-called *hidden simulation* condition was the final step in equalizing hands-on and simulated laboratories. It was added to determine whether or not there are any significant differences between these two modes if laboratory conditions itself are indistinguishable.

2 METHODOLOGY

This study was conducted in two consecutive phases. Study runs of both phases were carried out in local access domain. The objective of the first phase was to compare student learning through hands-on laboratories with that from simulated laboratories. Phase two was conceptualised to verify the quality of simulations used in phase one and at the same time give insight into possible subjective influences of the laboratory mode itself by comparing results of hands-on laboratories with laboratories in which hidden simulations were conducted.

As this study focused solely on comparing different learning modes, all other aspects such as accompanying lectures, experimental instructions, teachers, learning objectives, tests, working teams, and many more were held constant for compared conditions [9]. If improvements were possible in one of the modes (e.g. time-lapse in simulations), lessons were not optimised. Thus, this study does not determine which of the investigated laboratory modes has the potential to be the best to teach battery behaviours, but whether or not there are significant differences between hands-on and simulated laboratories when the same experiment is conducted. Also, a remote laboratory condition was not included in the comparison as this study solely compared in-person laboratory teaching with/without proper laboratory equipment in the local domain. Methodologies of both study phases are described in more detail below.

2.1 Laboratories, experiments, and instructions

Laboratories were part of different courses on battery basics designed for engineering students. Laboratory experiments on energy storages/lithium-ion batteries [10] were developed for all laboratory modes. Experimental procedures were created so that each step (e.g. discharging the battery to reach a specific state of charge) was the same in all modes. Thus, it was possible to use the same set of written instructions for all modes. The instructions included preliminary questions, guidelines for the experiments, and advice on analysis and collection of data.

Each session was executed as follows. After meeting in the laboratory (hands-on/hidden simulations) or at the computer pool (simulations), the experiment was introduced. Students connected the prepared cell to the device and opened the graphical user interface (hands-on) or started the simulation, using the same GUI (simulated) [9].

Parameters of battery cells during simulations and hands-on experiments were displayed on the computer screen as graphs and values. Hidden simulations laboratories were equipped with modified devices that additionally displayed the momentary/simulated values of current and voltage.

All student teams worked autonomously in a supervised environment, following written instructions. To start an experiment, students defined current and voltage sequences for each measurement. All laboratory experiments consisted of a series of measurements to collect data (current, voltage, and temperature over time) which were evaluated before the next measurement or at home to produce the requested conclusions and graphs (e.g. internal resistance over the state of charge).

All learning objectives could be met by following the experimental procedure/instructions without any further help from the instructor. The same teacher supervised all laboratories. Since the study at hand focused on a strict methodological approach, a remote laboratory condition could not be included, even though many students favour online education [4], [7]. Also, it was found that it might be difficult for students to differentiate clearly between remote and simulated labs [11].

2.2 Methodology to compare laboratory conditions

In order to minimise the influence of various disturbing factors, an in-subject counterbalanced methodology similar to a crossover trial was implemented [12]: Participants were divided into two groups. Both groups had the same learning objectives, which were clustered around either two or four content areas depending on the study run, as shown in *Table 1.* Each group was divided into teams of three to five students who conducted all laboratory experiments together. [9]

Each group worked on content areas in the same order but switched laboratory condition between sessions. The first group conducted even experiments in experimental condition A while the second group conducted the same experiments in experimental condition B. For odd experiments, groups switched the respective conditions.

To assess the influence of laboratory modes on knowledge acquisition, a 10-minute test was held approximately two weeks after each laboratory session. The study was fully anonymous, and participants did not receive incentives for taking part.

TABLE 1: STUDY RUNS

Study Run	Students	Female	Background	CA	Semester of Studies
RA1 Electric Mobility (B. Eng.) 2016	40	5%	German	4	4
RA2 Electric Mobility (B. Eng.) 2017	30	13%	German	4	4
RA3 International Summer School 2017	32	12%	International	2	3-9
RB1 Electric Mobility (B. Eng.) 2018	29	10%	German	4	4
RB2 International Summer School 2018	39	9%	International	2	3-9
RB3 Renew. Energy Syst. (M. Sc.) 2018	45	13%	International	2	8
All Study Runs	215	<11%			

RA1-RA3: hands-on vs. simulations RB1-RB3: hands-on vs. hidden simulations

CA 2: (B*) open-circuit voltage, and (C*) internal resistance and power, 2:00 h each.

CA 4: (A) contact and isolation resistance, (B), (C), and (D) energy of cells, 2:50 h each.

2.3 First Phase: Hands-on vs. Simulation

As shown in *Table 1,* the first phase was carried out between 2016 and 2017 in three study runs (RA1 to RA3). 2nd year electric mobility bachelor students were instructed in German (RA1, RA2), participants of the other run because of a variety of backgrounds in English (RB3). The educational research was explained to the participants during the first session in detail. Due to meeting in differing rooms (laboratory vs. computer pool) and due to the absence/presence of measurement devices and batteries, students were always aware of the experimental condition.

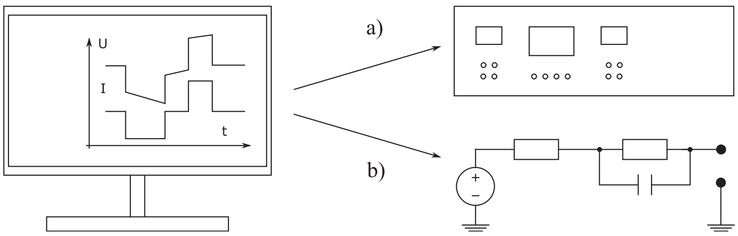

Fig. 1. Hands-on devices (a) as well as simulation models (b) were controlled by the same graphical user interface.

For the simulated experiments, a black-box simulation model that imitated hands-on battery behaviour was designed and calibrated (*Fig. 1*).

2.4 Second Phase: Hands-on vs. Hidden Simulation

Phase two followed the same concept. Here, influences of the perceived learning mode were investigated by comparing *hidden simulations* (framed hands-on) to real hands-on experiments. This experiment was performed in three study runs in 2018 (RB1-RB3), as shown in *Table 1.*

This time, participants used hands-on equipment in laboratory environment in both conditions. In the hands-on condition, real measurements were shown. In the hidden simulations condition, results of simulated battery behaviour were displayed. Participants of hidden simulations were presented with data calculated by the same simulation model as in the first study phase. To flawlessly imitate the hands-on condition, the output was not only shown on the computer screen but additionally displayed on the measurement devices (ref. *Fig. 2*).

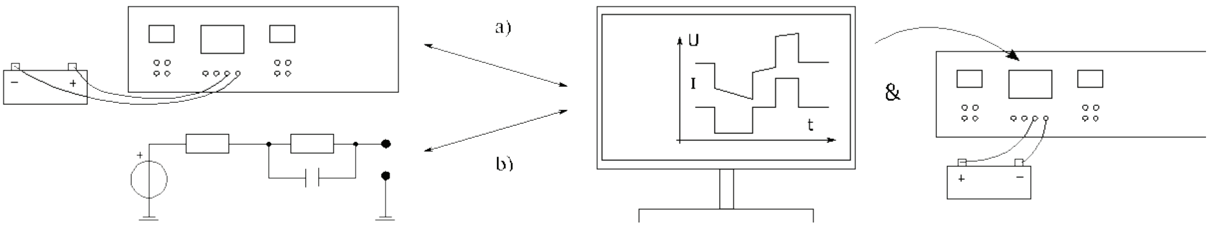

Fig. 2. (a) The hands-on device (with a real battery cell) or (b) with "hidden simulations" the simulation model was controlled by students, using the same graphical user interface. The results are displayed on the GUI and the test bench's displays while a battery cell is actually connected to the equipment. In that way in case of b) the students are not aware that they use simulations.

Participants were again aware of the ongoing engineering education study hands-on vs. simulations. However, this time, students were not aware of differences in data sources during their technical experiments: All students were given the *impression* that they were part of a *hands-on control group* for the full semester and therefore thought they all worked in the hands-on condition.

Fig. 3. Laboratory environment during hands-on experiments in the first phase and during hidden simulation as well as hands-on experiments in the second phase.

A lot of effort was spent on arranging these laboratories. Simulations (model, parameters) stayed the same as in previous runs, but computer-software and device-firmware [10] were extended to show simulation results in real-time on the device displays. A battery was connected, but no actual current was applied. Even the open/close sounds of the attached safety box were triggered. For a visitor it would not have been possible to distinguish the hidden simulation setups from hands-on setups when entering the laboratory or to determine that a comparison of lab conditions was running (ref. *Fig. 3*).

3 RESULTS

In all runs, participants' test results indicated reasonable knowledge retention with mean test scores ranging from 36% to 67%. In order to account for different group sizes and to exclude a potential influence of differences in difficulties of the content areas, data transformation was used. The difference between a student's individual scored percentage and mean percentage of all participants in the same test (e.g. mean result of all students of RA1 in content area A) was calculated and divided by the standard deviation of the respective content area from that run. This method is called Studentization [13], and its result is considered the *student's performance* in a single test. A value above zero indicated that the student's performance was above average, a value below zero a below-average performance.

In order to determine which laboratory mode produced better learning outcomes, the averages of all students' test performances in the two experimental conditions hands-on and simulated were compared using an independent-sample t-test.

3.1 Results First Phase: Hands-on vs. Simulation

In total, 102 students participated in the first phase. In each individual study run students' test scores after hands-on exercises outperformed those after simulations (see *Table 2*).

Mean student performance after hands-on laboratories significantly exceeded mean student performance after simulation in the German runs (RA1-RA2, $t(261) = 2.40$, $p = .018$, Cohen's $d = .29$). In RA3, which was an international summer school, even though no significant effect was found, the mean and effect size point towards the same direction as do the German runs.

Overall results showed statistically significant differences in the learning outcomes favouring the hands-on condition (RA1-RA3, $t(317) = 2.45$, $p = .015$, Cohen's $d = .27$).

TABLE 2: FIRST PHASE: STUDENT'S TEST PERFORMANCE: COMPARISON OF EXPERIMENTAL CONDITIONS

	Hands-on			Simulated							
Study run	Tests	M	SD	Tests	M	SD	df	t		p	d
RA1 B. Eng.	73	.12	.96	75	-.11	1.01	146	1.42		.158	.23
RA2 B. Eng.	58	.18	.83	57	-.18	1.10	113	2.01	*	.048	.37
RA3 Summer	28	.09	.94	28	-.09	1.05	54	0.65		.521	.17
RA1,2 Ger.	131	.15	.90	132	-.14	1.05	261	2.40	*	.018	.29
All	159	.13	.91	160	-.13	1.05	317	2.45	*	.015	.27

* = $p < .05$ d = Cohen's d (pos. = adv. of hands-on)

Since all lab modes were created to be very similar, the reason for these differences was unclear. The influence of the perceived laboratory mode was assumed to be major influencing factor.

3.2 Results Second Phase: Hands-on vs. Hidden Simulation

In total, 113 students participated in the second phase. *Table 3* shows the comparison of student's performances after real hands-on experiments with performances after hidden simulations (presented as hands-on experiments). None of the study runs (individual or in sum) showed a significant difference. Results of RB1 even showed a trend towards advantages of hidden simulations.

TABLE 3: SECOND PHASE: STUDENT'S TEST PERFORMANCE: COMPARISON OF EXPERIMENTAL CONDITIONS

	real hands-on			hidden simulations							
Study run	Tests	M	SD	Tests	M	SD	df	t		p	d
RB1 B. Eng.	55	-.16	.98	56	.16	.98	109	-1.74	†	.085	-.33
RB2 Summer	19	.02	.92	19	-.02	1.08	36	.09		.930	.03
RB3 M. Sc.	33	-.02	1.00	33	.02	1.00	64	-.13		.896	-.03
RB2,3 int.	52	-.01	.96	52	.01	1.02	102	-.05		.959	-.01
All	107	-.09	.97	108	.09	1.00	213	-1.28		.203	-.17

† = $p < .10$ d = Cohen's d (pos. = adv. of real hands-on)

4 DISCUSSION

Results of the first phase suggest that traditional hands-on experiments lead to better learning outcomes compared to simulations when teaching battery basics. This result was unexpected since hands-on experiments were conducted very similarly to simulated laboratories. The simulation model was devised by battery experts in order to imitate battery behaviour in the most realistic way. No perceived differences in battery behaviour were found in the students' protocols. The obtained result is contrary to the recent surge of studies reporting better or equal learning with non-traditional (virtual/simulated) labs [4], [7].

Nevertheless, hidden weaknesses of the simulation model could not be excluded completely. These could have influenced students' learning negatively. To validate the simulation model and assess the role of the perceived laboratory mode, the usage of simulations was framed as hands-on experiments and compared to results of hands-on laboratories in the second test phase. Here, no significant differences in learning outcomes of participants were found, suggesting that the simulations used worked as they should and the differences between the two conditions hands-on and simulated of phase one can be attributed to the perceived laboratory mode.

Lindsay's study (2005) evaluating lab-protocols delivered insight in the student's change of attitude depending on the laboratory mode the experiments were held in. The present research differs, as it focused on a specific subject (battery cells) where even in hands-on mode investigated physical dimensions were not tangible/audible (e.g. current and voltage) and where very little physical interaction with equipment was necessary. Smaller differences in learning outcomes between groups are to be expected when no interaction with the experimental setup is needed, compared to Lindsay's accelerometer experiment or for example an experiment in which the relation of the length of a pendulum and its period of oscillation is to be determined and thus, students frequently have to touch the investigated objects.

As hidden differences in the simulations could be excluded from having been the reason for inferior learning outcomes, psychological effects need to be considered to comprehend the effectiveness of the different laboratory modes. The students could have felt that simulated experiments were less relevant, and they might have lost some of the motivation to comprehend and remember what they had experienced and learned during the laboratory exercises. Also, the environments the laboratories took place in (scientific lab vs. computer pool) could have had an influence. This needs to be examined in future studies.

However, there are several study limitations that need to be addressed. Most of the analysed data is based on students from one German university of applied sciences enrolled in the same B. Eng. program “electric mobility” (RA1, RA2, and RB1). Due to the small number of participants in the international runs, overall results mainly reflect results from German B. Eng. students. Nevertheless, the international run with a mixed student background (RA3) showed better knowledge acquisition with hands-on laboratories as well. In addition, results are not generalizable to student populations with a higher share of female participants, as in all runs the majority of participants were male.

5 CONCLUSION

While Lindsay (2005) reviewed laboratory protocols and thereby determined the quality of the work and focus of the students in the respective conditions, findings of this study are based on written knowledge tests. Significant differences between the influence of simulation and hands-on laboratories in local domain on learning were discovered in the first phase of this study. Hands-on laboratories produced better test results. In the second phase of this study, the role of perception of the laboratory condition on student learning was examined. This time, learning environment and equipment used was the same in both conditions. Subjects involved in simulated laboratories thought that they conduct hands-on experiments. Under these circumstances, no significant differences were found in students’ test results.

It is reasonable to assume that differences in test results between laboratory conditions in phase one would have been even higher, had the experimental procedure included physical interaction. However, this would have altered only the hands-on condition, and therefore it would have been impossible to directly compare results of hands-on and simulated laboratories.

It was found that the learning environments which seemed to be connected to real-world implications (action and reaction were perceived “hands-on”) produced better learning outcomes. Nevertheless, it needs to be pointed out, that the authors do not recommend to trick students into thinking they are using devices which they are actually not. For example, combining cost-saving simulations with cheap “fake devices" (only a display). It is obviously unethical to do so outside of educational research.

6 ACKNOWLEDGMENTS AND OUTLOOK

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This research would not have been possible without students who generously agreed to take part in the study in order to improve the learning outcomes of future colleagues.

Results presented in this paper are part of an ongoing study. More data will be collected during summer semester 2019. Further studies will investigate the relationship between learning outcomes in the laboratory conditions hands-on, simulated, as well as hidden simulation and the educational experiences and background of the students (e.g. the completion of a vocational education and training program before studies, and practical experiences before enrolling in the study program).

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Recruiting international talent:

The importance of language skills for career perspectives of foreign engineering students in Germany

N. Strenger
Dr., Research Associate

Ruhr-Universität Bochum, Mechanical Engineering, Project ELLI2 – Excellent Teaching and Learning in Engineering Sciences
Bochum, Germany

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ABSTRACT

Facing a global competition for highly qualified workers in the STEM fields, German employers are realizing the great potential of degree-seeking international students of technical disciplines. In contrast to foreign talent which needs to be recruited from abroad, a most valuable asset is seen in the cultural and language skills those students have supposedly already acquired during their studies in Germany.

At the Ruhr-Universität Bochum, the Project ELLI2 aims at improving the conditions of teaching and learning in engineering education. The cooperative project of three German universities is funded within the Teaching Quality Pact by the German Federal Government and States. In its key area *Globalization,* the project focuses on aspects of internationalization in higher education contexts.

This paper will present selected findings of a recently completed dissertation in the field of Social Sciences which deals with academic migration in engineering education and was conducted in association with the project work of ELLI2. It will highlight results of a mixed-method approach that investigated motivations of international engineering students who come to Germany for their master's studies. One of its key findings is that - despite their great willingness to learn German before and during their academic migration – international students struggle with the language requirements of the German labour market. Conclusions will be drawn with regard to the importance that both international students and German employers place on cultural capital in the form of language skills when it comes to career perspectives at the interface between university and labour market.

1 INTRODUCTION

In a global competition for talent, highly qualified immigration is increasingly regarded by the representatives of German politics and economy as one of multiple measures to prevent a shortage of talent, especially in the fields of science and technology. International students who have already studied in Germany are regarded as especially valuable: Ideally, they have already gained experiences in German culture, possibly even work experience, and acquired German language skills during their studies. Furthermore, they are available for the German labour market directly after graduating [1]; [2].

For their higher education report 2015, the Association for the Promotion of German Science and Humanities together with McKinsey conducted a survey with 230 German companies, asking them among other things about their view on foreign students as potential professionals [3]. The survey results indicated that German companies increasingly rely on foreign graduates of German universities in order to meet their demand for qualified personnel: Half of the companies are already relying on foreign graduates today and 66% are convinced that the situation will tighten in the future [ibid.]. 65% of the companies wish for a recruitment strategy of international students which is in line with the demands of the German labour market and they want political strategies and higher education institutions to improve the transition from university into job market [ibid., p. 20].

During the last two decades, the influence of globalization on the German higher education system has led to a wide-spread implementation of international study programmes, particularly on the master's level. Today, there are more than 1,100 internationally oriented master degree programmes and 160 international Bachelor programmes offered by German universities [4]. In order to make up for their shrinking student numbers by the end of the 20th century, the technical disciplines and engineering subjects were among the first to implement international (English-taught) programmes [5]. Such international study programmes attract talent from all over the world and thus have a great potential for winning international graduates who stay on to work in Germany.

At the Ruhr-Universität Bochum (RUB), research was conducted on three international master's programmes in the engineering departments. The project ELLI2 in its key area Globalization focuses on internationalization in engineering education, fostering incoming and outgoing student mobility. In cooperation with the project's work, a doctoral research study in social sciences was conducted on academic migration in engineering education [6]. The main research aims were to find out about motivations of international students who come to Germany for their studies and about their potential willingness to stay on for the job market after graduation. The following chapters will present selected results on the importance of language skills that serve as cultural capital for international engineering students who come to Germany.

2 LANGUAGE AS CULTURAL CAPITAL FOR INTERNATIONAL STUDENTS

2.1 Research object

The engineering faculties of the Ruhr-Universität Bochum (RUB) offer three international master's programmes: Laser and Photonics, Computational Engineering and Materials Science and Simulations. All three master degree courses are taught entirely in English and international applicants do not have to have any German language skills in order to apply. While they are open for applications from international students as well as for Germans, there are only very few German students in these programmes. Most students are from (East) Asia and among the most common countries of origin are India, Pakistan, Syria, China and Iran.

The research conducted within the framework of a dissertation project in the social sciences [6] aimed at investigating the motivations of international students who come to Germany as degree-seeking students. The focus was on understanding their reasons for choosing the international master's programmes and whether they plan to turn their academic migration into labour migration by deciding to stay on to work in Germany after graduating.

2.2 Theoretical background and central hypothesis

The theoretical background of the investigation was based on the sociological capital theories by Bourdieu: In his capital theory, the late French sociologist Pierre Bourdieu differentiates between three forms of capital, namely economic, social and cultural capital (the latter being sub-divided further). He puts these three capital forms on a level with forms of power, each having their own way of institutionalization and making appearances in societal exchange depending on their respective application and transformation.

Economic capital for Bourdieu is the capital form that can be most directly converted, in its monetary form. Social capital comprises all social, societal and familiar relations and contacts, which can occur in a more or less institutionalized form and which rely on social acts of exchange in order to be converted [7]. Cultural capital, according to Bourdieu, exists in three different forms: 1. As incorporated cultural capital which is permanently acquired and internalized by its owner, 2. As objectified cultural which exists in cultural goods as material form (such as books or paintings) and 3., as institutionalized cultural capital, which is an objectified version of incorporated cultural capital, e.g. in the form of educational certificates and titles (ibid., p.187).

With regard to the international students of the three master's programmes, one key hypothesis was that German language skills serve as incorporated cultural capital on which the students place a certain value for their academic migration and which they try to accumulate during their studies in Germany, so that it can be transferred into job opportunities on the German labour market.

2.3 Methodological approach and research design

To examine this hypothesis (along with further hypotheses regarding also economic and social capital) from the students' viewpoint, an investigation was conducted in 2015 and 2016 with a mixed-method approach of quantitative and qualitative research methods: The first stage of the investigation consisted of a quantitative online-survey that was sent to all international students enrolled in the three engineering master's degree courses at that time (N=266). With a final participation number of 84 (after three reminders), the response rate was almost 32%. The second stage of the research design was a follow-up study with a total of 17 semi-structured, qualitative interviews. The interview guidelines were designed in a way that the results of the quantitative stage would either be confirmed or disproved [6].

3 RESEARCH RESULTS

3.1 German language skills before migration

While "having English as a teaching" language was among the top 3 reasons for choosing their study programme in Germany, more than half of the international students started to learn German while they were still in their home countries. 53% of the survey participants had German skills before their academic migration and 36% had taken German classes in their home country. The largest group of those with German skills before migration were on a beginners' level, while 20% each reached a lower intermediate or intermediate language level and 7% an upper intermediate level. The fact that so many students had learned German before migrating although German skills are not a prerequisite of their international master's programmes indicates that they consciously prepared themselves for Germany as a host country and that they regarded German skills as very important. All students (those who had German skills before migration as well as those who didn't) furthermore state that they expected to improve their German language skills during their studies in Germany.

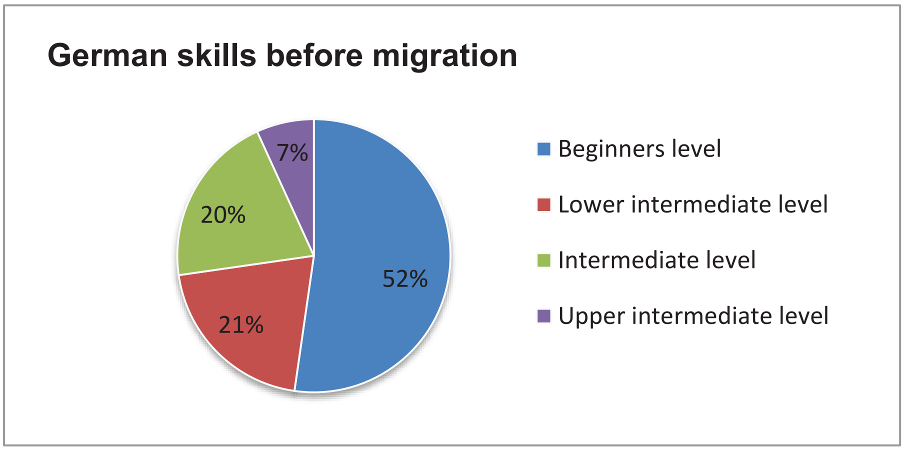

Fig. 1. German language skills before the academic migration to Germany [6]

3.2 Learning German while studying in Germany

The majority (88%) of all participants (N=82) state that they are currently learning German while they are studying in Germany. Only 12% do not actively pursue an improvement of their German language skills. Asked for the way that they learn German (multiple answers being possible), the largest group of students with 38% named classical German language classes. Further common ways of learning named by the participants were interaction with German-speaking people in the context of their studies (14%) as well as outside university (17%) and autodidactic language learning (16%). Online language courses (8%) or language tandems (4%) were named less often. Further forms of language learning that were described by participants in an open text field included self-learning with German movies and books, scientific literature as well as a project called “Sprachstunde”. This project is a student initiative started by the student council of the master’s programme “Computational Engineering” designed to foster language interaction between German and international students: German students (usually of philological disciplines) meet about once per week with a group of international engineering students (in a relation of about 1:5) in order to talk German. Participation is generally on a voluntary basis, but the study coordinators of Computational Engineering award Credit Points for regular attendance that can be recognized as part of the curriculum.

While most students learn German, their satisfaction with the progress they are making in learning the language is rather moderate: on a scale from 1 to 7 (1 representing “very satisfied” and 7 representing “not satisfied at all”), the mean value of all answers lies at 3.9, the median at 4.

3.3 Language skills and the search for part-time jobs

The quantitative results furthermore revealed an interesting connection between language skills and the search for a (part-time) job or internship. More than half of the international students who are searching for work during their studies described the job search as very difficult (33%) or difficult (30%). In an open answer question, participants were asked to describe the reasons for their difficulties in finding work. For a quantitative analysis, all free-text answers were coded and assigned to four different categories: All answers related to a lack of German language skills were coded as “German”, answers related to a lack of information for the job search as “Information”. If there were no specific difficulties perceived in the job search, answers were assigned to the category “None” and the category “Other” was chosen for different reasons which were named only once each. The majority (66%) of all participants in this section (N=38), described problems of the category “German”. Only 8% had difficulties related to lack of information and 18% described other difficulties.

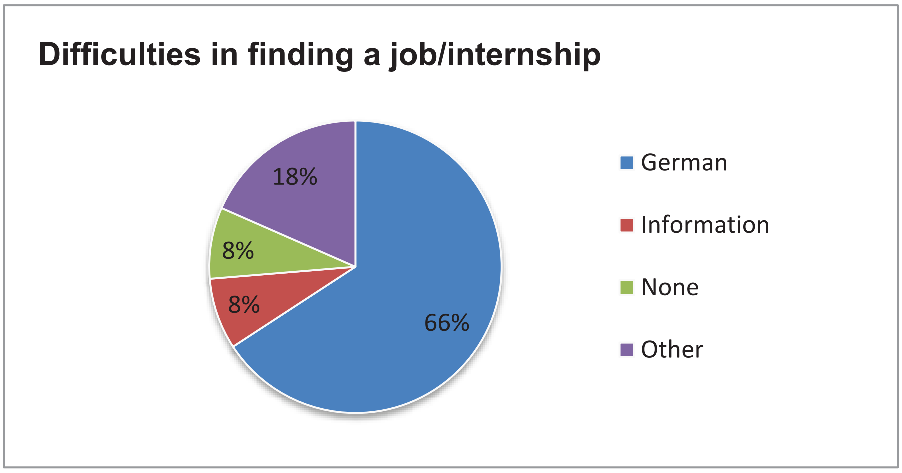

Fig. 2. Reasons for difficulties in finding a job/internship during studies [6]

Evidently, insufficient German skills are perceived as one of the main obstacles in finding a job during their studies. Language skills also play a role when it comes to choosing potential employers: Answering the question which type of career they would like to pursue after graduating from their master's, 46% of the international students stated that they would like to work as a research assistant or PhD candidate. About 40% would like to work in the private sector, while 12% are not sure yet and 2% select "other" fields of employment. The largest group of those who plan to work in the private sector (65%, N=40) would like to work in a large company with more than 250 employees. 32.5% would like to work in a medium-sized company with up to 250 employees and only one person wants to work in a small company with up to 50 employees. This is probably due to the fact that larger companies generally tend to be more international and accept English as working language.

3.4 Interview results

During the interviews, it was confirmed that learning German is very important for the international students. Most of them try to improve their German language skills during their studies but are not satisfied with the progress they are making. Several interview partners also stated that they had underestimated the importance of German for finding a job:

> "My impression from the internet was like – it would be much easier to find a job after your studies. But the point that I pretty much underestimated was the German language. In that time, I didn´t think that German language will play such a big role in my career here."

> "Before coming I thought, it´s not that hard…it´s easier to find rather than what I see now. Actually they need a high level of their language and I didn't know that and the choices, I thought there would be more…I mean it´s a little bit competitive now and it´s harder to find a job from what I thought before."

With regard to her career interests and the respective offer of subjects in Germany, one student even ponders whether it might have been better to choose a German-speaking master's course:

> "Thinking about it now, I think I would have preferred to take German classes before and then probably would have done a course in German, just because as I said, I am interested in automotive industries, and a lot of these courses are done in German and a lot of these options are in German. So I think, if I had options to do it again, I would probably come for 6 months or so taking German classes and then maybe do a German degree program. But when I was applying at that time, I didn´t really have an option to do a German program…even to consider that. The program being in English was definitely one of my deciding factors."

Apparently, the high relevance of fluent German skills for the labour market of the host country comes as a surprise to many and causes preoccupations with the international students. However, the interviews revealed a difference in the perceived importance of language skills for careers in industry vs. science. Many interview participants who plan to apply as doctoral candidates are convinced that English is the predominant language of research work:

> "[I]n Germany, if you want to find an internship or job you must speak at least good German. But in [our research institute], we are oriented on research and we have to do publications in English. My focus is research so actually I don´t need to learn German."

Another student describes learning German as a sort of plan B in case his plans for a career in research should fail: "[I]f I complete my master's and do not get a PhD position after a period of time, then I would also prefer to learn German. That's my plan, after my master's to get some good knowledge about German".

4 CONCLUSIONS AND OUTLOOK

The research results presented in this paper have shown that for international engineering students who come to Germany in order to obtain a degree, German language skills are very important. Although the international master degree courses at RUB are taught completely in English and German is no prerequisite, more than half of the students already learned German while they were still in their home countries. During their studies in Germany, the majority of students try to improve their German skills. This indicates that they regard German language skills as incorporated cultural capital which they try to accumulate.

Confronted with the requirements of the German job market, however, the international students encounter difficulties due to insufficient German skills and many seem to realize that they have underestimated the importance of fluency in the host country's language before coming here. With regard to potential working fields, many turn either to scientific careers or want to work in medium or large companies where it is more probably that fluency in German is not required.

In order to make the transition from university to labour market more easy for students in international study programmes, projects such as the student initiative „Sprachstunde“ might be a good option. Only few students are so far learning in language tandems and measures which bring together international and German students might be beneficial also for regular students in German study courses.

From the perspective of potential German employers, however, it might be advisable to prepare for the fact that international students are not usually fluent in German after only a few years in Germany, even though they graduated from a German university. At the interface of university and labour market, universities and employers should work together to provide intensive language classes at the career start of international talents.

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Mission (im)possible? Teaching social sciences to engineering students

V.I. Sucala[1]
University of Exeter
Exeter, United Kingdom

Conference Key Areas: New Notions of Interdisciplinarity in Engineering Education, 4th Industrial Revolution

Keywords: Industry 4.0, Social sciences

ABSTRACT

This paper explores the challenges of teaching social sciences to engineering students. While discussing this topic is hardly new, the challenges Industry 4.0 will bring makes it more acute. The rationale of this study is twofold: on the one hand it seems that employees' social skills are in short supply but in growing demand, on the other hand the suggestion to include social sciences into engineering education has a long history but less success so far.

The study's overarching hypothesis is that engineering students are perceiving social sciences as less relevant and useful for the engineering career. The research question was focused on how the engineering students perceive the relevance of social sciences to engineering, and how social sciences should be taught and assessed. The survey was applied to undergraduate and master students enrolled in engineering programmes of a British university between 2017 and 2019.

The conclusions outline the engineering students' perceptions and expectations. They suggests that the actual engineering curricula fails to make engineering students understand the need for social skills. Many of the students feel that social sciences could be helpful, but they would prefer non-compulsory and not-assessed training sessions. Neither the differences between social sciences and natural sciences, nor the impact of social sciences education on individual skills are not well understood.

In conclusion it is essential to revisit not only the content but also how non-technical knowledge is delivered to engineering students, and also how their expectations regarding what makes a good engineer are informed and managed.

[1] Corresponding Author
V.I. Sucala
i.sucala@exeter.ac.uk

1 INTRODUCTION

1.1 Rationale

The rationale of this exploratory study is twofold: on the one hand it seems that employees' social skills currently are in short supply but the demand is permanently growing. On the other hand, the current experience suggests that teaching social sciences topics to engineering students is rather a difficult task.

The suggestion to include social sciences and humanities into engineering education has a long history. Giebelhaus [1] enumerated various reports demanding it starting with 1930 Wickenden Commission Report. At the beginning this sort of suggestion was based on the engineers' need to deal with people. In 1968 the American Society for Engineering Education (ASEE) report showed that the American engineer was more and more becoming involved in administrative decision-making and policy-making positions, 50% of those replying to ASEE's study indicated that their functions were at least half administrative [2].

Almost three decades later Wenk was pointing in the same direction: 'While hardware components require expert knowledge, the delivery system fundamentally requires a general knowledge of business, public management, the social context, and human behavior. Put another way, the sum of sophisticated but narrow grooves of technical know-how do not add up to a working model of human society' [3]. Wenk was arguing that narrow engineering knowledge is essential in the modern society but it is simply insufficient to run successfully the more and more complex social systems such as industrial organisations.

More recently, the European Union's Future & Emerging Technologies Advisory Group report observed in 2016 that the integration of social sciences with engineering has been patchy, and in large areas of Horizon 2020 is either not present or merely paid lip service [4]. All these and many other reports and studies suggest that while the case has been made for almost a century, the success of this endeavour seems to be still out of reach.

1.2 Social sciences in engineering education

In a seminal study Davis Noble (1997) argued that engineering can be seen as the link between two forces that have shaped modern American society — the scientific technology and corporate capitalism [5]. From a slightly Marxist perspective, Noble argues that engineering has institutionalised the science into the service of corporate capital. Engineering education, which is the aspect of interest for this discussion, is one of the multiple ways in which this relation has been institutionalised. However, the last decades witnessed the reducing of the engineers' role and position within corporations.

Few years later on, Wenk observed that 'corporations, which used to have many engineers on their boards of directors, today are composed mainly of MBAs and lawyers. Few engineers hold public office or even run for office. Engineers seldom break into headlines except when serious accidents are attributed to faulty design' [6]. According to Wenk the main reason for this is a very simple – people ignore engineers because engineers ignore the people. But at the root of this could be various other causes – it could be the selection process, it could be also the engineers' education: 'by both inclination and preparation, many engineers approach the real world as though it were uninhabited'. Wenk also indicated the solution: a harmonisation of the natural sciences with human values and social organization, a teaching of engineering subjects within the larger social and organizational context. It isn't clear though how this harmonisation should take place within the engineering education. However, it is doubtful that this path has been proved to be successful so far. Matthew H. Wisnioski's verdict is rather radical: the liberal education has failed [7]. His insight into the history of calls for reforms of engineering education goes back as far as 1918. After describing in detail various other approaches in this direction, including some of the most recent attempts undertaken by Caltech or MIT, Wisnioski's conclusion is pessimistic: 'It may be absurd to champion the notion of a new humanism among engineers in a society in which humanism is so self-evidently moribund and engineering so diffuse.' But one could also find a way forward in this bleak landscape. Maybe it's not only about the education, maybe it also about how the engineers see themselves, how they value the knowledge and how they understand the world. As Wisnioski put it: 'How engineers contextualize themselves in social and historical terms – how they read social knowledge to read the world—is a harder lesson, because it redirects the question set onto the self. It is one, however, that has more potential to break the frame work of an ideology of technological change.' This conclusion is leading to this study's overarching question: how engineering students are perceiving social knowledge and, based on the answer to this question, how is engineering education to be re-designed?

2 THE CHALLENGES OF INDUSTRY 4.0

2.1 Industry 4.0 – the context

The advent of the Industry 4.0 process, in which Germany and United States are leaders, shows strong potential for an increase in efficiency and productivity. The concept of Industry 4.0 — meaning the 4th industrial revolution — has become an umbrella term for a number of inter-related technologies and concepts such as the internet of things, big data, advanced analytics, additive manufacturing, and servitisation. The smart factory is one of the final products of Industry 4.0 approach. Within such smart factories, cyber-physical systems monitor the processes and make decentralized decisions. By using the internet of things, the cyber-physical systems communicate and cooperate with each other and with humans in real time. However, although Industry 4.0 concept is a top priority for many companies, research centers, and universities, there is no generally accepted understanding of this term [8]. While most of these technologies already exist, their successful integration is challenging not only from the technology perspective, but also from the human perspective. The general consensus is that new skills and competences seem to be required for this industrial leap forward.

2.2 The impact

In order to understand 'the current and future impact of key disruptions on employment level, skill sets and recruitment patterns in different industries and countries', World Economic Forum commissioned a study 'asking the Chief Human Resources Officers (CHROs) of today's largest employers to imagine how jobs in their industry will change up to the year 2020' [9]. The study was based on the assumption that there is a significant gap between today's skills requirements and future skills requirements. The understanding of the future skills requirements is crucial for the educational providers in order to close the skills gap.

Unsurprisingly, the Report foresees a significant change of the skill sets required in both old and new occupations in most industries. Moreover, the Report estimates that 'overall, social skills – such as persuasion, emotional intelligence and teaching others

– will be in higher demand across industries than narrow technical skills, such as programming or equipment operation and control. In essence, technical skills will need to be supplemented with strong social and collaboration skills' [9]. Table 1 summarises the Report definition of social and resource management skills which are considered a part of the cross-functional category of skills.

Table 1. Definition of resource management skills and social skills, part of cross-functional skills category. Adapted from [10].

Skill/ability bundle	Skill/ability	Definition
Resource Management skills	Management of financial resources	Determining how money will be spent to get the work done, and accounting for these expenditures
	Management of material resources	Obtaining and seeing to the appropriate use of equipment, facilities and materials needed to do certain work
	People management	Motivating, developing and directing people as they work, identifying the best people for the job
	Time management	Managing one's own time and the time of others
Social skills	Coordinating with others	Adjusting actions in relation to others' actions
	Emotional intelligence	Being aware of other's reactions and understanding why they react as they do
	Negotiation	Bringing others together and trying to reconcile differences
	Persuasion	Persuading others to change their minds or behavior
	Service orientation	Actively looking for ways to help people
	Training and teaching others	Teaching others how to do something

Moreover, even the basic skills category includes process skills such as 'active listening and critical thinking' [10]. It is expected that these skills will become a growing part of the core skills requirements for many industries. It is self-evident that most of these skills require a basic knowledge of various social sciences concepts, theories, and methods. It is also evident that understanding such elements would require a dedicated and systematic effort that goes probably further than 'soft-skills' and 'global competences' training sessions.

The question that follows is how such knowledge could be delivered and such skills could be developed in the frame of the current engineering education, especially considering the long history of similar failed attempts.

3 THE ENGINEERING STUDENTS' PERCEPTIONS OF SOCIAL SCIENCES

3.1 Preliminary considerations

Below are few comments selected form the students' evaluations after completing a 4th year module including consistent elements of management and social sciences, and a teaching method slightly unusual for engineering education – the case study method. The module included elements regarding the history of specific management methods and techniques, and required students to read few articles and book chapters. The assessment was based on coursework only which consisted in a case study report.

‘Could be quite time consuming with readings’

‘Would have preferred to take other more technical and relevant modules in my final year that I could take to employers and talk about, gain more structural knowledge’

‘While some of the material on this course was useful, I question whether it should be compulsory’

‘Assessment wasn't great - the brief was a bit too vague compared to how specifically it was marked. It wasn't clear why this needed to be a group project, as it was just a research/lit review style essay’

While overall students’ evaluation of this particular module was rather positive, the comments section had made the author question the use of this method and turn back to the classical methods preferred by students – questions based on algorithms with unique numerical solutions. However, after careful consideration the decision taken was to investigate further the reasons for which engineering students are providing this sort of feedback. Intuitively, some general elements of students’ perception were transpiring out of the feedback:

- If there is just text, it isn’t knowledge therefore is not useful.
- It is knowledge only if it can be quantitatively measured.
- Employers want hard knowledge: software, formulas, equations, diagrams.
- Writing essay-style reports is not an appropriate activity for an engineer.

Worth mentioning that the students writing this feedback are in their final year, this meaning that they have the most mature perspective over the engineering profession a student can have. Considering all the arguments above, the author has considered that the idea of exploring engineering students’ perceptions regarding social sciences may bring some useful insights in this issue.

3.2 The exploratory study

An exploratory study has been designed consisting in a set of ten items presented in the Appendix. The students were asked to respond to a series of statements indicating the extent to which they agree with them. A five point Likert-type scale ranging from ‘Total agree’ to ‘Total disagree’ with a neutral point ‘Neither agree, nor disagree’ was used as the fixed choice response format. The academic ethical requirements and university’s procedures were strictly followed.

The study’s aim was to explore students’ perceptions regarding a number of statements reflecting few underlying hypotheses. There are 5 aspects subject of this exploratory study:

- Elements of social sciences **are useful** or rather **irrelevant** for an engineer
- The elements of social sciences should be taught **in the same way or in a different way** as all other engineering discipline,
- The elements of social sciences should be assessed **in the same way** as any other engineering discipline (e.g. questions with a single correct answer based on algorithms and formulas),

- The current curricula includes **too many** elements of social sciences, or **more such elements** would be desirable,
- The engineering degree overall result **should not** be influenced by the knowledge and understanding of elements of social sciences.

The exploratory research didn't aim for statistical relevance considering that the participation was voluntary and there was no sampling techniques used, but rather to understand how engineering students relate with these ideas. The survey was applied online to 3rd and 4th year students enrolled in engineering undergraduate programmes, respectively to students enrolled in engineering MSc programmes of a British university. The survey was emailed via a professional survey platform to approximately 300 students between 2016 and 2019. In total 65 responses were received until now and the analysis of these results is presented below.

3.3 Results

Considering the survey's exploratory nature, there have been recorded some interesting results so far. Below is the summary of these results.

1. More than two thirds (72.31%) of the respondents disagreed with the statement 'Elements of social sciences are irrelevant for an engineering career'. However, 18.47% of the respondents agreed with this statement, while 9.23% were undecided. This allows the conclusion that most of the engineering students feel that some elements of social sciences might be useful in their career, but it isn't clear which ones and more important, how could they be acquired.
2. The responses were more balanced regarding the way such elements should be taught. It appears that a majority (63.08%) of the respondents believe that social sciences are different than engineering therefore they should be taught differently than engineering disciplines. This raises the issue of understanding the differences between natural and social sciences, and their relevance and importance for an engineer.
3. The usefulness of social sciences elements for an engineering career was overwhelmingly agreed by the respondents (86.15%). This question was meant to verify the consistency of the answers to the first question. The answers are confirming the conclusion stated above – the engineering students believe that some element of social sciences could be useful.
4. A relatively small but relevant part of the respondents (20.00%) consider that the assessment of social sciences element should be done in an engineering manner - e.g. questions with a single correct answer based on algorithms and formulas, while 56.92% of the respondents disagree with this. This result suggests that the respondents tend to perceive social sciences different than technical knowledge, consequently assuming that the assessment should be also different.
5. The proportion of social sciences elements in the curricula was considered already excessive by 21.53%, while 49.23% of the respondents disagree with this statement and 29.23% are neutral. This raises the issue of introducing more social sciences elements in the engineering curricula without a proper management of students' understanding and expectations.
6. 35.38% of the respondents considered that their final result should not be influenced by their knowledge and understanding of the social sciences elements, while 43.08% of the respondents disagreed with this statement. In the context of the answers provided so far, the structure of the answers to this

item contributes to a better understanding of the engineering students' perceptions regarding social sciences knowledge. They consider that while it may be useful, it isn't a legitimate part of what they perceive to be the knowledge engineers need in order to succeed in their career.

7. Somehow in contradiction with the results so far, 80.00% of the respondents considered that some more social sciences elements would be helpful to develop skills useful for an engineer career. However, this answer might suggest a need perceived by the students to develop their skills.

The sample's structure was relatively well balanced between engineering undergraduate programmes (46.16% of the respondents) and MSc programmes (53.84%).

4 CONCLUSIONS

There are hardly reasons for optimism unless a significant change will happen in engineering education. In the current model, there are very low chances that engineering students will understand the acute need for the skills mentioned by various studies and summarised in the first part of this paper. Many of them feel that social sciences may be helpful, but they would prefer this help as non-compulsory training sessions, eventually not assessed. The differences between social sciences and natural sciences are not well understood, so is the impact of social sciences on individual skills that may be very useful in the near future. The respondents considered that social sciences could be relevant and useful for engineers, and the teaching and assessment of such element should be done rather different than in the case of engineering disciplines. Eventually some more elements could be added, but a large share of the respondents considers that their final award should not be influenced by the knowledge of these elements.

Hopefully, engineering curricula could be re-designed so more relevant elements of the social sciences will be introduced to address directly the knowledge and skills required by the Industry 4.0. But before this re-design, there is an acute need to understand why social sciences knowledge keeps failing in the engineering education. Based on the results of this exploratory survey, it can be argued that it isn't only the curricula content and structure, it is also the perceptions of the engineering students that contribute to this record of failures. The improvement of this poor record would require a significant change of both, perhaps with a greater emphasis placed on the later.

In conclusion it is essential to revisit not only the content and how social sciences knowledge is delivered to engineering students, but also how their expectations regarding what makes a good engineer are informed and managed.

5 LIMITATIONS AND FURTHER RESEARCH

As it was already mentioned, this paper presents the results of a study aiming to explore engineering students' perceptions regarding social sciences. The lack of representativeness is the major limitation which usually characterises any exploratory research. Therefore there is no base to assume that these results are valid for all engineering students. However, the results open few potentially seminal avenues that might provide helpful insights into the main challenges faced by the engineering education required by Industry 4.0 technology progress.

Further research will need to understand how engineering students understanding of the social sciences is produced and how it can be managed according to the industry's requirements. This demands a better understanding of how the dichotomy between social science and natural sciences is informed before the students even start their higher education journey. If this dichotomy is produced before the university, it will require a solid strategy to address it adequately.

Another future research should look into how the general skills described by various reports as required by the technologies of the future are translated into specific components. It is unclear how much of the skills described in Table 1 requires knowledge that could be acquired by the classic learning process and how much is developed by training or by using other teaching methods. This ambiguity contributes to the students' state of relative confusion regarding what constitutes social sciences and how this type of knowledge and skills could be acquired and should be assessed.

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Appendix

Survey

Please express your agreement with the following statements on a scale from ***-2 (total disagreement)*** to ***+2 (total agreement)***

Important note: there are no correct or wrong answers. It is very important to understand your perception regarding the importance of social sciences in engineering.

Definitions:

In the understanding of this survey, ***social sciences*** include: sociology, psychology, economics, anthropology, management, organisation studies.

By ***elements of social sciences***, we mean concepts (e.g. free market, motivation, behaviour, organisation, social group), theories (e.g. hierarchy of needs, neo-liberalism) and methods (e.g. cost-benefit, interview, personality test, case study) that were developed in one of social sciences.

1. Elements of social sciences **are irrelevant** for an engineering career, because some people are born with social skills, some other are born without social skills, and the employers are interested in engineering knowledge rather than social skills
2. The elements of social sciences should be taught **in the same way** as all other engineering discipline, because all of them are part of science.
3. The elements of social sciences should be taught **differently** than other engineering discipline, because social sciences are different than engineering and natural sciences
4. Elements of social sciences **are very useful** for an engineering career because they help me understand better the human behaviour and help me develop the skills required to succeed in an organisation
5. The elements of social sciences should be assessed **in the same way** as any other engineering discipline (e.g. questions with a single correct answer based on algorithms and formulas)
6. The current curricula includes **too many** such elements of social sciences, I would like to have more engineering elements instead
7. My engineering degree overall result **should not** be influenced by my knowledge and understanding of elements of social sciences, because I'm trained to be an engineer
8. Some **more** elements of social sciences would help develop skills an engineer needs in her/his career, because such skills could be developed and improved

Please indicate the programme category you're enrolled in (choose between BEng, MEng and MSc)

Balancing a change management process

A case study of how to approach curriculum change in higher education

N Svarre Kristensen
Research assistant
Aalborg University
Copenhagen, Denmark
E-mail: nsk@create.aau.dk

LB Andreasen
Associate professor
Aalborg University
Copenhagen, Denmark
E-mail: lba@hum.aau.dk

L Busk Kofoed
Part-time lecturer, Professor Emeritus
Aalborg University
Copenhagen, Denmark
E-mail: lk@create.aau.dk

JR Bruun-Pedersen
Assistant professor
Aalborg University
Copenhagen, Denmark
E-mail: jpe@create.aau.dk

Conference Key Areas: Strong demand for democratic involvement in educational processes, Integrated learning environments for the digital native learners

Keywords: Managing change processes, integration of courses and project, PBL, Bricolage, Action research

ABSTRACT

As part of a research project on possible future directions for problem-based learning (PBL) in a digital age, experiments are made to develop a flipped and integrated semester at a BSc engineering programme in Media Technology. The aim of the experimental research is to create a curriculum structure that integrates courses, student projects, and digital resources. This paper investigates how to approach the development of a new semester design with an active involvement of the teachers in the process. In the specific experiment, a planned organizational change management process, based on action research was established to develop a new semester concept and facilitate the teachers' development process, in co-creation with the research team. This process, however, was too far from the existing collaboration culture, and too time demanding for the teacher team. A change in the managing approach was made; a bricolage approach 'doing things with what is at hand' was integrated in the change management process. To illustrate this management process, the data is gathered during the development process, as well as during the first parts of the 2019 spring semester. The empirical data body is consolidated through summaries from development meetings, interviews with teachers, and surveys with student participants. The balance between a planned management approach and an emergent ad hoc management approach, showed to become essential for working with the project goals of creating a flipped and integrated semester.

1 INTRODUCTION

Practicing planned organizational change management (POCM) [1], in this case reviewing how to approach the development of a new semester design, means entering a difficult management process. How to strategically approach change is evidentially impactful as the US national research council reports that 70% of all major organizational change strategies in business, government and educational institutions, fail within two years and are abandoned [2]. The change strategy chosen in this experimental research project has been informed by Kurt Lewin's three step model, developed in 1946 [3], involving the steps of unfreezing-change-refreezing. The quantity of change management models abounds today, but a literature review by Rosenbaum et al. reveals that the 13 most used models all have clear links to Lewin's model from 1946. The affiliated models since developed have provided refinements and more detailed explanations, but the authors argue that no fundamental changes have been made since Lewin's model [1]. The change process for a 4th semester university program, Medialogy has consequently been designed with roots in Lewin's model, based on action research. However, the design for change meets unexpected obstacles in the 'change' step, due to time priorities and the need for autonomy in the change process. This paper will examine the balance of managing a planned organizational change process, while implementing a more emergent and ad hoc, bricolage approach to the change process. The bricolage approach is a less pre-planned approach, and to move between the emergent bricolage approach and the mere POCM approach, became an important part of the intervention on 4th semester Media Technology at Aalborg University.

2 BACKGROUND

Aalborg University is known for its Problem Based Learning (PBL) approach, where disciplinary knowledge provided by courses are supporting and applied in the student-led, problem-oriented semester projects. In 2010 the problem- and project-based learning model at the university was reformed. Different structural problems regarding examination of group-based vs. individual performance, standardization of accreditation requirements, adjustment to the Bologna Directive and accountants for a new grading scale, put pressure on the previous model for PBL. Hence, a new model were deployed, where courses and semester projects are largely assessed separately [4]. After the reformed model, the focus on practicing the PBL principles has been criticized for being diluted [5]. Problems with routinisation of the project work has been pointed out, and a risk of putting more emphasis on the disciplinary course work than the problem-oriented semester project work has been notified [5].
In an ongoing research project “PBL Future - Future directions of PBL in a digital age” (2017-2020), a subproject seeks insights and solutions to this problem through a case

study at the BSc media technology engineering programme (Medialogy). Here, a combination of new digital learning tools are explored, along with experimentation on how to establish an improved structural integration of both disciplinary courses and the student-led semester project work. With a focus on how the structural integration of courses and projects on a full semester is affecting the support of PBL, a flipped and integrated semester was agreed to be planned and developed in collaboration between teachers and a research team. The flipped and integrated semester should build on two initiatives; 1) using a flipped learning approach to create more time for active learning in the classroom [6] and 2) an integration initiative. The process of managing this change will be presented in the paper.

On the basis of interviews with former students at the specific semester, we found indications that there was a low degree of integration between courses and projects [7]. Furthermore, a survey made by the general PBL Future research project covering the entire Aalborg University, showed that teachers across all faculties rated the importance of creating a connection between projects and courses, as one of the most important issues when practicing PBL [8].

The focus in this paper is based on the research question: *How can a change process of further integration between courses and semester project work be facilitated, and what are the benefits and concerns of using a planned organizational change management approach when changing a semester structure?*

For answering this question, we will present the case study and experimental research carried out at the 4th semester of the BSc engineering programme of Medialogy. Relevant data will be used for analyzing the process of change towards a higher integration of courses and projects, and the different methodological approaches framing the initiative will be discussed.

3 METHOD

3.1 The specific semester case

The engineering education at 4th semester of Medialogy in Copenhagen has normally been driven by 4 course teachers plus teaching assistants. Supervision of students' projects will involve a number of other teachers, depending of the number of project groups formed at semester start. In the specific semester examined by this paper, the course teachers were connected to both courses and supervision. The general semester theme framing the academic direction was 'Sound Computing and Sensor Technology'. The three courses consolidating the theme were Audio Processing (AP), Physical Interface Design (PID), and Design and Analysis of Experiments (DAE). The courses' content rely more on math and programming than previous semesters. Many students fail at the ordinary course exams, and passed students generally consider it a difficult semester. On a grade scale where 2 is the grade needed for passing the course and 12 is the highest grade, the average course grading in 2018 were: AP: 3,5. PID: 1,7. DAE: 4,8. The low scores were a motivating factor for teachers to develop the semester and partake in the experimental research project.

3.2 Data sources

In this case study [9] we have been working with experimental methods inspired by co-creation [10] and ethnographic approaches [11] including experimental ethnography [12]. This means that we have been working with a research design as something that develops in line with the study itself. The empirical basis for this paper consists of three different kinds of data, concerning the development and collaboration process with the 5 teachers of 4th semester at Medialogy.

3.3 Data

30 August 2018 and 23 November 2018	Minutes from meetings with teachers	Agenda for meeting: Introduction to PBL Future and status
April 2019	Semi-structured individual interviews with teachers A-E	Interview focus: Teachers' experiences, the initiatives done at the flipped and integrated semester, communication, and problems on the way
June 2018	Pilot interview with 11 students from Audio Processing Media Technology 2018	Interview focus: Evaluation of the course
December 2018	Survey with previous 4th semester students 2018	Survey focus: Evaluation of 4th semester

Minutes from the meetings have been used for documenting how development and decisions have materialized along the way, leading towards the change process.

The semi-structured, video-recorded interviews, performed with each of the teachers, have been the primary data for reflection on the planning process. All 5 interviews were filmed and fully transcribed. A thematic analysis has been made for coding the data in the following categories; motivation for change, communication, integration, flipped learning and problems. In this paper, the categories of communication and integration will be used for shedding light on the research question [13]. The videos lasted 35 minutes on average, recorded in clips of 20-30 minutes (therefore they are labelled v1-v3). Furthermore, a small pilot interview with 11 students attending the AP course from the past year's (2018) semester was performed, to investigate issues in the teaching practice. Additionally, a survey was performed with all students attending the 2018 4th semester, to investigate possible problems across the 4th semester courses.

4 UNFREEZING

4.1 The need for change

In the first step of *changing* the 4th semester structure, the current ways of doing things had to be "unfreezed". The teachers need to see that change is necessary. Well established customs and social habits can work as inner resistance to change, and this has to be broken [14]. In the case of 4th semester, the motivation to change was pretty clear. The AP course had a lot of failing students and in the interview, evaluations done by the research group, the teachers could see a lot of criticism towards the course. The PID course was also failing a lot of students and the main teacher at the course quickly agreed to participate in the change process. Meanwhile, the DAE course was a bit different. The DAE teacher had already changed the course to a flipped course 4 years prior. Since the flip, it had shown better results in student gradings. This DAE teacher played the role of first initiator and a good example, showing that the flipped learning approach can work. To support the motivation and show why a change was needed, the research group made the survey on previous 4th semester students of 2018, which indicated problems when looking at how courses and projects supported each other. The students reported that especially regarding the AP and PID courses, they had difficulties to transfer course content to their semester projects [7]. This feedback from students should work as motivation for change - not just to a flipped learning approach, but also to create a better integration between courses and semester project work. The teachers all announced that they were very motivated to participate in this process of change (Minutes, 30 Aug 2018). "Unfreezing" is not always necessary if the participants already is prepared to change and it seemed to be the case at 4th semester.

4.2 An action research strategy

Lewin's POCM model is built on action research [15] and to develop the concept of a flipped and integrated 4th semester and thereby entering the "change step", action research methods were used [16,17]. Action research implies continuous cooperation between researchers and participants and together they determine goals and action to implement the goals. Keeping all involved parties, both teachers and researchers, informed about interventions and results at all times is very important [15]. The research team therefore planned to meet with the teachers frequently in the fall of 2018, to develop the flipped and integrated semester that was to be implemented in spring 2019 [7]. This showed to be a substantial challenge. The teachers found the process to be too time demanding and would rather do the development meetings themselves (Mail from C, 13 Sep 2018). A teacher later explained that "*it made no sense to have meetings with 8 people, when we are only 5 people running the courses. We teachers needed to talk together in terms of the content*" (Interview, C, v1, 6.38). This feeling of being pressured on time and wishing to develop the new semester without the researchers being part of the development, resonated between teachers. It was a turning point for how to manage the change process, and the researcher team stepped back a bit, to find a more sensitive approach and another balance, using the planned organizational change management approach vs. a more emergent approach.

4.3 The change

Doing the change, Lewin describes as 'reeducation'. It is more than just to acquire new information, habits or skills, it is to change knowledge, values, standards and emotions within the behavior patterns that are enacted in norms and interpersonal relations. Therefore Lewin puts great emphasis on the social aspect of making a change successful [18]. Research shows that 70% of adults' knowledge is fully automated and unconscious [19] and changing habits and behavioral patterns is extremely difficult. Lewin says:

> "*Only by anchoring his conduct in something as large, substantial and superindividual as the culture of the group, can the individual stabilize his new beliefs sufficiently to keep them immune from the day-by-day fluctuations of moods and influences to which he, as an individual, is subject*" [18, p. 59]

The research group had planned to be part of the support group, supporting a new culture, keeping them on the track with the change. Meanwhile, as teachers gravitated towards each other instead, the research group adapted and stepped backwards, allowing the teacher group to form their own supporting group, for each other, for the change ahead. It also meant reformulating the POCM approach, where action research principles is the main tool for management; letting the change initiative come from a collaboration between teachers and researchers, to a more sensitive and emergent way where the teachers had more autonomy. A bricolage approach was chosen.

4.4 Change by a bricolage approach

Change and innovation done by a more 'ad hoc' approach, that is based on the needs of the participants, has been demonstrated before [20]. Claude Lévi-Strauss introduces the notion of bricolage to describe a particular mode, in which humans relate to their environment through practical reasoning. Bricolage is by Lévi-Strauss characterized as a particular way of acting as "doing things with whatever is at hand" [21], as opposed to doing things in prescribed systematic ways.

Innovation and institutional change is often only acknowledged when pushed from higher-level management, while the day-to-day innovations created by practitioners are not acknowledged to the same degree. But Fuglsang and Sørensen discuss a more practice-based perspective on development, innovation and deals, in a case study where innovation from employees can be recognized in the organisational processes [22]. They describe three levels of working with innovation and institutional change: 1) Top management-initiated innovation, 2) Management-mediated innovation, 3) Bricolage [22]. Going from the action research approach, where the researchers are in constant collaboration with the practitioners, to a bricolage approach, the development of a flipped and integrated semester concept was up to the teacher group themselves to a high degree. To support the teachers as much as possible in this process, the research group now found themselves more as management-mediators, instead of co-creators.

4.5 Management mediators supporting the teacher group

Letting the teacher group develop and change semester structure as bricoleurs, meant that the researchers had to step back and let the teacher group do the development. Management, at this time, was focused on negotiating for more resources from the top management. The teacher group sought IT tools to support the integration between the AP and PID courses, and resources for a research assistant that could support the teaching at both of these courses. This research assistant became an important communication link in a culture where it showed that teachers weren't used to talking much together. In previous years, the communication across the semester's courses had not been that active:

> "*Definitely we [the teachers] are talking more together this semester. Several years ago, I was co-teaching this course and I don't remember talking to anyone about what is happening on the other courses [..]. We didn't talk, I didn't know what was happening. Now I have a much more clear idea of what is going on in the other courses.*" (Interview, A, v2, 19.39).

The research assistant played an important role in this communication. He described the communication as still being a problem and that his role as connected to both courses became an important communication link:

> "*Between courses it was pretty tough, I still haven't managed to get [both teachers] in the same room for a meeting. They both get second-hand information from me, because I meet both doing classes. I don't think it was a problem though. I would say – most of the communication was done through me, [one teacher] would ask questions of what [the other teacher] was doing, or I would just tell them both what was happening in the other class - bringing them up to date*" (Interview, B, v2, 6.35).

Having a research assistant that were directly connected to two of the three courses became a very important part of creating better integration. The communication culture between the teachers as a whole group, however, became a problem. At a meeting in November 2018 during the preparation phase, it was clear that teachers hadn't yet succeeded finding time to discuss and plan the flipped and integrated semester concept, towards the upcoming spring 2019 semester (Minutes, Nov. 2018). They believed they didn't have time, and hadn't been able to schedule meetings for development. And thereby, did not manage by themselves, to support each other in the change. The research group then interfered, and started scheduling meetings with teachers again, where the top priority was to facilitate a space, shared simultaneously by the teachers, for talking together and developing the semester structure. One of the teachers describe the researchers' role as followed:

> "*They [the research group] have the integration role. We as teachers know our own course and know how we can try out new things here, but we don't know the other courses. The PBL Future team brought us together and made us understand this integration effort*." (Interview, A, v2, 3.05).

Putting emphasis on integration hasn't come by itself for the teachers. Development of the separate courses seemed to be easier to do on their own, but innovating towards integration between courses seemed to be difficult for the teachers. Still on the sideline, in the balance of planning the change and mediating the innovation, the research group in higher degree now tried to become an implicit part of the teacher group, supporting the communication and the common goal of change. The research team were around when the teachers had lectures, they kept asking questions, they observed, and did surveys focusing on the integration. Information about what the teachers did and how it worked were given as instant feedback and the research group thereby supported the teacher group by giving them information about the practice of the 4th semester. This was balancing towards a more action research approach -

gathering data about practice that can be part of co-creating change process, the teachers accepted and appreciated. One teacher says:

> "*When the semester actually started running I think it has been very helpful to get your interview feedback from the students, because that is something we usually don't get. They don't answer the online surveys and it is very useful to read the comments from the students. And also to have you there to sample the lectures and know that afterwards we can look back at this material and maybe evaluate it in a coherent way – that is nice*." (Interview, C, v1, 6.38)

The research team have thereby not just been mediators for innovation, but had to obtain a balance with the role of change management, along the way.

5 THE BALANCE OF MANAGEMENT AND BRICOLAGE

Letting the practitioners of the change be bricoleurs and doing the change by what they are motivated by, can be beneficial in a busy scheduled working situation. However balancing between the POCM approach and the bricolage approach in the middle of it all can create concerns, because the bricolage approach might need more defined end goals. One of the teachers expressed that she would have liked more guidance:

> "*When you are a group that don't really know what a typical semester project would look like on the semester, it has been difficult to talk constructively about the change. So ideally you would start from the project and then think, what would be a good ideal semester project and how can we support that and the learning goals within the different courses. Maybe that should have been the starting point – to make it more tangible for us*" (Interview, C, v1, 8.11).

The teacher quote explains the integration strategy that the teachers developed in collaboration. It isn't necessarily the only way to build the integration concept, as other integration strategies using more structurally based integration or problem-oriented integration, might as well have been implemented [23]. But letting the teachers define the concept themselves in an action research-theoretical framework, may have amplified engagement and motivation [16]. Looking at the teacher quote above and knowing that the teachers in high degree did the change as bricoleurs they might have needed more guidance. The balance between planned change and a more emergent bricolage approach is difficult. Fuglsang and Sørensen is pointing out a problem of 'disconnection', that can occur between the management initiators, management mediators and the bricoleurs. A disconnection that in the case of 4th semester Medialogy might be seen in the huge communication challenges between the teachers. If the communication culture of a teacher group, that are to create integration between their courses, isn't that well-functioning, there is a risk of losing the support in a group. Thereby, the change management has to be balanced in a delicate, attentive manner.

5.1 Reflections on benefits and concerns when facilitating change of a semester structure

The bigger, structural changes performed in this case study at the 4th semester at Medialogy in AAU, CPH, has shown some problems in how to approach the change management process. How much has a change to be facilitated, and how much are practitioners themselves able to initiate and define their change. Using Lewin´s planned organizational change management model rooted in action research, it is important that the practitioners themselves are involved in the design of the change. This is an engaging and motivational factor for the practitioners. What we have met in this experimental case study, is that the action research approach didn’t fit with the silo-thinking of the teaching practice at the 4th semester Medialogy. The teachers were engaged in changing to a flipped and integrated semester, but they didn’t want to engage and spend the time with the research group in co-creating what and how the change was to be done. Initiating a change process where integration between the courses were a goal it made a lot of sense that the teacher group themselves grouped up and worked on figuring out what and how the flipped and integrated semester should look like. Using a bricolage approach thereby became an important tool for developing and changing the 4th semester structure, because it gave the teachers autonomy to work on the change themselves. However we found a communication culture between the teachers that made it hard for the teacher group to find and articulate a common change process, and to be effective in the development of the change. The research team needed to balance some structured meetings and create communication links across the semester. Both the planned organizational change management approach and the bricolage approach showed benefits and concerns. The bricolage approach let the teachers themselves work with changing the semester structure, and a lot of change was seen, especially implementing the flipped learning approach. However, it still didn’t bring teachers out of their silo-thinking, but in this case, the role of innovating mediators was important for other reasons, for instance, as the negotiating of the extra resource of an across working research assistant that linked the communication across two of the courses. Also, planned organizational change management was important, to support the communication between teachers. Planned meetings were necessary to ensure the alignment of teachers' schedule, for discussion and development of the flipped and integrated semester. The mix of a structured and planned change approach, and a bricolage approach, has in many ways worked well for developing a more integrated semester structure. This may be of inspiration to other development initiatives, at engineering education programmes. The approach has helped removing communication barriers, as an ongoing, dynamic balance between open-ended and more structured change development processes.

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Novel prediction test for freshmen at BME, Faculty of Chemical Technology and Biotechnology

Brigitta Szilágyi[1], Gábor Hornyánszky, Szabolcs Berezvai
Budapest University of Technology and Economics
Budapest, Hungary

Dániel Horváth
EduBase Educational Services LLC and Budapest University of Technology and Economics
Budapest, Hungary

Áron Hives
EduBase Educational Services LLC
Budapest, Hungary

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ABSTRACT

Each year about 350 students get accepted to the three BSc programmes of BME, Faculty of Chemical Technology and Biotechnology having heterogeneous knowledge in mathematics. In September 2018 we tested the freshmen's competency in mathematics with a novel computerized test with which we could not only measure their procedural competences but also their ability to apply high school knowledge while solving unusual exercises. Our goal was to measure the students' competences and based on the test results offer them catch-up or talent-development opportunities. In this study 242 students were tested: 110 chemical, 93 biochemical and 39 environmental engineers. The test took 70 minutes, consisted of 17 exercises and was carried out on computers. Students who studied higher level mathematics in high school wrote a different test from those who did not. As a result, we got a comprehensive picture of the knowledge the students have acquired in high school.

After analysing their performance in the first semester, it can be stated that our hypothesis was verified. Namely, those who did perform well in the first two parts of our test (where basic procedural competence was tested in a classical way), also succeeded well later, while those having weak performance in these parts should be supported by close-up possibilities. Those who got great results for the third part (including unusual exercises) were also successful in the first semester. Moreover, it

[1] Corresponding Author
Brigitta Szilágyi
szilagyi@math.bme.hu

can also be concluded that although higher level mathematics is not a requirement to get into the university, its lack makes it much harder to be successful.

1 INTRODUCTION

The primary objective of Budapest University of Technology and Economics (BME) with its eight faculties as a higher educational institution is to train ambitious and diligent students to become professionals with skills and competencies in industry and research. In order to improve, or at least maintain its position in the world economy to exist as an innovative, knowledge-based society, the EU is at risk by the lack of Science, Technology, Engineering and Maths (STEM) students in both secondary and higher education, which results in a significant shortage of qualified employees in R&D and industry [1]. Another problem is that in STEM areas many of those who start their studies do not remain in the programme they have enrolled in and a high rate of students drop out without a degree - much higher than in other areas [2-3]. Unfortunately, this rate is quite high at BME too, almost 30%. A positive exception is the Faculty of Chemical Technology and Biotechnology (VBK), especially in case of the Chemical Engineering programme. Since the introduction of the new curriculum in 2010, which has solidified the catch-up system, drop-out rates first fell below 20% and then stagnated between 10-12%. Out of the BSc graduates, 85-90% of the Chemical Engineers continue to pursue an MSc degree at BME VBK, while in Biochemical Engineering this number is around 70-80% and 10-15% of MSc graduates enter a PhD programme at VBK.

1.1 Educational concepts at VBK

In addition to the appropriate level of knowledge and motivation of the enrolled students, this outstanding result is supported by the Faculty's efforts to help its students not only to complete the courses, but also to earn all the credits they need for obtaining their degree through good grades.

It is not enough to start the preparation of students after the enrolment to university, but it is advisable to start it beforehand. Recognizing this issue, the Faculty regularly organizes mid-term workshops (Professional Days) for high school students, helping them to prepare for graduating in advanced chemistry level, and offers a 10-day summer training camp where high school students are educated in Math, Physics, Chemistry or Biology.

Students already enrolled will be given the opportunity to develop their skills in the traditional Chem-Calc Camp before commencing their studies. (During the 8 days summer program the participants can receive preparation in Math and Chemistry in different levels.) For students of the Faculty, there are many opportunities to join VBK's talent management programmes besides completing their mandatory academic tasks [4]. Important elements among others are the activities performed in the Szent-Györgyi Albert Special College, as well as the outstanding work on the Faculty’s Scientific Students' Associations (called as TDK in Hungary).

1.2 STEM Projects at BME

In the period between October 1, 2014 and September 30, 2017, VBK – together with three other faculties from BME– participated in the ReadySTEMgo (Erasmus + Strategic Partnership, Project No: 2014-1-BE02-KA200-000462) project. The main purpose of this project was to investigate the factors that contributes to the successful completion in science and engineering programmes. Furthermore, it also analysed the key skills and competences that enrolled STEM students must have in order to successfully pursue their studies and earn a diploma in the STEM field of their choice. The work of the strategic partnership research also included the selection and creation of diagnostic tests, the development of skills and competences, the development of the intervention tools using innovative learning methods to assist in the improvement of the identified deficiencies. In addition, the programme has placed emphasis on overcoming the difficulties that can be observed among the so-called first-generation students (students whose parents do not have a higher education qualification) [5-8].

The Faculty of Chemical Technology and Biotechnology is also an active member in the so-called EFOP 3.4.4 project founded by the Hungarian Government and the European Social Fund in the framework of the Széchenyi 2020 programme. The goal of the EFOP project is to present STEM programmes to high school students, with related projects and potential career opportunities in a form appropriate to the communication expectations and style of adolescents. Within the framework of the project, BME (including VBK) promotes the specialties of STEM programmes through interactive presentations, including spectacular experimental demonstrations and lectures. Moreover, we offer a wide range of interesting faculty programmes to interested high school students including four different summer camps.

The analysis of professional fields must be included in such a complex project, namely the assessment of the professional needs of high school students, or the publication of supplementary materials helping them to enrol to universities and to successfully complete their programmes.

This latter subproject aims to help BME students by investigation three key elements for successful studies: discovering the learning skills of incoming students, preparing a series of analytical tests to examine these skills and developing various learning materials to improve these skills. These three core tasks will support students at STEM-type programmes even at European level, since by exploring their optimal learning strategies students will be able to develop their skills individually.

2 INVESTIGATED GROUP

In this study 242 freshmen participated: 110, 93 and 39 being enrolled in chemical engineering, biochemical engineering and environmental engineering bachelor studies, respectively. The following histograms (see Figs. 1-4.) give an overview of the students' distribution of entrance points in 2018. Note, that in Hungary a centralized university entrance system works, where students can earn 500 points (200 pts. for high-school results, 200 pts. for graduation result of two specific subject selected by the university and 100 points are extra points).

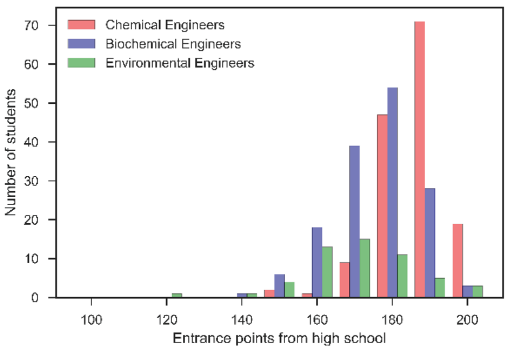

Fig. 1. Distribution of entrance point obtained from high school results

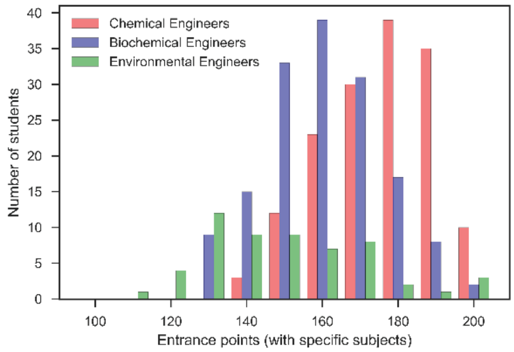

Fig. 2. Distribution of entrance point obtained from specific subjects

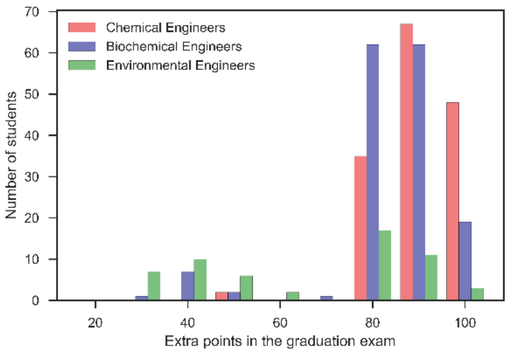

Fig. 3. Distribution of extra points of the entrance points

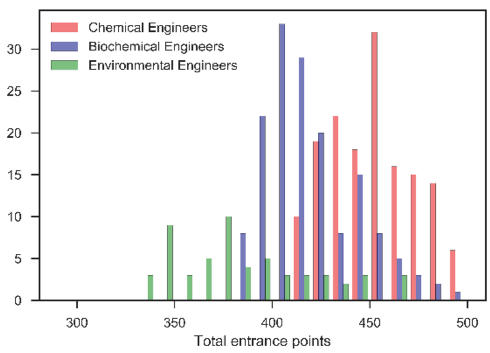

Fig. 4. Distribution of total entrance points

In previous years (2015, 2016), the students of several faculties of BME also completed the LASSI (Learning and Study Strategies Inventory) test [5-8]. The confidence of students towards their studies and results has great influence on their performance and attitudes towards their tasks. Fortunately, according to the survey, the Chemical engineering students at VBK were quite confident [5-8]. Although, university studies also bring sharp change in their life and in their way of learning, but this is not equivalent to being in trouble. The need is great, and most students are motivated by the upcoming deadlines and examinations. Additionally, it is commonly assumed at BME that the lack of acquired knowledge and skills cause great problems even in higher grades as low retention rate indicates.

3 THE NOVEL COMPETENCY TEST

With the enrolled students to VBK in 2018 a novel mathematical competency test was written in order to obtain a comprehensive picture on their mathematical skills and competencies. The proposed multi-block test, which also includes unusual exercises for Hungarian students, is also able to identify students with deficiencies in maths in order to provide them supplementary materials (prepared within the framework of the previously mentioned EFOP 3.4.4 project) for independent close-up. Another important goal during the test preparation was to help discovering excellent students for whom advanced courses could be offered within the talent management programmes at BME. Furthermore, it was also important for us to offer the adequate development program for all students using only a single test.

3.1 Test method

The test was computerized on EduBase (www.edubase.net), which is a cloud-based educational platform. Their quizzing system – called EduBase Quiz – offers a secure, convenient and straightforward way to handle massive online testing (simultaneous examination of even hundreds of students).

The test was conducted on multiple locations concurrently and was monitored both locally on each location by apprentices and centrally by the EduBase system. In each room there were at least 4 apprentices proctoring the students by standing behind them. In addition, the EduBase system on itself can detect suspicious student activity that might indicate cheating behavior, such as switching tabs in the browser or capturing screenshots of their monitor. Suspicious activities are being reported in real-time next to the student's name on a central page which aggregates their current status and results in the exam. Fortunately, none of the students were marked as suspicious by the EduBase system. For the previous reasons, we believe that the measured results accurately represent their knowledge.

3.2 Structure of the test

In this project two separate competency tests were prepared: the basic one for those who had studied mathematics in high school on basic level (3 lessons per week) and the advanced one for those who had attended advanced lessons in the last two years (5 lessons per week). However, the structure of the tests was completely similar and contained some common exercises as well.

The proposed test is also capable to examine the times needed to complete the tasks. It is also important that students are able to solve the given tasks in time. Therefore, the tests were designed in such a way, that they can only be fully completed with an expected speed. This means, that there was a lack of time in Block 3 for those, who spent too much time in Block 1 and 2. There were several exercises where the step-by-step solution leads to a long way to the answer, while a deeper understanding of the topic makes the question to be solved much quickly and easily (e.g. instead of solving an integral its geometric meaning should be checked and utilized). Knowing the importance of proportional thinking in chemical studies, several of such tasks were included and some text assignments were presented in a chemical context.

The test took 70 minutes, consisted of 17 multiple choice exercises, each with 4 possible answers and only one correct answer. The tests (basic and advanced) were divided into three blocks.

The first block (Block 1), containing the first four exercises in basic and the first five exercises in advanced level, controlled the basic, procedural computing knowledge. Fillers had to be accounted for their degree of familiarity with power, their identities, their confidence in logarithmic expressions, and their understanding of basic functional concepts. Our first hypothesis was that the fulfilment of these tasks (at least 60%) was a necessary condition not only for Calculus 1, but also for subjects requiring mathematical knowledge.

The second block (exercises 5-10 and 6-10, respectively) contained slightly more difficult tasks compared to Block 1. Here we tried to map the existence of important knowledge for later studies like Calculus. Compared to the tasks in Block 1, there were more complex examples that were set in the form known from high school including geometric, functional knowledge and logical statements. Our second hypothesis was that those who solved at least 6 tasks from Blocks 1-2 (i.e. exercises 1-10) will be able to complete the harder subject with good results, while others might have some trouble with the math-based subjects in the first academic year.

The last block (Block 3) contained unusual tasks that could only be solved by students having profound knowledge from high school and who are able to apply it while solving unexpected exercises for them. To solve the tasks of this block, the highest level of abstraction was needed, for example, there was a parametric geometry task, for which an understanding of functions was also needed for the correct solution.

3.3 Results of the test

The tests were completed by 249 students out of the 363 freshmen at VBK, which means 69% fill rate. Among those who filled the test, 123 students completed the basic test, while 126 students the advanced level test.

The test results are summarized in Table 1. It can be clearly seen that the average result is higher in the advanced group test as it was expected since those students had learnt Maths in advanced level with extra lesson per week (usually 5 math lessons per week). We also investigated the Block performances which is also listed in Table 1. In case of Block 1 the advanced group has performed much better, which means that their procedural knowledge is profound and concrete. In case of Block 2 and 3 the performance of the two groups are more or less the same, however the tasks were more complicated in case of the advanced group.

Table 1. Results of the test

	Basic test	Advanced Test
Total number of students	123	126
Mean point	7.82	8.38
Standard deviation	3.33	3.13
Block 1 mean	2.35 (max 4)	3.58 (max 5)
Block 2 mean	2.85 (max 6)	2.49 (max 5)
Block 3 mean	2.61 (max 7)	2.03 (max 7)
Success in Block 1 (at least 60%)	59 students	107 students
Success in Block 1-2 (at least 60%)	40 students	60 students
Total (at least 60%)	26 students	33 students

The test results for both in basic and in advanced level are summarized in Fig. 5., which shows a distribution close to Gaussian. Consequently, we can state that the difficulty and the complexity of both tests were adequate for the standards.

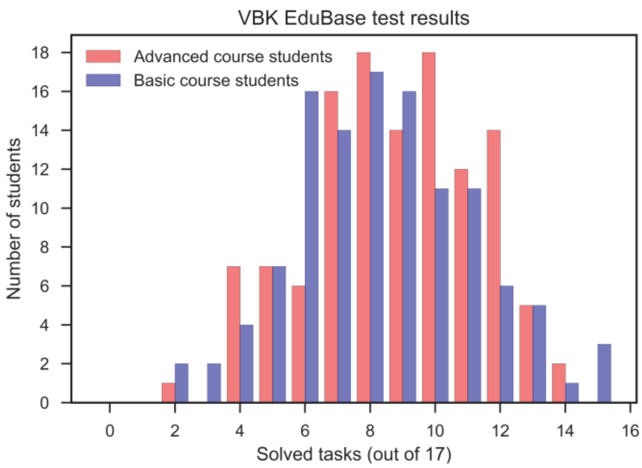

Fig. 5. Distribution of test results

3.4 End of semester results

At the end of the semester, the performance of students in math-based chemistry subjects were also analysed in detail, since mathematics is only a tool for chemical, biochemical and environmental engineers. Therefore, the prediction performance of our test was investigated for subjects including Calculus 1, General Chemistry and General Chemistry Calculations and Physics for Environmental Engineers according to Table 2.

Table 2. Math-based subjects in the first semester

	Chemical Engineers	Biochemical Engineers	Environmental Engineers
Subject 1	Calculus A1	Calculus A1	Calculus A1
Subject 2	General chemistry + General Chemistry Calculations	General Chemistry + General Chemistry Calculations	Physics for Environmental Engineers

In our analysis the average of the math-based subjects (MBS) were compared with the prediction test results for each student. The distribution of end-semester results in MBS for the top and bottom 10 and 20% percentages of the test (see Figs. 6-7) also illustrates the excellent prediction value of the proposed test. The results also shows that the test helps not only to detect students who need catch-up but also the excellent and talented students since a significant portion of students who were in the top 20% of our test, performed excellent in the first-semester and completed their MBS subjects with at least 4 in average.

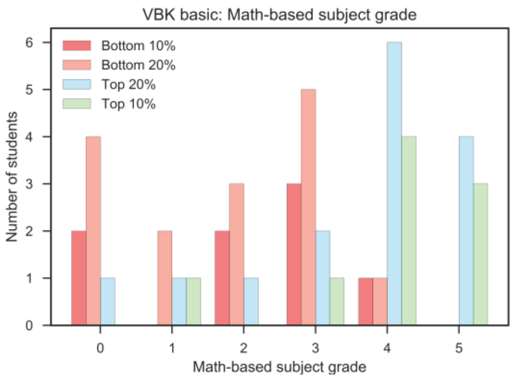

Fig. 6. Semester results in MBS in case of the basic group

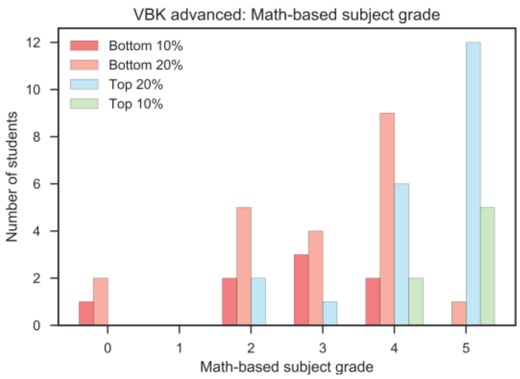

Fig. 7. Semester results in MBS in case of the advanced group

If we compare the results in Block 1 and the MBS subject results (see Table 3), it can be concluded that only a couple of students failed to pass all the MBS subjects who passed our test (denoted with bold in Table 3), which confirms our first hypothesis.

Table 3. The relation of Block 1 and MBS subject success

		Math-based subjects	
		Pass (all the subjects)	Fail (at least one of the subjects)
Block 1	Pass (above 60%)	139	***27***
	Fail (below 60%)	43	37

Additionally, based on the results in Table 1 the so-called odds-ratio (also known as the cross-correlation ratio) can be obtained, which expresses that how many times the student is more likely to pass all the MBS subjects if they pass Block 1 in the prediction test. In this case the odds-ratio was 2.36 for the basic and 3.81 for the advanced groups, respectively. For the total group the odds-ratio regarding Block 1 was 2.95. Similarly, the same calculations were performed for the results of Block 1-2. In case of the basic group the odds-ratio was 2.58, while for the advanced group 5.14.

4 CONCLUSION

We can conclude that a novel competency test method has been developed that predicts the performance of enrolled students at the time of entry with excellent accuracy and helps the identification of students who need catch-up or talent management. The developed method can easily be applied even for thousands of enrolled students without any significant extra work thanks to the application of the EduBase online platform.

However, the question may arise, why it is necessary to test the knowledge of incoming students in addition to the enrolment procedure. As Figs. 8-9. in Appendix show in the Hungarian higher education system, the entrance points are not informative enough regarding mathematical competencies. These scatter plots represent the relationship of the test result, the entrance points from specific subjects and the total entrance points, while in the main diagonal the histogram of the student results are presented. It can be stated that students with high scores have successfully fulfilled our test as well, but nothing more can be claimed with certainty.

4.1 Future plans

The research has not been completed yet, as competency test results are to be compared with the results of the second semester in order to investigate the quality of prediction in longer term. We assume, that those who performed well in Block 3 will achieve similarly good results in the following semesters.

We also believe that our efforts will pay off, as we can ease the situation of the next generations, we can promote the STEM programmes, which are in great demand in the world.

During the summer we will analyse how the students have completed the subjects of the spring semester, and from the academic year 2019/2020, we are planning to take the measurements at the beginning of the autumn semester with freshmen again. Subsequently, we provide additional online catch-up course for underperforming students using EduBase's Online Educational Platform, which allows them to complete the missing knowledge at their own pace and strengthen the weaker areas.

ACKNOWLEDGMENTS

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APPENDIX

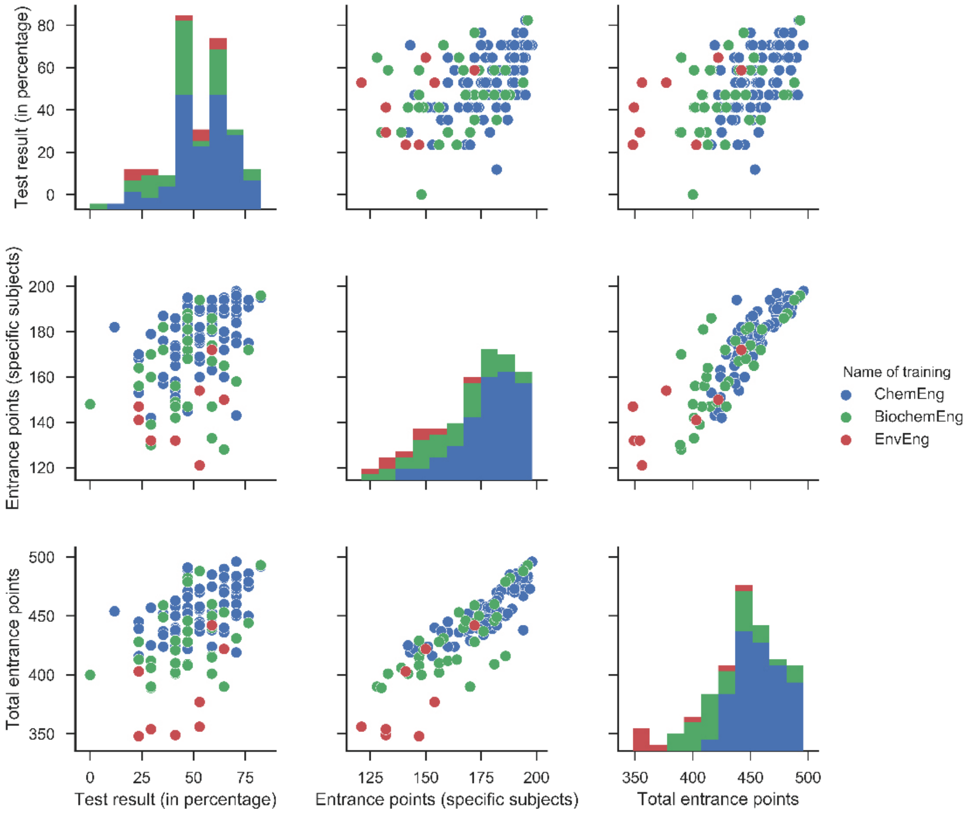

Fig. 8. Scatter plot matrix of entrance points and test performance of the basic group

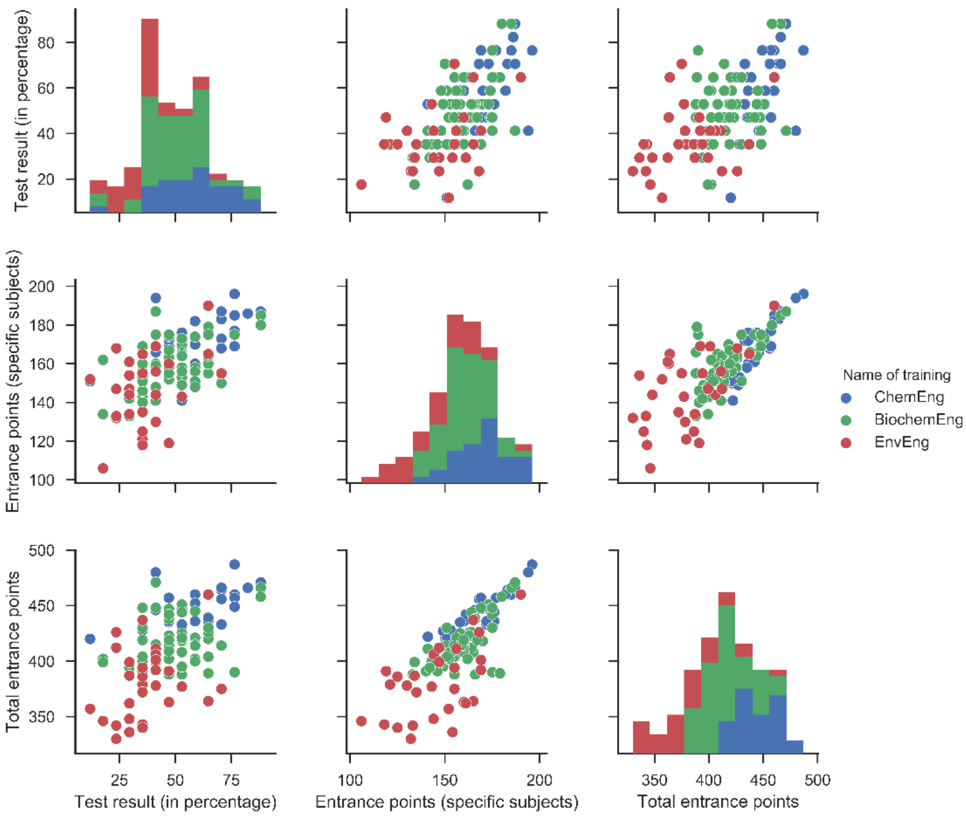

Fig. 9. Scatter plot matrix of entrance points and test performance of the advanced group

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The dynamics of Higher Education in Mozambique and Interplay with the Working Market: The contribution of Engineering, Humanities and Social Sciences

Pedro Joao Uetela

University of Western Cape, Mozambique

ABSTRACT

The empirical data from Mozambique where HE has quickly grown since the mid-1990s over the liberalization of the market is instigating concerns on the linkages between universities and the industry. Drawing from a tracey Methodology of Mozambican graduates in two universities, Eduardo Mondlane University (UEM) and Pedagogical University (UP) in the domains of Engineering, Social Sciences and Humanities, this article embarks on investigating the contribution HE made to the Mozambique labor market (between 1970s to 2000s). In so doing, the paper shows that tracey studies as a research method that accounts for relevance of HE has been severely neglected in the country. In exploring such new method this research brings a new unit of analysis based on two embryonic notions namely that despite public debate developing the view that the surge of graduations leads to unemployment, in Mozambique there are fluctuations in terms of institution of instruction, field of specialization and period graduates enrolled in HE. Secondly, there has been a dominant misconception of viewing universities solely as channels for employability rather than paragons where cultivation of knowledge, culture and skills necessary for adjustment in different contexts of life are nurtured. The rapid growth of Social Sciences & Humanities and devaluation of engineering skills within universities in Mozambique sustains all these views.

Key Words: HE, fields of knowledge, employability, Mozambique. Engineering

Review of Literature: Contribution of knowledge universities generate to society and implications

International analyses on the expansion of HE (see Teichler, 2005:453 and Tight, 2012: 279) have increasingly urged for a looming prediction of university crisis since the 1970s. During this period, the public debate instigated investigations on the effects of rapid growth and inflation of HE with focus for future employment as a result of the highest number of graduates terminating university. The case of Mozambique's establishment of HE shows an apparent contradiction in terms of rise of university and concerns of future unemployment nexus. There are several approaches for such delink on the interplay between the inception and development of high learning in either Africa or elsewhere and concerns on the absorption of the graduates by the industry. In Africa the focus on engineering skills has been less emphasized and minimization of practical problems affecting the country prevail as a result.

The international scrutiny of universities based on employability and application of the abilities Higher Education Institutions (HEIs) confer to the graduates; (see Tight, 2012) show changing relationships between universities and the industry. In addition, the employing market has now shifted priorities from humanities and social skills to concentrate on engineering abilities contradicting the long held type of investment African states made on social sciences and humanities. Still in SSA the landscape interlinking skills and development reveals the dominance of a kind of university that less addresses the need for engineers on one hand and overwhelming existence of social scientists on the other.

These drifting contradictions confirm the loom of new themes that dominate the public debate on the interpretation of HE's meaning. In this sense the link between expansion of HE, work and skills can be interpreted as a phenomenon that belongs to a field of its own, which is research in HE. Internationally, the necessity of linking universities, skills acquisition and application through employment has been evidenced by riots emerging in the 1960s, which led both national and regional states to address participation, expansion and inclusion in HE as indexes that influence solutions to practical problems when approached from the theoretical and empirical perspectives uniquely to high learning.

Furthermore, the swift of concentration to focus on market management in the 1980s as a new theme implied new strategies of governance in HE whereas internationalization and globalization in the 1990s have accelerated investigations of proximities between universities to become modern institutions where generation of knowledge and applicability interconnect. The definition of skills that contribute to minimization of national problems has been in this perspective allied with dominant topics when in Africa theoretical and empirical evidence did not match. The approach idealized by Tight (2012) on the importance of current themes as a starting position to address the way universities operate complies with Teichler (2005) empirical data about the description of the abruption of enrollment rates, graduations and employment nexus debate. In the context of Germany envisaged by Teichler (2005), for instance, university-based centers were popularized within universities as means of interlinking relevance of knowledge that became produced and applicability in the labor market, always aligning this with the quick rise of university graduates (Teichler, 2005: 455).

It is then undoubted that the correlation between universities, state and industry have since constituted international debates and curricular adjustments that aligned with the dynamics of labor market occur/red. However, even though this level of analysis (international) may be deemed as universal considering the perspective of inheritance of the Western university that spread across the African continent (including in Mozambique), concreate concerns on the theme university-employment-practical skills remains predominantly shaped by either national or regional levels under which particular higher education systems operate apart from contextual approaches.

Analyzing the national context of Mozambique, the linkages between universities, knowledge and applicability of such knowledge in the industry is meriting both cautious and systematic research. Consequently, even though the system in itself remains elitist (see Author, 2016: 27) as only about 3% of the population aged to go to university have access, a case common with other contexts of similar GDP as Mozambique, research is evidencing a unique feature of the latter country's HE. The nation is characterized by existence of exclusive shifts on the relationship between graduates and employability and the magnitude of disproportionality is considerably surging only in the last decade (2010s). Historical perspectives on the genesis of university in Mozambique may explain some of these paradoxes, especially the predominance of social sciences and humanities versus marginalization of engineering courses.

When the Mozambican HE awakened in 1962, the character of universities remained that of selecting and instructing the dominant Portuguese elites. The public debate on the role of HE for labor force prevailed undebatable as a result and the need for practical skills was less emphasized. There are at least two reasons that explained such perspective. Primarily (a) is the fact that the function of university was not mainly that of nurturing the industry but was explained in terms of both instigation and establishment of distinctive groups of citizens namely the knowledgeable (Portuguese) and the unknowledgeable (indigenous Mozambican). In the international level both Castells (2001) and Rothblatt (1997) described this approach in terms of generation of science for its own sake. In addition, (b) the notion of university versus formal employability in the context of Mozambique was novel not excluding the fact that such interlink lacked competitors as only one Mozambican graduated from university at this period. The emergence of HE in Mozambique instigated theoretical skills rather than empirical abilities.

Immediately after independence between 1976 and 1995 the state remained the unique provider of HE in Mozambique, it both steered and legislated the public universities that dominated the country. It also focused on social sciences and humanities given there was no sufficient funds to invest on practical courses. As a result, there was a stable correlation and interplay between universities and relevance through direct applicability of the knowledge that HEIs conferred to the industry based on the graduates. However, the liberalization of the market that followed subsequently in the context of Mozambique apparently confirmed the paragon of the demise that university graduation and employment are necessarily interconnected. There are visible empirical factors that contributed for this when investigating the growth of Mozambican system of high learning. The surge of private HEIs associated with the increasing number of graduates that terminated university after this period incremented lack of optimism on universities for those who solely regarded either access to HE as a success or guarantee for job. A quick survey on the stages of Mozambican HE growth as indicated, in terms of universities, enrolments and graduations may account for the complexity of the above captioned inconsistencies between access to university and value of the science universities generated as industry emerged and integration became competitive.

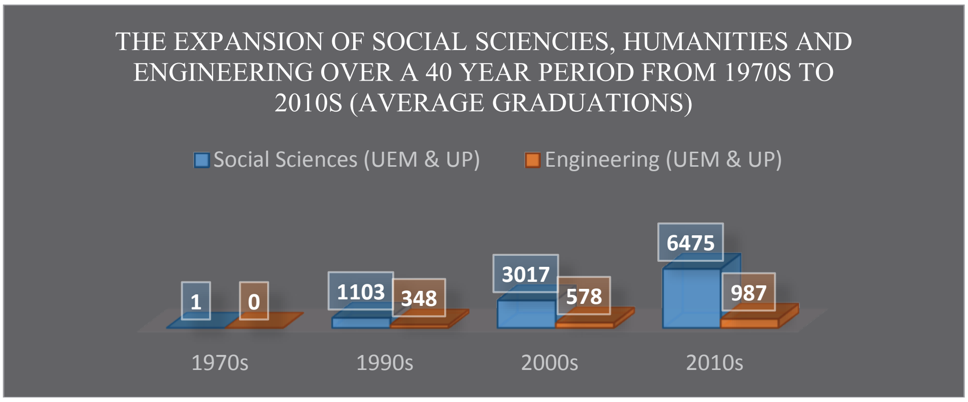
Table 1: Historical emergence of universities, enrolment and graduations: earlier connections with the industry and arena of specialization

Period	Nr. of Institutions	Average inputs	Average Outputs
1962-1975	1	500	400
1976-1995	3	1000	900
1996-2016	50	10000	8500

Source: Interpretation of Mozambican HE Expansion and Graduations

The three categories indicated in table 1 above account for the overall landscape of the rapid expansion of the Mozambican HE system with both institutions and inputs surging abruptly in the last period of analyses (1996-2016). However, such growth has been less visible in engineering as it dominated social sciences and humanities. Given the focus is to interpret the correlation between the contribution of two universities to the industry and map the gap existing between graduations and employment based on tracey study of the graduates from Engineering, Social Sciences and Humanities, the notion of an existing delink between university expansion and work force suggests an indigenous analyses of university rise. Graph 2 pictures the empirical evidence about the rise of participation in higher education in Mozambique in compliance with the domains set to be analyzed.

Graph 2: Selection of the courses and average participation in higher education (graduations and interconnection with the work market).



Source (interpretation of statistical data on higher education expansion in Mozambique & Uetela 2017: 22).

Despite the gradual rise of participation in HE for the categories selected as the main domains that interlinked universities with the industry (between the 1970s and 2010s) through knowledge production, variations in these fields of professions may outstand. In addressing this perspective, the global context’s research in HE has strongly indicated the necessity of understanding both cultures of knowledge production and levels at which such nurturing or cultivation of tribes concerning knowledge occur (see. Jawitz, 2009; Jones 2009; Healy, 2005; Henkel, 2005; Maassen, & Cloete, 2002;

Neumann and Becher, 2002 and Tight, 2012) in order to enable assessment of the way universities generate skills that influence the industry.

Hence, along with cultures and levels of analyses the dominant themes of interest for the researchers above captioned became identities, autonomy, policy, communities, atributes, contexts, tribes of knowledge and field. All these categories comply to the concern that the way Social Sciences, Humnanities and Engineering are structured to influence the industry in the context of Mozambique is shaped by international analyses though the national level dominates the maginitude at which graduates' expertese contribute to the economy.

The analyses about the contribution of the universities to the industry may not solely be limited to the increasingly growing comunities of knowledge generation as it may contradict this study considering it was based on 3 cultures from where the graduates became traced. However, it is also linked to what Gibbons et al (1994), Gornitzka (2008) and Gumport (2000) consider as the consequences of the global dynamics that are driven by shifts in institutional arrangements which even though maintain borders of knowledge the interconnection between universities, the state and the market have sharply been delinked.

Definition of Methodology: Tracing graduates from Engineering, Social Sciences and Humanities courses at UEM and UP in Mozambique

The differentiation between Engineering, Social sciences and humanities especially measured by employability and acquisition of skills that are relevant to solve practical problems has been less debated in Mozambican HE despite universities being sites where systematic knowledge and practical problem solving is constructed. Assessing how graduates become employed in compliance with the knowledge obtained in HE (Engineering, Social Sciences and Humanities) may suggest a new approach of both teaching Engineering skills within Mozambican universities and lessen their marginalization.

Based on academic registration of the universities selected, this study sampled from 1913 students that graduated in engineering between 1970s to 2010s (see table 2) distributed in averages accordingly (1970s:0 graduates; 1980s-1990s: 348 graduates; 2000s: 578 and 2010s: 987). A scale of 5 was applied (1913:5) as a means to determine the representative sample of the engineers who graduated from UEM over the period the study covered (382 engineers) and then traced those.

In terms of Social Sciences and Humanities, the above referenced strategy was also applied though with a sharp reconfiguration in the latter professions given the significant differences in terms of statistics presented between fields of specialization. For the Social Sciences and Humanities as also shown in table 3 the average distribution over the period under investigation is as follow (1970s: 1 graduate; 1980s and 1990s: 1103 graduates; 2000s: 3017 graduates and 2010s: 6475 graduations). Therefore, out of the 10596 total graduates from the domains (Social Sciences and Humanities) a scale of 10 was defined in order to trace 1.059 workers (graduates).

Under this strategy table 2 bellow shows how sampling exercise for following up (to trace graduates) was determined in the fields of knowledge production and universities selected. In addition, table 3 subsequently accounts for the structure of the questionnaire applied for interviews and the results obtained which place Engineering, Social Sciences and Humanities at different stages.

Table 3: Sampling strategy and definition of tracey study for the Engineering, Social Sciences and Humanities at UEM and UP

Selected Field	University	Total of graduates	Total of sample and scale
Engineering	UEM	1913	1913:5=382.6 graduates
Social Sciences & H.	UP	10596	10596:10=1059.6 graduates

Source: Data interpretation

Table 4: Structure of the questionnaire applied for follow up and outcome from the informants

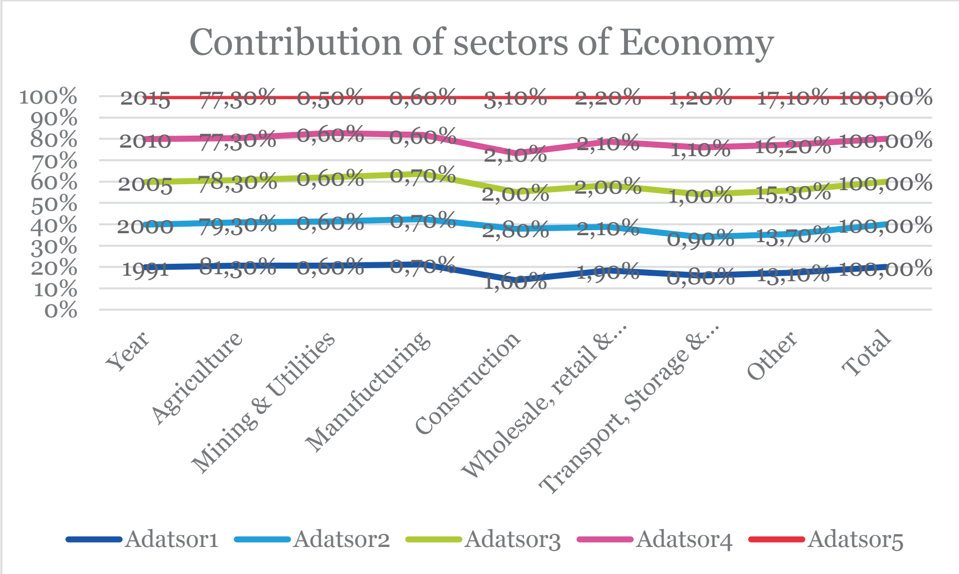
1. Gender	Percentage of respondents
(a) Male	75%
(b) Female	25%
Total	100%
2. Age range of the respondants	
(a) 24-years old	7%
(b) 27-years old	7%
(c) 28-years old	7%
(d) 29-years old	12.75%
(e) 30-years old	12,75%
(f) 32-years old	7%
(g) 33-years old	12,75%
(h) 34-years old	7%
(i) 35-years old	7%
(j) 36-years old	7%
(k) 38-years old	12,75%
Total	100%
3. When did you graduate? (Social Sciences, Humanities & Engineering)	
(a) 1999	5,25%
(b) 2003	5,25%q
(c) 2005	10,50%
(d) 2006	26,25%
(e) 2008	5,25%
(f) 2009	5,25%
(g) 2010	5,25%
(h) 2011	16%
(i) 2012	5,25%
(j) 2013	5,25%
(k) 2014	5,25%
(l) 2015	5,25%
4. What course did you attend?	
(1) Engineering	16,00%
(2) Social Sciences and Humanities	84,00%

5. When did you start looking for a paid job?	
(a) Before University	30%
(b) During University	10%
(c) After University	55%
(d) Did not seek for job	5%
For those whose answer was (c) in the previous question (obtained the job after graduation) how long did it take you to obtain a paid work after terminating HE?	
(1) 0 to 3 months	50%
(2) 4 to 6 months	18,70%
(3) 7 to 9 months	0%
(4) 10 to 12 months	0%
(5) more than a year	31,30%
6. Considering your job and activities, to what extent do you apply the skills and knowledge conferred to you by the university?	
(1) Always	50%
(2) To a greater extent	35%
(3) To some extent	10%
(4) Rarely	5%
(5) I do not use	0%
7. To what extent does your job correspond to the area of specialization?	
(1) Perfectly	20%
(2) To a greater extent	30%
(3)To some extent	20%
(4) Thinly	15%
(5) Does not at all	15%
8. Did university participation meet the expectations you had before attending HE?	
(1) Perfectly	20%
(2) To a greater extent	25%
(3)To some extent	35%
(4) Thinly meets	5%
(5) Does not at all	15%
9. Based on your experience, would you recommend someone to go to university?	
(a) Yes	95,20%
(b) No	4,80%

Discussion

The context of Mozambican alignment between expansion of HE and application of Engineering, social sciences and humanity skills through employment drawn from the data above described confirms the theory that national levels of analyses are important and shape specific HE subsystems. The description of the contribution of the industry to the Mozambican economy over the period analyzed becomes interesting to address the share of Engineering and the new approach universities should make to teach practical skills in order to solve practical problems. From the statistics, the specialization of graduates selected show variations in terms of contribution each arena of knowledge production makes to the economy of Mozambique as the study by Balchin et al (2017) over a 2-decade period further evidences on the link between skills and growth of the economy in the country.

Graph 3: Contribution of the sectors of the economy where graduates of Engineering, Social Sciences and Humanities might be employed.



Source: Interpretation of Balchin et al (2017: 16) versus data from the follow up of the graduates

Results and Conclusions

HE in Mozambique has emerged rapidly since its inception in indigenous context in the 1970s though a considerable growth of both universities and graduations significantly increased in the mid-1990s overall. The fact led to new concerns on the link between universities and work turning into a public debate since the 2010s, the moment the number of graduates in Social Sciences and Humanities surged abruptly. Furthermore, whereas in the international context both research on HE and reflections on the consequences of the growing statistics of graduates that finished university became a popular dispute in the late 1970s (cf. Tight, 2012 and Teichler, 2005), the case of Mozambique features a national analysis of its unique conceptualization.

Universities in Mozambique remain the modern spotlights that instigate transformation through informed knowledge and have since their inception maintained dominance in preparing and impacting skills that are necessary for the workforce (Castells, 2001) extending this to the generation of systematic knowledge, instruction of the human capital and dominant elites in societies. However, this did not occur at same level in all arenas of knowledge production. The actual concerns on the misalignment between graduations and labor in Mozambique evidences that there has been less emphasizes on teaching Engineering skills as theoretical problems rather than practical have dominated since. The case of Mozambique remains unique and merits a local level analysis in the sense that despite growing interest on matching expansion of HE and work, research is showing high levels of misrepresentation of engineers in a period where practical skills for practical problem resolution is relevant. Universities are both meaningful and important institutions as informants from both engineering, social sciences and humanities urge other clients to be part (cf. 95, 20% of respondents who support the role of university and informed knowledge in enhancing transformation) to the extent of yearning others to enroll.

The assessment of university relevance and meaning based on the interplay between access and acquisition of skills for work, show variations for the specific case of Mozambique. Whereas the majority consent to have acquired a paid job in the first 3 months after graduations (50% of the informants) there is also a reasonable number of graduates who remain unemployed for at least more than a year (30% of respondents). These statistics indicate that even though overall analyses of the meaning of universities show a correlation between graduations and work (the 50%) which contradicts the other perspective that growing enrollments lead to unemployment (the 30% unemployed graduates within a minimum of one year period), may sustain the contradictory functions under which Engineering and social sciences are mingled in within Mozambique. There are at least 3 perspectives of analyses that impact on the variations of the results from this research in terms of either relevance or irrelevance of universities reproducing the skills acquired in Engineering and social sciences disciplines which are essential for job attainment and contribution to the economy.

The placement of the universities selected (UEM and UP) and the courses analyzed in terms of (Social Sciences and Humanities) do not feature at the same level that foster equilibrium on the results. Again, the cultures of knowledge and institutional analyses (Neuman, 2002 and Tight, 2012 respectively) can be recalled to describe the Mozambican HE, which suggests that institutions and vocations are also key elements in linking graduations with employment. UEM and the profession of Engineering are both highly ranked and with few graduates respectively. Hypothetically, this fact led to quick integration in the labor market though the share for the growth of the economy and solution of practical problems remains low. The approach of eliticization of both institutions and graduations contradicts the dominant discourse that rising numbers of graduates going to university has led to unemployment if one considers this empirical evidence. Furthermore, the case of 50% respondents who quickly acquired employability, confirms the theory access to university versus employment nexus as correlated.

On contrary perspective, the case of UP (Social Sciences and Humanities) shows a different evidence as compared to UEM and Engineering. In the latter case both enrollments and graduations have considerably grown faster. Consequently, the theory of disconnection between universities and employment may comply to the situation of UP where surge of graduations in Social sciences and humanities has led to disproportionalities between graduates and job opportunities. The case of 30% statistics pointing to the integration after one year might characterize specific contexts of the majority of universities with specializations that alike the Pedagogic University have invested in domains of knowledge production that became popularized rather than eliticized as is the case of Engineering.

The antagonic and descriptive concerns on the landscape of the Mozambican context in terms of the link between universities and employment imposes the necessity of a cautious and analytical approach based on both contextual and national analyses in order to lessen prejudices that the rapid growth in graduation rates has always led to unemployment of the participants in HE. Instead, based on the fields of specialization analyzed, whereas in some contexts rapid expansion and graduation rates have resulted in cultivation of skills that foster knowledge culture essential for solution of practical problems in the industry, the case of domains of knowledge production that became popular has driven to unemployment (Engineering versus Social Sciences and Humanities) respectively.

The second perspective is associated with the periodicity in which such domains of knowledge production either emerged or developed. Though at the beginning (1970s and 1980s) both Engineering, Social Sciences and Humanities were at the initial stage, the role of universities at this moment in Mozambique was not necessarily employment. Preferably, the mission of HE remained that of producing knowledge that was relevant to strengthen public institutions that turned weakened after the colonial drift. During the liberalization of the economy in the 1990s there was a swift predominance in deeming universities as the modern institutions that instigate the link between knowledge and work allied with the inception of new markets.

The analyses of Mozambique's interconnections between graduations and work based on the second perspective above suggest that not only institutional, arenas of knowledge production and periodical developments of HE are essential but also historical perspectives and dynamics of ideologies have affected the interplay between expansion of HE and the popular disputes for engineering and social sciences. The fact that some graduates affirm to have looked for jobs either before or during university studies suggests that employability is not necessarily aligned with participation in HE or university certificate. Thus, formal employment is viewed by the majority of the informants to be conferred by universities given that a significant percentage (55%) did not seek job before HE completion. This approach shows that the dominant misconception that universities have the role of mainly preparing professionals for work is not solely a public concern but it also shapes the categories of reasoning internalized by key participants in HE (the graduates themselves). In addition, the case of engagement in jobs before and during university participation considered as part-time occupations that guarantee subsistence while waiting for the standardized appointment conferred after university further sustains the major vision of university in providing employability independent of the arena of expertise.

The third element that emerges is the role of the state that remained insufficient in both steering public HE allowing the insurgence of private universities a case which increased graduations in social sciences and humanities and lessened the capacities of Engineering. The historical development of Mozambican HE as prescribed by the empirical data presented in this research accounts for a surge of both universities and graduations only after the 1990s when liberalization of the economy became emphasized with individual institutions also preparing graduates for the labor force. This fact is revealed by the growing statistics in the fields of Engineering, Social Sciences and Humanities both at UEM and UP from this period. Considering these universities and their arenas/cultures of knowledge production are ancient as compared to other institutions and domains, the demise of the correlation between graduations versus employment might be high at other universities that remain novel and the industry has been sharply reluctant in admitting their labor force/capitals.

The fact that the state has shifted priorities both as a provider and steering force of HE in the context of Mozambique, has incremented unbalance between universities, courses offered and employment. This is a contradiction in a context characterized by access to higher education that remains considerably elitist (3% of participation). In the international perspectives where the public debate on increasing graduations versus unemployment emerged, the discussion has been associated with the fact that their systems were moving towards universalization of access in all knowledge disciplines (above 45%) as Trow (1970) describes.

In Mozambique at least 7 economic sectors feature as the main participating powers to the growth of the economy through GDP overall categorized in terms of (i) Agriculture, (ii) Mining and Utilities, (iii) Manufacturing, (iv) Construction, (v) Wholesale, Retail & Hotels, (vi) Transport, Storage & Communication and (vii) Other. The influence of these sectors to the growth of the economy of the country suggests that there has been an increasing demand and reliance on knowledge produced in social sciences and humanities and transformation of the country then moved slowly. Given that universities have become the new paragons where various actors interconnect to select relevant knowledge and culture (see Delanty, 2002) the predominance of the 7 above captioned sectors that influence growth in Mozambique impose a necessary interconnection between universities and growth of the national state at least in terms of systematic knowledge and utility nexus.

Such findings, which contradict the concept of demise of universities that dominated Africa and the role they play for societal and cultural change in Mozambique comply with the public debate that the notion of knowledge age is driving across national and regional perspectives. Therefore, the need for reinvention of universities not only as the institutions that guarantee employability but also where relevant knowledge for application at different contexts features as the new model that will shape curricula and definition of the meaning of university in the case of Mozambique.

An outstanding question arises based on the data from this country imposing a reflection on how universities can maximize relevance and continuity of their existence in a period where the delink between surging graduations in Social Sciences and Humanities versus employability since the 2000s is leading to high levels of contestation and demise of HEIs. Consequently, a threefold measure recommendation outstands for the case of Mozambique as a means to maximize the relationship between universities, work and skills that Engineering, Social Sciences and Humanities offer. Firstly, there is a need to restructure curricula in the courses selected for follow up (Engineering, Social Sciences and Humanities) in compliance with the market. The alignment shown in the data between the area of specialization and the current job of the graduates represented by 20%, 30%, 20% and 15% totalizing 85% imposes reforms on curricula of the specializations sampled. Despite existence of variations in levels of correspondence only 15% of informants showed disconnection between the field of instruction and arena of employability, an approach mapping the prevalence of the notion that specific skills and expertise will lead to specific jobs on one hand. However, on the other hand statistics show that the way under which markets operate is dynamic and predicted jobs are eroding. Hence, the need for curricula structure which, fosters skills that are transferable to different contexts of application and employability including self-employment becomes indispensable for university not only in Engineering courses, but in many other domains of knowledge generation.

Secondly, the meaning of university should shift from the view of promoting public good to the notion of private benefits (see Gumport, 2000) in a sense that the attachment between access to university and employability promoted by the state in terms of public interest is sharply reducing in the country. Even though it appears as a contradiction to foster private benefits in situations where universities play a public role, the state at which a necessary correlation between graduation and employability is slightly decreasing in Mozambique, imposes a cultivation of new abilities on participants of high learning. Those are not based solely on disciplinary contexts (pure Engineering, Social Sciences and Humanities). Instead, new notions need to be integrated within disciplinary cultures focusing on heterogeneity of knowledge, interdiciplinarity, multidiciplinarity or even interinstitutionalization (see Gibbons, 1994). This novel drift will enable that even in cases where the growing number of specialists (Social Sciences and Humanities) that their integration in the industry occurs after at least one year, the new abilities based on multiversity (see Rothblatt, 1997) will foster integration in dynamic perspectives of the markets especially through maximization of graduates' own employability. The perspective leads to the last analysis and attempt to respond to the quest of growing unbalance between graduations, knowledge domains and employability in the perspective discussed for the context of Mozambique, which is associated with the decrease of influence on the role of the state.

Consequently, research in HE and data analyses drawn from this investigation reveal a sharp delink between the triple-helix's main stakeholders of HE in Mozambique viewed in the global context as pivotal to instigate success based on the way universities should operate (cf. Clark, 1983). The case of Engineering in Mozambique suggests that the applicability of the previous two looming notions of interlinking rapid growth of graduations versus employability is only possible through nurturing a strong state that will invest on graduates' own employment and will bear with the risks of what is meant by entrepreneurship. Furthermore, the interplay between these three spotlights that will guarantee the success of the link between university outputs and integration in the labor market needs to be constantly strengthened. Such measure can be maximized through both informed and restructured curricula policy design so that the knowledge culture that is relevant for both self-employability and steer relevance of HE in the country based on the notion of knowledge society can be systematically cultivated through domains that are practical.

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EduScrum Method in Teaching Mathematics for Engineers

D. Velichová[1]
Slovak University of Technology in Bratislava
Bratislava, Slovakia

J. Gabková
Slovak Univversity of Technology in Bratislava
Bratislava, Slovakia

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ABSTRACT

Among a number of well-established active learning activities the eduScrum methodology is introduced as a well-known framework for project management adapted to education of mathematics for engineers. EduScrum is founded on empirical process control theory empiricism, asserting that knowledge comes from experience and making decisions is based on known facts. It was successfully adapted and implemented into the education as eduScrum method. EduScrum employs interactive, incremental approach to optimize achievability of learning goals and control risk. Implementation of this method needs a lot of preparatory work, which means a thorough didactical plan and strategy for the whole period of teaching particular course, and development of didactic materials to be used during collaborative activities in the classroom. Paper brings results on introduction of this innovative active learning and teaching method into basic courses of Mathematics for the first year engineering students. Several resources and tools were used to analyse the results of implemented empirical experiment, as study of research resources, natural didactic experiment, didactic tests and questionnaire that was non-standardised, cognitive and objectively scorable. The aim was to find level of knowledge acquisition and to compare abilities of students to solve mathematical problems independently, and as a collective work in small groups. Questionnaire was aimed to discover attitudes and opinions of students on this teaching scenario.
Evaluation of experiment results and students' achievements is presented in statistical data supplemented by analysis of feedback obtained from students.

[1]D. Velichová
daniela.velichova@stuba.sk

1 INTRODUCTION

The Fourth Industrial Revolution era with emerging 4D industry is imposing new challenges to the whole society and human activities, education at the first place. Universities are requested to provide their students with high scientific and soft-skill competencies needed for their future careers. The roles of teachers in this new framework are changing accordingly. Teachers must be prepared to work within international and multicultural teams practising „group collaboration“, rather than work on individual basis, disconnected from everyone else in the world, see [1]. The environmental changes, the lack of natural resources and time, new communication means and media, competitive environment and information data appearing in enormous amounts with high speed, are factors pushing teachers to work differently, to get out of the academic autonomy and isolation, and to collaborate with students and community of colleagues, and consequently to change the traditional ways of delivering knowledge, as mentioned in [2].

Giving our students a stimulating learning experience in various different learning environments and introducing innovative ways of teaching focused on active learning is at the heart of the Education Strategy of our age, [11]. Then main goal of this strategy is to enhance the quality of teaching and assessment, by working with students to draw on expertise and best practice both within and outside the institution, developing thus also teaching staff at all levels, and offering both - teachers and students, a vibrant and transformative experience. We should work with our students as partners, to enable them to develop their ambitions, fulfil their potential and make a positive contribution to the world, [3].

2 ACTIVE LEARNING METHODS

Many various experiments have been realised to study benefits of active learning and various analyses were published in a plethora of studies. We can mention some of the most important ones: an increase of content knowledge, development of critical thinking and problem-solving abilities, creative thinking, imagination, openness, collaborative and interpersonal skills, responsibility, and many others. Learner motivation, definitely, remains the most important from all the benefits provided by implementation of active learning methods, see [4] - [6].

Among a number of well-established active learning activities the eduScrum method will be introduced in details. Scrum methodology is a well-known framework for project management, and eduScrum is its adaptation to education. EduScrum, like Scrum, is founded on empirical process control theory – empiricism. Empiricism asserts that knowledge comes from experience and making decisions based on what is known. EduScrum employs an iterative, incremental approach to optimize the achievability of learning goals and control risk. Implementation of this method needs a lot of preparatory work. This consequently means to prepare in advance a thorough didactical plan and strategy for the whole period of teaching particular course by this method, and careful development of suitable didactic (teaching and learning) materials that are to be used during the collaborative activities in the classrooms, in more details described in [7] and [8].

The main idea is to prepare a detailed timetable of many specific activities distributed throughout the course run, during which students cooperate in small groups, usually 4 – 5 persons, and solve as a team in advance prepared collection of problems that are related to particular educational material unit, called sprint. Number of problems to solve might vary, but usually there is one problem attached to each team member. Teams of students work independently, in terms of their own organization and distribution of work in a given time slot. They can discuss all issues together and solve given problems individually or as a team, which is managed by one of them who acts as a group leader – scrum master. This role circulates among all students in the group during the course. Group leader distributes task problems to members of his team, and she/he is responsible to check and correct their solutions, to collect them all and finally she/he reports on the achieved results of the particular team work. Finally, students discuss the whole activity with all other groups in the class.

3 EXPERIMENT WITH EDUSCRUM METHOD IN TEACHING ENGINEERING MATHEMATICS

European project DrIVE MATH – Development of Innovative Mathematical Teaching Strategies in European Engineering Degrees, No. 2017-1-PT01-KA203-035866, developed and managed by the ISEP University in Porto, Portugal, is aimed at developing a novel and integrated framework to teach maths classes in engineering courses at the university level. Project partners, Technical University in Chemnitz, Germany, University Lyon 1, Claude Bernard in France, and Slovak University of Technology in Bratislava, Slovakia, cooperate on examination of the best strategies for implementation of active learning methods, innovative teaching strategies and adaptation of course curricula emphasizing the problem-based-learning approach, learning by doing (hands-on), and application of the eduScrum as pedagogical approach promoting active learning in engineering mathematics courses. More information is available at the project web-pages [9] and [10].

A short analysis of the results of experiment carried out at the Faculty of Mechanical Engineering STU within the DrIVE MATH project activities is presented in the following. Experiment was implemented in the academic year 2018/19, in the basic courses Mathematics I and Mathematics II of bachelor study programmes for the first year engineering students. The randomly chosen group of 99 students attended together lectures from mathematics delivered in lecture theatre, where the respective theoretical parts of maths were presented with example solutions of selected problems and various dynamic applications on PC. Students were distributed to 5 smaller working groups, about 20 students in each, for attending tutorials, while various teaching scenarios were applied during the academic year: team work, individual work, revision of theory, or simple presentation of solution strategies and examples of solved problems by teacher.

EduScrum method was implemented for the team work of students in small groups. There were prepared and implemented 5 sprints for team work in the first semester for subject Mathematics I, and 3 sprints for team work in the second semester for subject Mathematics II. Students were distributed to small groups of maximum 5 persons, randomly and according to their own choice (sometimes there were only 3 or 4 of them in one group), and they could use all available resources (open books approach) to find the solutions, together or one by each, according to their decision.

For comparison, there was applied also an alternative method of individual work, which was realised by elaborating worksheets prepared for students as tests with simple tasks. Students had to solve these test individually as closed book tests, usually after a self-study period, and they had to write 4 tests in the first semester and 3 tests in the second semester.

The main goals of the experiment were to find out:

- abilities of students to solve mathematical problems independently, and within a small stable group throughout the semester,
- attitudes and opinion of students on this form of teaching scenario,
- opinion of students on different teaching and testing styles – team work by means of eduScrum and individual work by writing tests.

Topics of sprints in Mathematics I covered Linear algebra, Functions with one real variable – basic properties, Differential calculus, Integral calculus I – indefinite integrals, and Integral calculus II – definite integrals. In Mathematics II the covered topics were Coordinate geometry of Euclidean space, Extrema of functions with two variables and Multiple integrals.

Each sprint consisted of 5 problems related to particular topics, one or two of which were settled as applied problems from the mechanical engineering field. Students were supposed to work in small teams in groups of 5, while always another one of them was the scrum master in the role of team leader. During the team work students cooperated together, though each one was responsible for solution of one from the problems distributed by team leader. They were allowed to use all study materials prepared by themselves. Major part, about 60 minutes of the practical exercise lasting 100 minutes, was spent solving the tasks. Team leader collected team results and delivered these to teacher before the presentation part started. Each group had to present one of the problems in front of the class, while team leader was supposed to do so. Finally, after checking of delivered solutions, teacher attached the points to each of the group so that all students in the group received the same total score of this collaborative work.

Individual work during classes consisted of self-study at home and consecutive individual work with worksheets prepared for students with problems to be solved without using any materials. Here the problems consisted of simple and more mechanical exercises, while 4 chosen topics for Mathematics I were Limits of functions and equations of asymptotes to function graphs, Derivatives of functions, Integration methods for indefinite integrals, and Determination of integration domains for definite integrals. In test for Mathematics II topics included Differential equations, Partial derivatives of functions with two variables and Integration domains for multiple integrals. Each student reached individually his point score which was added to the score he achieved from the team work.

Several resources and tools were used to reach the results of the empirical experiment, such as study of research resources, natural didactic experiment, didactic test and questionnaire. Used didactic test was non-standardised, cognitive and objectively scorable. This simply means that we have invented our own questions, focused on feedback we expected to receive from students, which was their opinion on different forms of educational strategies and scenarios, and assessment of study achievements. Questionnaire was aimed to discover attitudes and opinions of students on this teaching scenario and on inclusion of application of mathematics to the subject itself. Cognitive tests (surveys, pilot tests, and other tools) can be used to understand how respondents interpret your questions and instructions, understand the meaning of survey questions, and to recognise not well formulated questions. This type of testing can also evaluate different survey techniques used in the field to increase response or cooperation, and can help to sort out the meaning of survey responses. The aim was to find out the level of knowledge acquisition and to compare abilities of students to solve mathematical problems independently, and as a collective work in the small groups. Test was objectively scorable, as the items in it left no room for judgment in the scoring of responses. The most common form of objective item is the multiple-choice cognitive item, which eliminates the examiner bias and errors. Respondents' opinion on the implemented eduScrum method for the team work compared with the individual work was obtained also by free interviews with students.

4 ANALYSIS OF EXPERIMENT RESULTS

Prior to qualitative analysis of experiment results the analysis of its respondents is presented. The experiment was attended by 99 students, from whom

- only 1/7 were female students,
- almost 50 % were grammar schools graduates,
- more than 30 % graduated from technical secondary schools with mechanical specialisation,
- almost 20% graduated from other secondary schools,
- almost half of students have reached Matura from mathematics,
- many of students attended 5 and more lessons from mathematics per week at the secondary school, due to their choice to attend seminar from mathematics aimed to prepare students to Matura from mathematics and to take some topics at the university level (differentiation and integration of functions).
- number of students, whose mark from mathematics at the secondary school was 1 or 2 or 3, can be regarded as comparable, which was reflected in the overall average mark from mathematics at the secondary school that is very good – 2,2 (median is 2). This average mark was influenced only insignificantly by number of students (8 %) who received weak mark 4 from mathematics.

Further on it was found that almost one half of students attended Preparatory course of Mathematics at the faculty, which is realised each academic year before the start of the winter semester. Course is aimed to students who need to supplement and strengthen their knowledge from secondary school mathematics. As much as 63% students from those, whose mark from mathematics at the secondary school was 4, also took this course. It follows from the above that students from secondary schools have got very good ”initial conditions“ for the start of their engineering university study. It was assumed that the better mark from mathematics at the secondary school means the better score achievement in the experiment.

The experiment was still going on when this paper has been written (it was approximately in the second third of its run) the overall statistical verification will be realised after its completion, i.e. at the end of the second semester of the academic year 2018/19, in June 2019. Some of the partial results are presented in this paper.

Average point score for team and individual work was over 60%. In team work, this score was influenced by a very small, almost zero number of points students achieved for solving applied mathematical problem in each topic. Score in individual work was influenced by problems caused by insufficient knowledge form the secondary school mathematics, comparison see in Fig. 1.

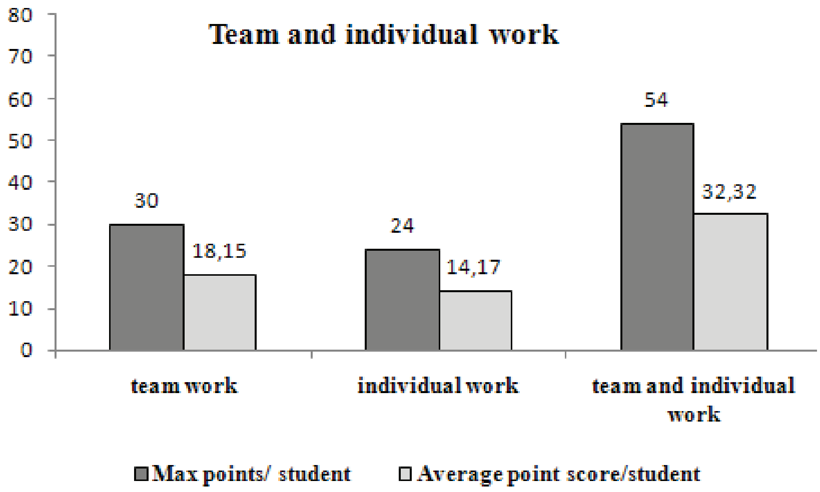

Fig. 1. Results of team and individual work

More than half of interviewed students (52,6%) regard mathematics as demanding subject (“very demanding” and “demanding”), while mathematics is not demanding only for 5,2 % of students. One of the rather negative aspects is the fact that after almost 2 semesters of study at the university, many students still evaluate their knowledge and skills from secondary school mathematics as weak, see Fig. 2.

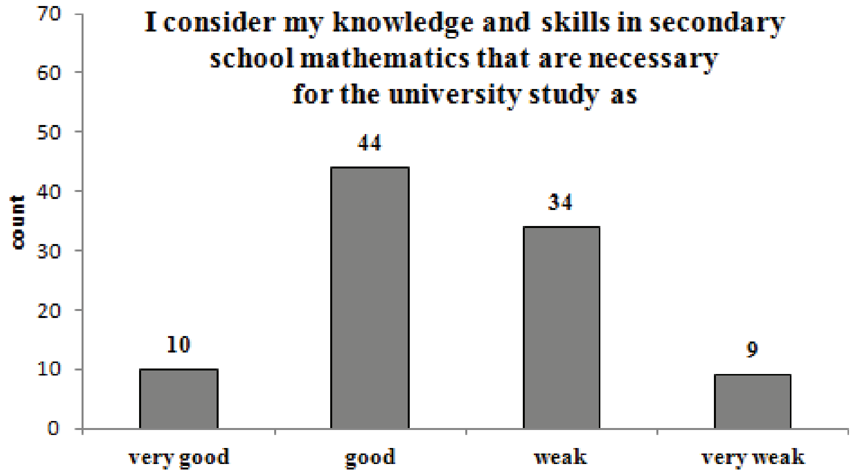

Fig. 2. Self-assessment of the secondary school mathematics knowledge

These facts could be particularly explained by the following arguments:

- students came to study at FME STU from different types of secondary schools with different approach adopted to teaching mathematics and different scope of the subject, which was reflected in different levels of their mathematical knowledge and skills,
- students do not have sufficient working methods, habits and skills for study at the university (to work independently, systematically, to be able to apply knowledge in practical tasks, to acquire knowledge, which is steady and sustainable, ...),

– university freshmen in the 1st year must overcome the difficulties of the transition period changing their study approach adopted at the secondary school to the university style,

– students who attended Preparatory course of Mathematics were „directed“ to take it by their parents, or these students were the best ones, who expected to receive more information there, not only to repeat the knowledge they have already acquired.

Majority of students appreciated team work assessment as prior to individual work (almost one half), and the next big group did not prefer any of them, as they found the applied teaching/assessment strategy as having little effect or influence on their study achievements, see Fig. 3. It could be interesting to know, which students, the better ones or not, made the choice of answer “team work prior to individual work”.

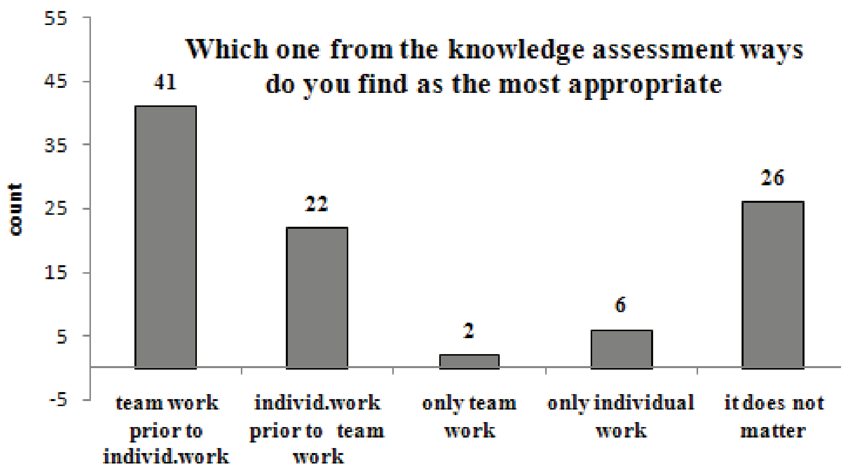

Fig. 3. Comparison of team and individual work

As mentioned before, average score in team work was influenced by applications of mathematics included in each from the topics. These problems caused difficulties to 75% of students who answered that it was “very difficult” and “difficult”, see Fig. 4.

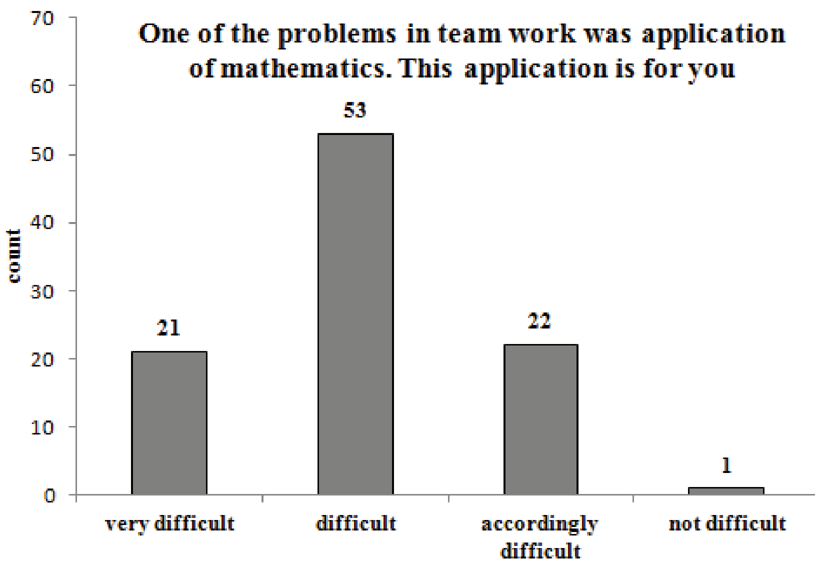

Fig. 4. Complexity of applied problems in subject mathematics

Interviews with students revealed also that:

– applications of mathematics demonstrate how mathematics can be used continually in special technical subjects,

– these problems need to be introduced into teaching mathematics from the first year of university study,

– students “started“ to work with different variables (in mathematics variables are denoted usually only as *x*, *y*), and also with constants denoted generally (e.g. gravitational acceleration constant *g* usually understood as value 9,81 m/s^2),

– students became aware of the parallels in the conceptual backgrounds of mathematics and technical subjects, for instance mathematical concept of stationary points of function is related to concept of the equilibrium position of the state in technical disciplines.

Remark: Used applications of mathematics were selected from the lecture notes for specialised subjects taught at the faculty. Some of them are introduced in the lecture notes as examples of solved problems. The advantage of these applications is that once in the further study students will “remember them”.

Questionnaire survey revealed, see Fig. 5, that team work helped more than to 72% of students to understand learned content better. As they said in the interview – this taught them also to work in team, to be responsible for their solutions and for the team as a whole, to lead constructive discussions about problems, and to gain new knowledge in problem solving. Individual work did not only help to 1/7 of students to practise learned material better, but up to 85% of students grasped the learned topics considerably better than they expected at the beginning of the academic year.

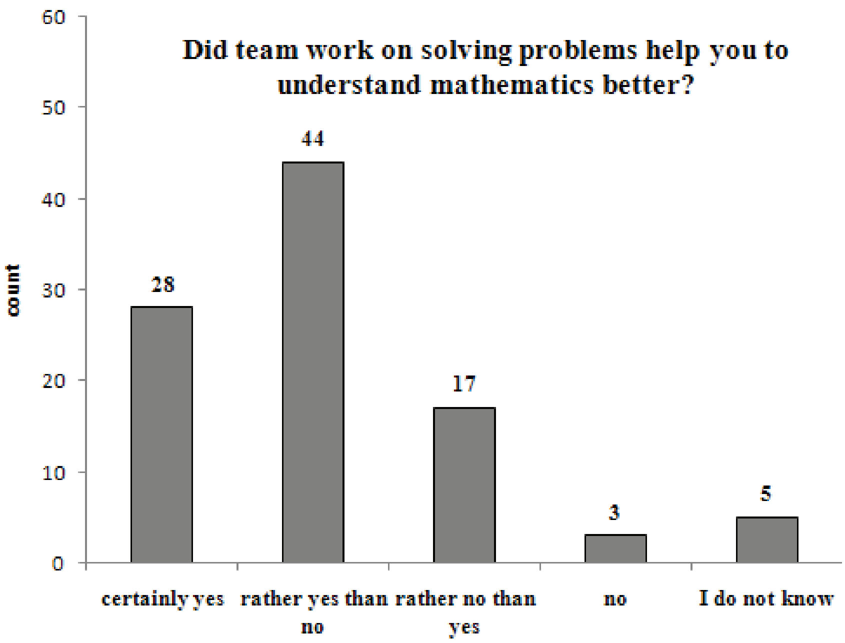

Fig. 5. Team work on solving mathematical problems

Traditional ways of assessing knowledge of students at the secondary schools, and also at universities (up to now), are based on individual work of students in form of written tests. EduScrum method introduced to students a new way of knowledge assessment, which they rated positively. Interview results and questionnaire showed that up to 80% of students would prefer to assess knowledge in mathematics during semester not only by individual or team work, but in combination of both methods, as can be seen from diagrams in Fig. 6. The newly implemented eduScrum method, chosen as the most recommended way of teaching/learning and assessment scenario, proved to be interesting not only for students, but for teachers, too.

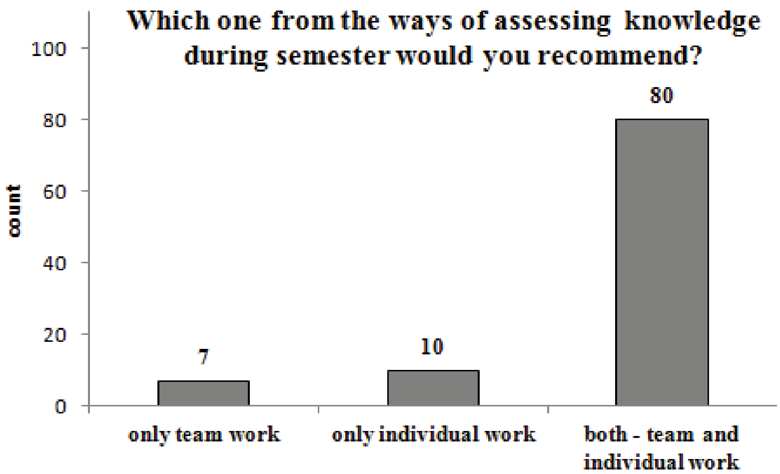

Fig. 6. Preferred ways of assessing knowledge during semester

5 SUMMARY AND ACKNOWLEDGMENTS

The main goal of the described didactical experiment was to understand priorities of young people who begin as freshmen at the technical university studies with diverse study strategies, very different level of knowledge and learning skills, and uncertain motivation. University educators seek to improve their teaching methods in order to meet the expectations of newcomers, but sometimes our efforts are directed in wrong way, missing the target group of students. Their needs differ from our conviction how they are used to work, learn and acquire new knowledge and information, due to many factors that influence our everyday life and inevitable generation change.

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Analysis of Estimated Useful and Mandatory Engineering Skills for Innovative Product Design

Ilmars Viksne
Senior Researcher
Riga Technical University
Riga, Latvia
Email: ilmars.viksne@rtu.lv

Janis Eriks Niedritis
Professor
Riga Technical University
Riga, Latvia
Email: janis.niedritis@rtu.lv

Santa Puskarjova
Senior Expert
Riga Technical University
Riga, Latvia
Email: santa.puskarjova@rtu.lv

Antoine Lanthony
Project Officer / Coordinator
Institut Supérieur de Mécanique de Paris – Supméca
Saint-Ouen, France
Email: antoine.lanthony@supmeca.fr

Mohamed El Idrissi
Education and research coordinator
Institut Supérieur de Mécanique de Paris – Supméca
Saint-Ouen, France
Email: mohamed.el-idrissi@supmeca.fr

Antonios Tsakiris
Dipl.Ing.Mechanical Engineer
Aristotle University of Thessaloniki
Thessaloniki, Greece
Email: ants@auth.gr

Athanassios Mihailidis
Professor
Aristotle University of Thessaloniki
Thessaloniki, Greece
Email: amih@auth.gr

Françoise Côme
Secretary General
European Society for Engineering Education
Brussels, Belgium
Email: francoise.come@sefi.be

Mireille Dunez-Simon
Head of the Research and Higher Education Service
Établissement public territorial Plaine Commune
Saint-Ouen, France
Email: mireille.dunez-simon@plainecommune.com.fr

Thomas Jouanlanne
Expert the Research and Higher Education Service
Établissement public territorial Plaine Commune
Saint-Ouen, France
Email: thomas.jouanlanne@plainecommune.com.fr

Conference Key Areas: Engineering Skills; Innovation as the context for Engineering Education; Sustainable Development Goals in Engineering Education.

Keywords: engineering skills, general skills, soft skills, skill levels, future engineer.

INTRODUCTION

Globalization and rapid technological development lead to radical changes in the national and regional economy. This process also changes client behavior, demand structure and has crucial influence on the labor market. In order to ensure employability and competitiveness of future engineers, it is necessary to continuously improve the study process in engineering education in accordance with the research, technology and labor market development tendencies. Engineers are expected to have not only specialized technical knowledge but also personal skills such as teamworking and leadership abilities. Moreover, they should have critical and creative thinking, ability to communicate effectively, as well as capability to handle and manage complex and unfamiliar problems and proficiency to utilize acquired skills to contribute to local community and society in cooperation with institutions and business.

The present study specifies and analyses the relevance of the skills for engineering education that are based on the convergence of project/problem-based learning, product design using rapid prototyping and computer-aided design methods. The main research methods employed are literature review, internet survey and descriptive statistics. 1115 respondents answered to the survey by 16th April 2018, when the results were gathered for analysis. The survey audience included industry representatives, academic staff, students and members of community authorities.

The study was carried out in the framework of the Erasmus plus strategic partnership project No 2017-1-LV01-KA203-035426 "Education, Business and Community Cooperation Model for a Creative European Engineering Education" under the Erasmus+ Program. There are five partners in this project: Riga Technical University (Latvia, coordinator), Institut Supérieur de Mécanique de Paris – Supméca (France), Aristotle University of Thessaloniki (Greece), Établissement public territorial Plaine Commune (France), and the European Society for Engineering Education – SEFI (Belgium).

The results are already used within the EBCC project, and it is expected that the study results will contribute to the engineering education among SEFI members and other engineering universities.

LITERATURE REVIEW

European Federation of National Engineering Associations considers skills as the ability to apply knowledge and use know-how to complete tasks and solve problems that in the context of the European Qualifications Framework are either cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments) [1]. Previous studies on engineering skills confirm the significance of both technical (hard) and nontechnical (soft) skills. It is important to determine the optimal proportion between hard and soft engineering skills and the required level of these skills.

The “Future of Jobs” report presents information and data collected by the World Economic Forum [2]. It provides specific information and analysis about middle-term trends in global industry and their impact on job functions, employment levels and required skills. The selected skills are based on O*NET Content Model. The report shows that 33% (share of jobs requiring skills family as part of their core skill set) of jobs in the industry group entitled “Basic and Infrastructure” are expected by the survey respondents to require complex problem-solving as one of their core skills in 2020. Other skills have following shares: social skills – 17%, process skills – 19%, systems skills – 26%, resource management skills – 15%, technical skills – 20%, cognitive abilities – 19%, and content skills – 13%. The complex problem-solving skills dominate also in total, 36% of all jobs across all industries needs them, but data are different for other skills: social skills – 19%, process skills – 18%, systems skills – 17%, resource management skills – 13%, technical skills – 12%, cognitive abilities – 15%, content skills – 10% and physical abilities – 5% [2].

Employers expect that engineering graduates have acquired both technical and soft skills that together form the overall engineering competency needed for graduates’ employability and successful professional career [3]. The study curriculum should ensure the qualitative fit between the outcomes of the learning process and expected skills of newly employed engineers. Ability to manage projects, people and activities has same importance as technical skills. Many studies prove that the ability to manage technology projects is one of the fundamental competencies of engineers [4]. There are evidences that person’s gender and experience in industry influences judgements on the importance of professional skills but particularly in relation to the importance of pure technical skills over soft skills. For example, female respondents consider non-technical skills more important than male respondents [5].

Some publications describe practical procedures for integrating in the educational process activities aiming to support local community in solving real problems related to local area. Such complex learning involving not only academic theory, contextual problem analysis and problem solving, but also awareness of possible societal impacts. For example, the National Institute of Technology, Maizuru College offers practical engineering education that teaches how to utilize engineering skills to contribute to local area in cooperation with local society. The students apply their practical engineering skills and propose solutions to real problems related to local area by fabricating prototypes needed for problem solutions. The authors recognize difficulties to contribute to local area directly by educational activity [6].

Also, students can feel themselves less at ease with some kinds of skills. A self-assessment experiment was conducted at ISMEP-Supméca in France to track how students' perceptions of their abilities changed. It has shown that the students self-assessed easily progresses during a project period in methodological and technical skills (9 skills – 40.1% increase over the 3 modules where the experimentation took place), then in management and communication skills (5 skills – 34.6% increase), and finally in behavioral and cultural skills (6 skills – 19.3% increase) in which some rare students even felt worse at the end of a project period than in the beginning. So, it is also interesting to compare if key-skills according to the survey conducted could be considered by students as difficult to acquire and enforce [7].

METHOD

A survey was developed in order to determine to what extent students should acquire skills considering the research, technology and labor market development tendencies and needs of local community. It assessed the overall perception on the requested level of skills through close-ended questions. The survey was anonymous. The questionnaire was written in four languages (English, French, Latvian and Greek) and uploaded to an on-purpose built site to allow for easy participation. The English version is shown in Appendix.

A random sampling technique was employed. The authors used primary data analysis techniques including a quantitative method of descriptive statistics analysis to evaluate the survey results.

The survey consists of two sections: The first section includes evaluation questions about the essential engineering skills whereas the second one includes information about the respondents' profile.

Concerning the first section of the survey, a list of 14 skills was created taking into account previous studies on skills for engineering education, especially, results and outcomes of projects PLACIS [8] and EPICES [9]. 29 main skills for engineering students that could be acquired during engineering courses have been specified and applied in these projects. The skills covered the three main groups: methodological and technical skills, management and communication skills, behavioral and cultural skills. Then, at ISMEP-Supméca, this 29-skill grid was reduced to a 20-skill grid and used especially for self-assessment, as already stated previously. In the current study, a refreshed, more compact grid was developed. It was made up of the following 14 skills: technical problem analysis skills (SK01), ability to assess technical solution alternatives (SK02), ability to substantiate and present technical problem solutions (SK03), project management and control (SK04), resource identification and rational use (SK05), product manufacturing management skills (SK06), general IT skills (SK07), specialized IT skills (SK08), technical creativity (SK09), communication skills (SK10), leadership skills (SK11), self-assessment skills (SK12), learning skills (SK13), and teaching skills (SK14). The survey form contains a more detailed explanation of these skills, for example, self-assessment skills are characterized as the ability to conduct self-analysis, to evaluate accurately their own level of knowledge and performance of skills.

In the questionnaire, the respondents had eight choices to pick from: proficiency level (PL), advanced level (AL), upper intermediate level (UIL), intermediate level (IL), elementary level (EL), beginner level (BL), not needed anymore (NN) and not sure (NS). If a respondent has selected 'not sure', then this answer was not taken into account in the future analysis. Each answer option had a numeric value ranging from 0 to 10. The answer ‘proficiency level’ had value 10, but the answer ‘not needed anymore’ – 0. The survey form included also a field for comments.

The profile section provided information on age, gender (female or male), position (enterprise or human resource (EHM) manager; enterprise employee (EMP); city, department, region manager or human resource manager (LG); member of academic staff (ASF); doctoral student DS); master student (MS); bachelor student (BS)), country and some additional information.

The survey was conducted from 1st January till 16th April 2018. Based on the answers gathered, the authors conducted an exploratory statistical study. The Kolmogorov-Smirnov test was applied to determine whether the survey answers followed the normal distribution having a bell-like shape [10]. The significance level of the test was set to 5% for the all respondents’ groups.

RESULTS AND DISCUSSION

A total of 1115 respondents participated in the survey. 558 or 50.0% respondents come from Latvia, 262 or 23.5% from Greece, 168 or 15.1% from France, and 127 or 11.4% from other countries. Respondents provided information on their occupation: the largest group is enterprise employees with a share of 457 respondents, followed by bachelor students – 275, members of academic staff – 190, master students – 177, enterprise or human resource managers – 118, doctoral students – 60, and local government representatives – 50. 190 respondents marked that they have 2 or 3 occupations simultaneously, including 149 which were both employee and student or member of academic staff.

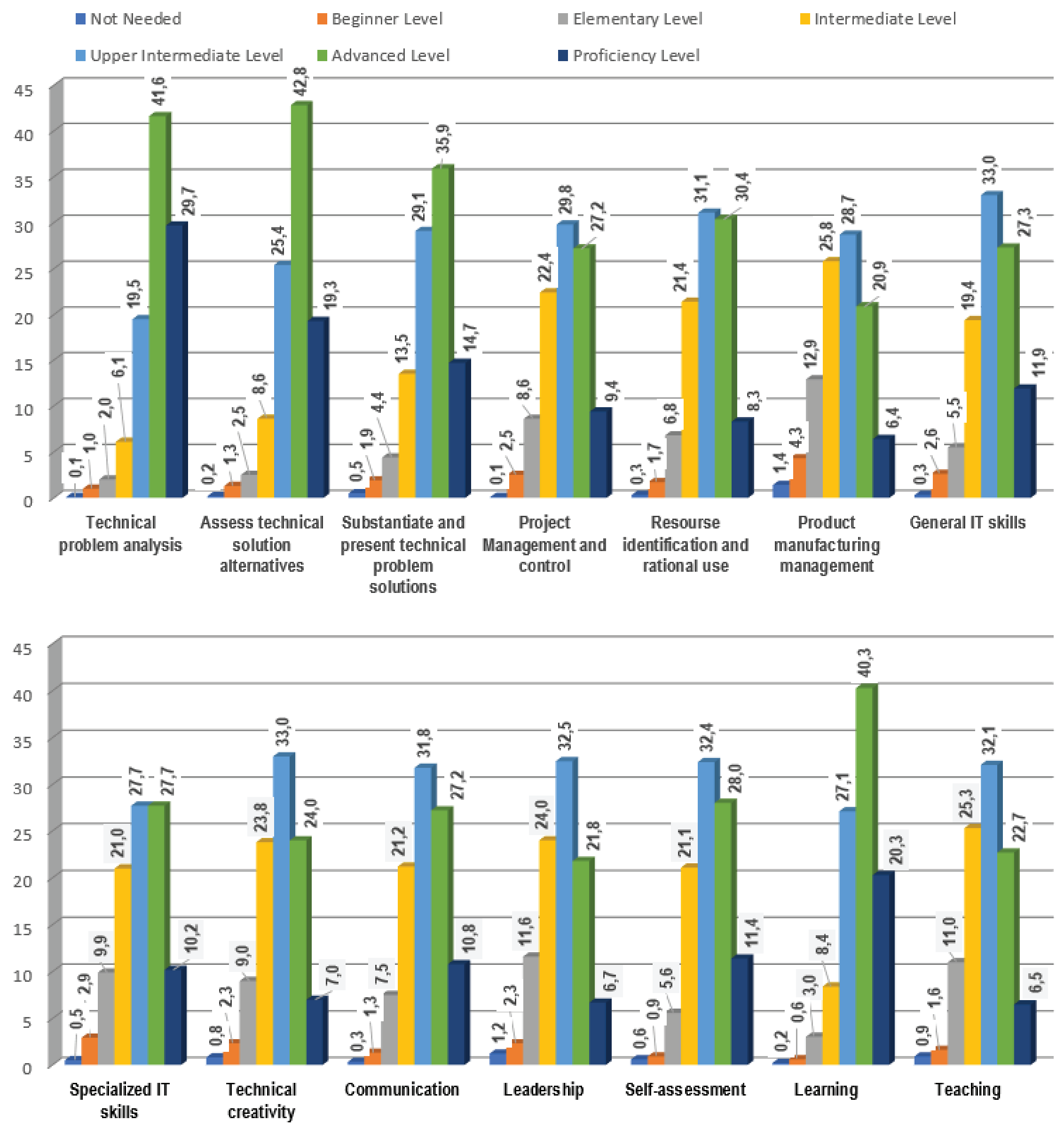

Figure 1. Summary of the survey results

The summary of all responses to the questions on the needed level of the acquired skills is shown in the *Figure 1*.

The Kolmogorov-Smirnov test demonstrates that the provided answers do not match to the normal distribution. The maximum value D_{max} for each skill answer is bigger than corresponding critical value D_{crt} for 5% significance level. The maximum values D_{max} are between 0.119 and 0.172, but the critical values D_{crt} are close to 0.041. Hence, the distribution seems to be asymmetrical. The median values MD range between 8.33 and 6.67, whereas the mean value M of the skills varies in the range from 6.05 for the product manufacturing management skills to 8.13 for the technical problem analysis skills.

The respondents recognize the need to acquire at a higher level the problem analysis skills (M = 8.13; MD = 8.33), the learning skills (M = 7.73; MD = 8.33) and the ability to assess technical solution alternatives (M = 7.72; MD = 8.33). 71.3% of the respondents suggest the proficiency level or the advanced level for the problem analysis skills.

Students should be able to identify a problem, determine the factors that influence it and creatively assess the interconnections.

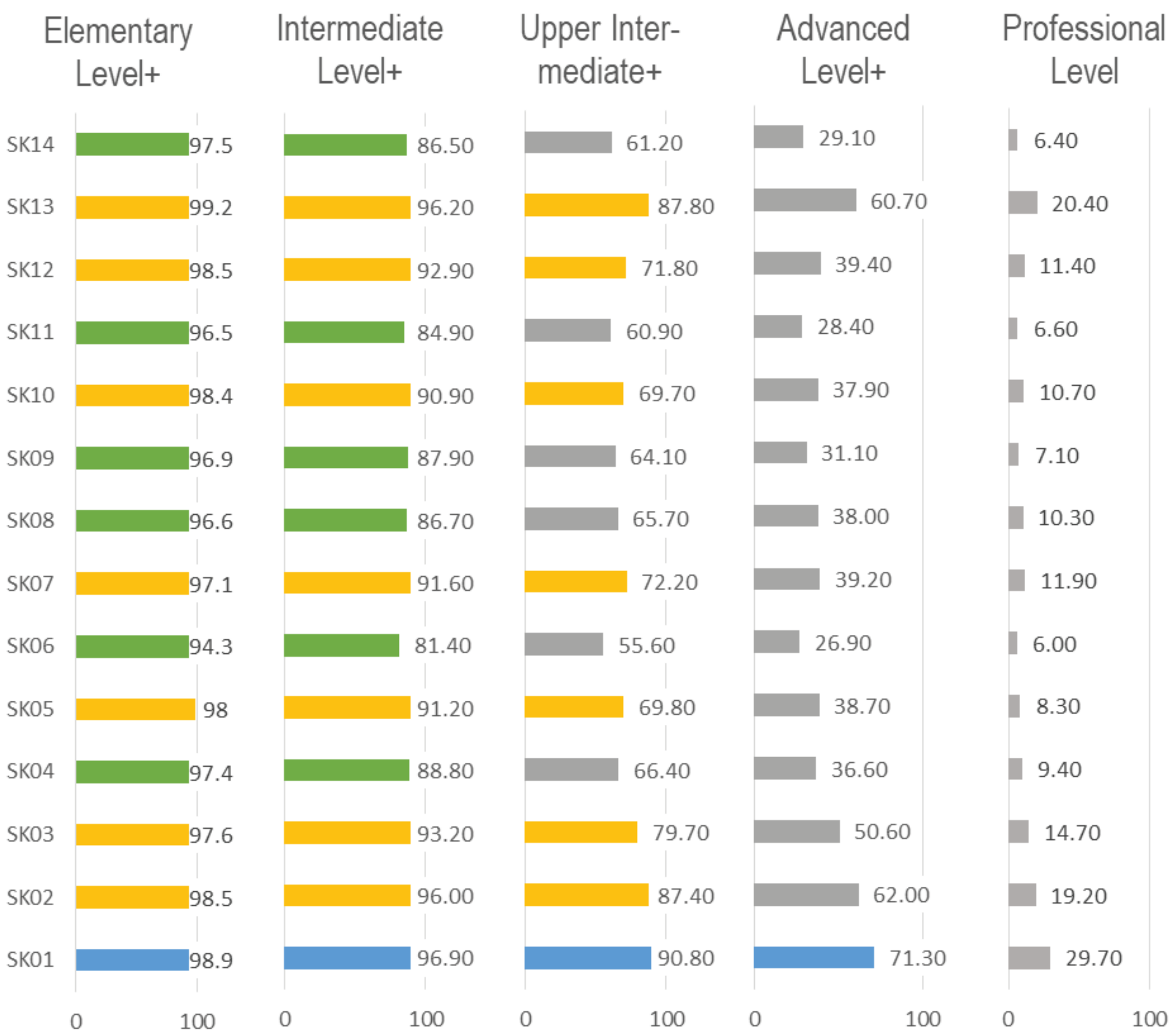

Figure 2. The suggested level for acquired skills and cumulative percentage of answers

About ten percent fewer respondents advocate the proficiency or the advanced level for the learning skills (60.7%) and the ability to identify technical solution alternatives and conduct their comparative assessment (62.1%). The survey shows that the learning skills are just as important as technical skills in all sample groups. The strong learning skills are required for success in professional career and during studies in a university or non-formal learning in various professional development courses.

Among the skills with a lower recommended level are the product manufacturing management skills (M = 6.05; MD = 6.67), the leadership skills (M = 6.27; MD = 6.67), and teaching skills (M = 6.34; MD = 6.67). Less than one third of the respondents suggests the proficiency or advanced level for these skills, respectively 27.0%, 28.5% and 29.2%. So, the respondents believe that product manufacturing management skills could be advanced in the next workplace and according the business needs and specifics. However, more than 81% respondents think that these skills should still be acquired at the intermediate or higher level.

The so-called "soft" and "hard" skills can be found among the ones with a higher as well as with a lower recommended level. So, if looking back to some skills where students self-assess not really well, these ones are distributed among both very valued and less valued.

SK03, meaning the ability to substantiate and present technical problem solutions, has a mean value above 7, but if we look at the median value, the result is lower. This indicates a distribution more concentrated in the lower levels. Hence, around 50% of responses are situated between BL and UIL, whereas for the SK01 (technical problem analysis skills) only 27.6% of the responders consider it as less important.

Figure 2 shows the cumulative percentage of answers by skill level starting from the elementary level towards higher levels. Consequently, the value next to the bar shows how many respondents advise the level of this column or higher for the skill. If the value is equal or bigger than two thirds, then the authors count that level as required for the skill.

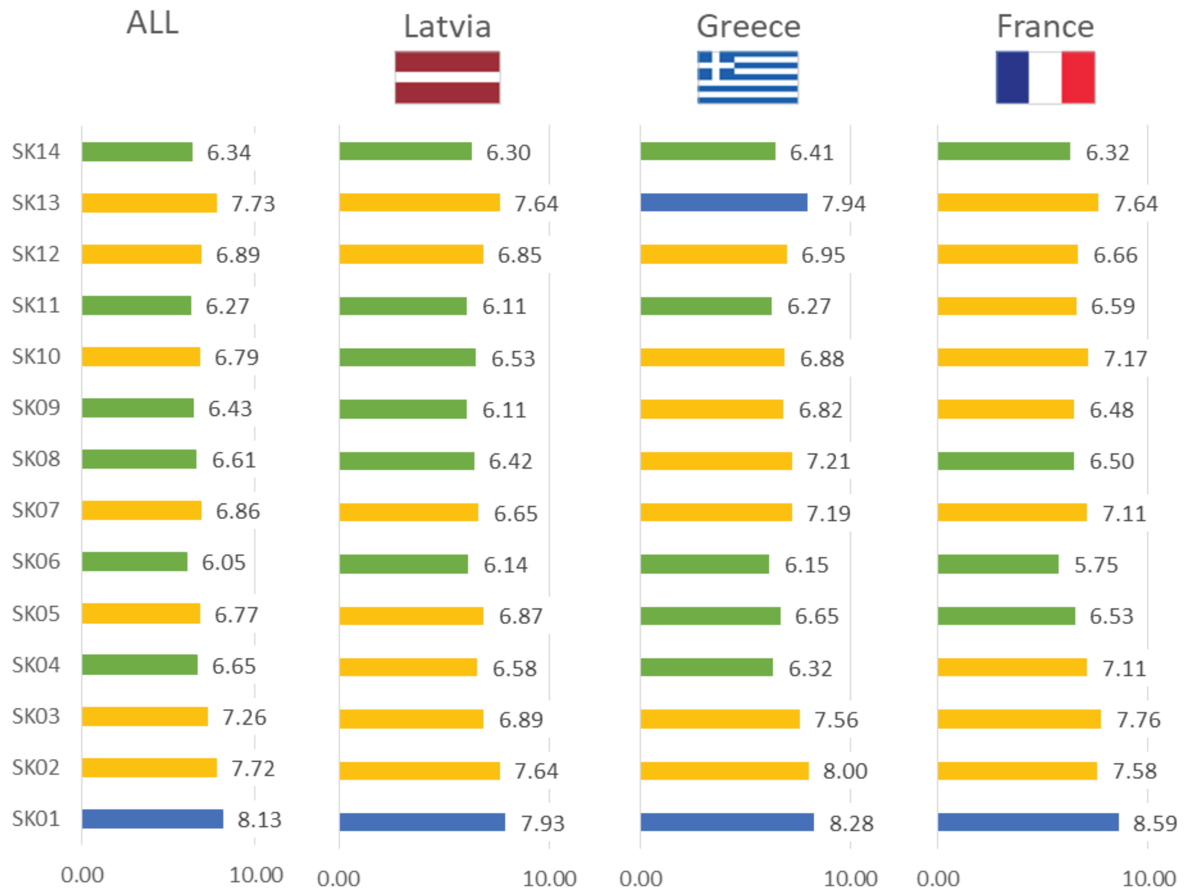

Figure 3. The suggested level for acquired skills and the mean value of the skills by the sample groups

There are 4 levels for the 14 selected skills: advanced level (light blue), upper intermediate level (light gold), intermediate level (light green) and professional level (light grey). The survey indicates the top position of the technical problem analysis skills (SK01) that is requested at the advanced level. The upper intermediate level needs 7 skills: the ability to assess technical solution alternatives (SK02), the ability to substantiate and present technical problem solutions (SK03), the resource identification and rational use (SK05), the general IT skills (SK07), the communication skills (SK10), the self-assessment skills (SK12), and the learning skills (SK13). Other 6 skills are needed at the intermediate level.

The study includes data processing and analysis for the sample groups by country and occupation. The authors compared the answers of the sample groups with answers of all respondents (see *Figure 3*). There are generally no substantial opinion differences between the sample groups and survey respondents in total. The differences in the requested skill level do not exceed one level and the mean values have usually differences less than 5% (the maximum is 8.3%). The views of all groups are identical for the upper intermediate level to the ability to substantiate and present technical problem solutions, to the general IT skills, and to self-assessment skills as well as for the intermediate level to the teaching skills.

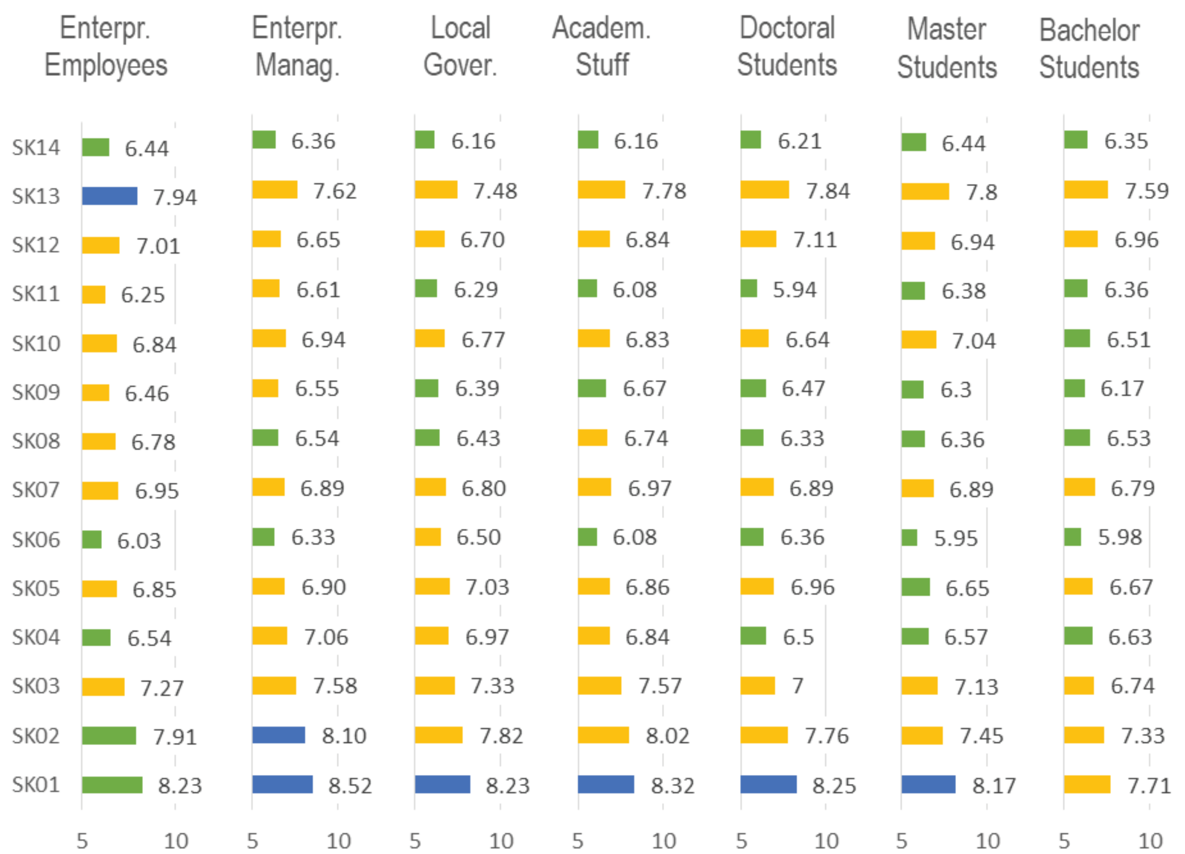

Figure 4. The suggested level for acquired skills and the mean value of the skills by the sample groups

The opinions are clearly divided only for four skills: The project management and control (SK04), the resource identification and rational use (SK05), the specialized IT skills (SK08), and the technical creativity (SK09). Management of enterprises and public institutions as well as academic staff appraise the project management and control skills higher than the employees and all students' groups, including doctoral students. The bachelor students evaluate almost all skills less important than other groups excluding the leadership and the self-assessment skills. The enterprise employees and academic staff suggest (*Figure 4*) acquiring the specialized IT skills to the upper intermediate level, but other example groups and in total – to the intermediate level.

The share of the doctoral students in the survey is 5.4%, but their assessment of the skill levels completely matches to the results of the whole survey.

Concerning the difference of opinions among countries, there are some particularities that can be highlighted: the ability to substantiate and present technical problem solutions (SK03) is obviously more valuated by respondents from France, whereas specialized IT skills (SK08) are more valuated in Greece.

CONCLUSIONS

The survey assesses the overall perception on the acquired level of 14 skills through close-ended questions. It employs a random sampling technique and the questionnaires were distributed through online. The study authors use primary data analysis techniques including a quantitative method of descriptive statistics analysis to evaluate the survey results. The survey data processing and analysis for the sample groups by countries and occupation to explore opinion differences between the sample groups and survey respondents in total. The performed Kolmogorov-Smirnov test demonstrates that the provided answers do not match to the normal distribution. The survey results indicate the crucial role of the methodological and technical skills. More than two thirds of respondents believe that technical problem analysis skills should be acquired at the proficiency or advanced level, whereas more than half of respondents think that the ability to assess technical solution alternatives and the ability to substantiate and present technical problem solutions should also be at the proficiency or advanced level. The learning skills also reach high approval rate. More than 60% respondents consider them as key skills that need to be acquired at the proficiency or advanced level. The survey data processing and analysis of the sample groups by country and occupation show that there are no substantial opinion differences between the sample groups and survey respondents in total. All groups consider the upper intermediate level for the ability to substantiate and present technical problem solutions, the general IT skills, and self-assessment skills as well as for the intermediate level to the teaching skills. The differences in the requested skill level do not exceed one level and the differences of the mean values are negligible. The study results will contribute to future development EBCC project, especially in writing guidelines in order to improve the implementation of selected skills. They will also contribute to the development of the engineering education among SEFI members and other engineering universities.

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Developing interdisciplinary engineering education
The role of educational leadership

J.I.A. Visscher-Voerman[1]
Saxion University of Applied Sciences
Deventer, the Netherlands

K.J.P. Brouwer-Truijen
Saxion University of Applied Sciences
Deventer, the Netherlands

C.L. Poortman
University of Twente
Enschede, the Netherlands

Conference Key Areas: New Notions of Interdisciplinarity in Engineering Education

Keywords: Educational Leadership, Leadership Practices, Interdisciplinary Education, Curriculum Change

ABSTRACT

Many Higher Education Institutes intend to implement interdisciplinarity in their engineering programs to help students prepare for future work. Realizing interdisciplinary education is not easy and requires good educational leadership. In former research by Leithwood et al, four broad categories of leadership practices have been identified as important for leadership success: setting direction, developing people, developing the organization, and managing the educational program.

In our research, we study the role of educational leadership in designing and implementing interdisciplinary engineering education. Context is the Smart Solution Semester of Saxion University of Applied Sciences, where third-year students from three or more disciplines work together in project teams on large (25 ECTS) projects, provided by research groups and business partners.

Research questions are:

- How has interdisciplinary engineering education been implemented?
- What were leadership behaviors, practices and actions in this process?

In the first phase of this qualitative, exploratory project, five key stakeholders, identified as being educational leaders, were interviewed through semi-structured interviews, focusing on the educational leadership practices. All interviews were recorded and written down verbatim. Data were coded and analyzed with Atlas.ti.

Findings are that all leadership practices were -though not equally- visible;

[1] Corresponding Author
i.visscher@saxion.nl

Implementation success depends on the amount to which the educational change has been a bottom-up initiative;
For interdisciplinary work, it is important to get to know each other's discipline, including the structure of underlying knowledge. Students are not supervised in this process, nor are the teachers working together.

1 INTRODUCTION

To meet the challenges of the future, it is important that engineers are capable of working in interdisciplinary settings. Complex problems in areas such as safety, health, or climate change, do not only require the application of technical and scientific knowledge, but also require the application of 21st century skills such as creativity, complex problem solving, digital skills, reflection, and the collaboration and co-learning of engineers in interdisciplinary teams. Many Higher Education Institutes intend to implement interdisciplinarity in their engineering programs to help students prepare for future work. In Saxion University of Applied Science in the Netherlands, a whole semester in the third year is dedicated to this interdisciplinary work.

Although the importance of interdisciplinary education in engineering programs is acknowledged, realizing it is not easy. It requires educational leaders and teachers of different educational programs to collaborate consistently, since they share the responsibility for the interdisciplinary curriculum. Interactions between teachers provide opportunities to share expertise [1]. In this respect, the way in which teachers are being supported is an important factor [2]. Teachers should not only have an 'interdisciplinary attitude' but should also experience room for strengthening their learning and working together.
Educational leadership influences the successful implementation of (sustainable) educational change [e.g. 3], also specifically in the context of realizing high quality science and engineering education [4].
In our research, we study the role of educational leadership, distributed from formal leaders to teacher leaders, in designing and implementing interdisciplinary engineering education. This is studied in the context of the interdisciplinary semester at Saxion University, in which third-year students from more than one program work together in project teams on large (25 ECTS) projects, provided by research groups and business partners. More information n the semester is provided in section 3.1.

2 CONCEPTUAL FRAMEWORK

There are two concepts that are central in this research: interdisciplinarity and educational leadership.

2.1 Interdisciplinarity

What exactly does interdisciplinarity mean? Interdisciplinary challenges do not only require the mere application of knowledge from different disciplines, but also an integrated synthesis of that knowledge. Through combining and integrating knowledge from different disciplines, new knowledge and innovative approaches can evolve through which challenges can be solved more adequately and effectively [5]. Multidisciplinarity, interdisciplinarity and transdisciplinarity can be regarded as placed on a continuum [6], ranging from no or partial integration to full integration of knowledge. When professionals from different disciplines work together, side by side, analyzing and solving the challenge without integrating the different perspectives, this is called multidisciplinarity. Within interdisciplinary settings, knowledge from different disciplines are integrated to construct a new perspective on the situation at hand. Transdisciplinarity refers to the construction of new knowledge that is synthesized from the different disciplines and underlying epistemologies. A new, integrated knowledge field emerges in which learning goals, skills, and concepts transcend disciplinary skills and concepts [7]. The higher on the continuum from isolated to transdisciplinary education, the better 21st century skills, positive student attitudes and teacher enthusiasm are promoted [7]. At the same time, this asks for more teacher involvement, professional development as well as sustainable facilitation by management. The distinction between inter- and transdisciplinary learning is “opaque” [6, p.53], and both terms are used indiscriminately in the literature. In this study, we use the word interdisciplinary.

2.2 Integrated and distributed educational leadership

The quality of the design and structure of interdisciplinary education is impacted by the interactions and (shared) responsibilities between those who are involved in the teaching and design process, and by the way in which these persons are facilitated. Powerful leadership with a clear vision on education and personal commitment are crucial to realizing a new paradigm for science and engineering education [4]. In former research by Leithwood et al [8], four broad categories of leadership practices have been identified as important for leadership success: setting direction (clear vision), developing people, developing the organization, and managing the educational program. The first category, setting direction, permeates in all activities and decisions that are being undertaken. Thus, following others [e.g. 9, 10], Muilenburg et al. [11] distinguish between three core functions of integrated leadership (see table 1). In the literature, increasing attention is being paid to integrated and distributed leadership. The question then becomes, how are activities in the three core practices integrated, and how are these activities distributed between stakeholders?

Table 1 Core functions of educational leadership [11]

Managing the educational program (teaching and learning)	Developing the organization	Understanding and developing people
• Creating a productive work environment for bother teachers and students • Monitoring school activities and results • Giving feedback to teachers based on observations of teaching processes • Allocating teachers and support staff to curriculum parts	• Developing a clear vision and goals • Managing the school environment and working conditions • Connecting the school to the community outside the school • The strategic allocation of means	• Intellectually stimulating and individually coaching teachers • Setting an example for teachers • Setting HR-policy in the school • Promoting and participating in teacher learning and development

3 RESEARCH APPROACH

3.1 Context

Within Saxion University of Applied Sciences, interdisciplinary education has been implemented in a central semester, in which currently 22 programs participate. The semester initiated within the faculty of Life Sciences, Engineering ad Design (LED), which houses bachelor programs in these domains (such as chemical engineering, electrical engineering, forensic research, biomedical engineering, industrial product design, mechatronics, information science, nanotechnology). LED started the discussion about the need for educational improvement, somewhere 2013-2014. This culminated in the design and development of the then-called 'living technology project. Since its first implementation, the number of programs participating in this interdisciplinary semester is growing, up till 22 per September 2019, including also programs from social or health disciplines. This is one-third of all Saxion bachelor programs. With the growth of the semester, the name changed into Smart Solutions Semester.

In the semester, third-year students from three or more disciplines work together in project teams on large (25 ECTS) projects, provided by research groups and business partners. The size of a student project team varies from 4-8 students. They are supervised by a tutor, focused on the learning and working process. During a time frame of 20 weeks, students work on this project, almost full-time. They meet with their tutor and client regularly, about once a week, not necessarily in the same meeting. In the meantime, they develop their project at Saxion, at the client's office, at home or at any place they feel fit. In-between sessions, they may ask their tutor for support or advice, or they may ask the instructor or another teacher to give a masterclass on a specific subject.
Some examples of projects are: green walls for classrooms, 3D-printing with concrete; early diagnosis of complex diseases (osteoarthritis); Metastasis on a chip; light detecting textiles; collaborative robots in a production environment. Since students come from different disciplines, they are supposed to share views, values, approaches, and knowledge, in order to be able to solve the question at hand. It is the role of the tutor to coach the students on their use of knowledge, research abilities, and their professional behavior (e.g. communication with client; teamwork, work ethos). Tutors do not assess their own groups.

3.2 Research questions

We started an explorative study with the aim to learn more about the design and implementation of interdisciplinary education, as well as the supportive or hindering factors of educational leadership in this process. Data gathering was focused on obtaining rich, descriptive information on both the design and implementation processes and the role of educational leadership in the program, especially in the faculty where it all started. The research questions for this explorative study (and object of this research paper) are:

- Within the faculty of LED, how has interdisciplinary engineering education been implemented?
- Within the faculty of LED, what were leadership behaviors, practices and actions in this process?

3.3 Respondents and data collection

In order to answer the research questions, qualitative interviews were conducted with stakeholders with a leadership role, focusing on their experiences with the semester. Semi-structured interviews were conducted late 2018 and early 2019. The focus was on the integrated leadership practices. The dean of the faculty identified 5 respondents, who were to be interviewed: a team leader (TL), head teacher (HT), researcher (RE), educational specialist (ES). These 4 respondents were the main educational leaders within LED during the initial design, development and implementation of the semester. They are still involved. The 5th respondent is the current overall project leader (PL), who got this role two years ago, when the semester was growing across faculties.

Each interview started with a number of general questions about interdisciplinary education and its design and implementation. Subsequently, respondents were invited to describe as concretely and detailed as possible how implementation occurred. After these general, open questions, the interviewer posed concrete questions derived from the three leadership practices, asking the respondents to specify their own role. Examples are (practice of managing educational program): What have *you* done or organized to support teachers while they were/are implementing the semester? What changes did *you* make in the curriculum to make the Semester part of it? How do *you* monitor the implementation and its results? What didactic means did *you* design to help teachers implement? To what extent did *you* decide to select teachers who fit the semester?

3.4 Data analysis

All interviews were recorded and transcribed verbatim. Data were coded and analyzed with Atlas.ti. Codes for citations and fragments were directly derived from the conceptual framework [11], as provided in table 1. Each leadership practice got a key code, and the activities a subcode. Apart from these, codes were applied to fragments about the general history of the program and to the concept/definition of interdisciplinarity. After coding, all fragments related to the same code were compared and contrasted, resulting in the description of the results. Key statements are supported with a quote.

4 RESULTS

The goal of the study was to provide rich, descriptive information on both the design and implementation processes, and on the role of educational leadership in the program. These descriptions are provided in the following sections. We did not quantify the results other than counting how many quotations were coded with a specific code for each interviewee (see Table 2 for code frequencies), indicating which leadership practices interviewees were referring to most frequently, and showing what differences there are between interviewees, or what leadership practices got most or least attention.

Table 2. Code frequency per interviewee

Respondent	General		Managing educ progr.				Developing organis.				Developing people				Totals
	History of program	Definition / implem.	productive environm	Monitoring results	Feedback	Teachers to crc	Vision	Working conditions	Connecting to comm	Allocation means	Coaching teachers	Setting an example	HR-policy	promoting learning	
TL	0	14	4	4	0	1	14	4	0	0	9	0	0	1	37
ES	2	10	0	1	0	6	4	1	2	4	4	0	0	2	24
HT	3	14	0	6	0	3	4	0	1	3	1	0	0	3	21
RE	2	4	1	2	0	3	0	1	6	1	1	0	0	2	11
PL	3	7	2	3	0	3	9	6	2	4	2	0	0	6	37
Totals	10	49	7	16	0	16	31	12	11	12	17	0	0	14	130

4.1 Implementation process of interdisciplinary education

The start: According to the respondents, there is no concrete starting point for the implementation of the interdisciplinary semester. There were several initiatives which came together. Such as an education day within the faculty where teachers from different disciplines met, the ongoing question of management for a better integration of research in the educational program, the increasing interdisciplinary character of the research projects of staff. Several programs felt the need to work together more efficiently, combining research, design and development in their education programs. They just started doing so, and designed an interdisciplinary project for students, the living technology project.

When other programs from other faculties indicated that they would like to join this type of education few years later, the interdisciplinary semester was born. This also asked for more organization, and a project leader was appointed.

Working procedures: According to the respondents, the semester has 3 goals: collaborating professionally in an interdisciplinary team, researching and creating a product. Students are, however, judged primarily on the progress of their learning, rather than on the quality of the product, since research and design processes may be functional in itself but lead to no concrete end products. The collaboration process between students is important.

According to RE, while working on interdisciplinary projects, the focus for students is not so much on fully grasping and incorporating the knowledge and skills of the other disciplines, but on understanding that disciplines have an effect on each other and that the whole is more than the sum of its parts. Others indicate that it is important that students get to understand the terminology of each discipline, and that they try to understand what the other persons really means (ES, PL). This implies that students should be able to account for their methods and have social skills to collaborate with other disciplines (RE).

Ideally, the preliminary project description is formulated in such a way that it becomes clear that students from different disciplines/programs are needed to work

together. Current practice is that several of the projects provided by research groups have a strong base in one discipline (PL).
It is up to students to show that they are going to solve a business challenge, aligned with client's wishes (PL). It is important that students have an equal share in the project, preventing freeriding. They are being coached by a tutor, who coaches students on the process. "*The role of the tutor is to create a safe learning environment*" (TL). Although tutors should -ideally- guide the process as little as possible, there are large differences between tutors ranging from directing strictly to giving students the control (ES).
Since the number of programs joining the semester is growing, several (former) questions are being raised (again): should the supervisor and/or assessor be a specialist in the subject? How to assess interdisciplinarity? Can a tutor also be a client? Overall, tutors should guide the process in a questioning way. And many new tutors find this difficult (TL). Also, since the project is meant as a vehicle for learning, this means that not all projects end with a clear and working product. Some of the clients find this difficult.
The respondents indicate that this type of education represents the future of education. And it may need preparation in former years as well as a follow-up process in the 3rd or 4th year. But not all students ánd tutors are fully comfortable, using this form.

4.2 Managing the educational program (teaching and learning)

The creation of a productive working environment: The PL obtains all projects. It is important that students can work in projects that ask for knowledge from their own discipline. The TL indicates, however, that there is too much emphasis on administration and accountability. This prevents them from investing in the development of the semester, for example through further professional development of tutors or development of assessment.

Monitoring activities and results: Currently, the program committee acts according to the PDCA-cycle. The HT stresses the importance of in-between monitoring of tutors, but also of students. The RE indicates that after the first implementation of the semester, tutors had more time to monitor student progress intensively than nowadays.
With respect to the monitoring of students, assessors are still calibrating the level of assessment. It is an important step for the further development of the implementation of the vision of the semester. But this process is very time consuming. The interviewees do not know whether tutors are being monitored by their own supervisors or by team leaders.

Giving feedback to teachers based on observations of teaching processes: Overall, it is not common to supervise tutors during the tutoring process. Incidentally, tutors could share experiences, or a new tutor could join a more experienced tutor, to watch and learn, but there is no structure or culture in which leaders observe tutors and provide them with feedback on their tutoring process. Currently, there is a trajectory of voluntary intervision, in which only 10 tutors participate.

Allocating teachers and support staff to curriculum parts: The allocation part is fairly simple. The client is stakeholder of the project. Since tutors are supposed to only coach on process, rather than content, they can be assigned arbitrarily to the project group.

4.3 Developing the organization

Developing a clear vision and goals: Especially the TL and the current PL mentioned the vison more often than the others. The TL stresses the importance of developing a clear vision. At the first implementation of the semester, this was done during an education day. Because of this process, all tutors involved shared this vision. Now that more programs are joining, the PL took the initiative to revisit the vision and write it down, reflecting the current situation. New tutors were and are not involved in this vision process. According to the TL, this is hindering the quality, because *"it creates a top-down structure and general allocation of people".* It can lead to problems, when the meaning and vision are not communicated properly and that the professionals do not understand why which decisions were taken. According to TL, the key to success is to ask the professional how the education should be shaped. Creating the curriculum together is fundamental to success.

The strategic allocation of means and managing the school environment and working conditions: Now that the semester is growing, an interfaculty project team has been formed (ES), consisting of 7 people. All members have their own responsibilities such as assessment, matching, or tutor development. Tutors have four hours per week per group for tutoring, training, (voluntary) intervision, and contact with clients. According to the respondents, this leaves no time for further development of the semester.
With respect to leadership, the TL stresses the importance of transforming the culture towards one with an atmosphere of trust. This also implies confiding in tutors, that they know what they do, since the success of the semester depends on the quality of the tutoring. *"It is, however, important to realize that not every teacher is capable of good tutoring and not every teacher is happy with this role. The selection of tutors is, thus, crucial".* Also, it is important to have enough experts available, who can be consulted by the students during the project process.

Connecting the school to the community outside the school: The project assignments are issued either by industry or by university professors. Through such assignments, industries make themselves known to students. For all clients, it is important to realize that this is an education project, as a vehicle for student learning. Since some large programs joined the semester, it might mean that some of the students are assigned to projects that do not have a base in their discipline. Although "*it can be very refreshing to have those students in your group, [but] it implies that research groups or external clients should be somewhat flexible" (RE).* This might hinder the acquisition of new projects.
Given this background, several opportunities could be explored, according to RE, such as researchers serving as an intermediary for industry, or forming student groups around a theme and -as such- joining forces, or having two student teams working for the same client, fostering competition.

4.4 Understanding and developing people

Intellectually stimulating and individually coaching teachers: According to the PL, the formulation of a vision based on current practice, and further alignment of the goals, activities and assessment was very helpful for her and the teachers. The TL indicates the importance of paying attention to the different perspectives of the teachers involved on the vision. Teachers want to help and shape education, so this means

that they should be involved from the start. "*This is my main lesson: it does not help when you define something at the strategic level and 'spread it out' over the organization. I need to be there with my team, let them do that work, and support them" (TL).* Teachers can come with questions or hurdles they are facing, but also for inspiration or to get other perspectives. It seems that teachers do so with their own TL, and less with the TL or the ES of the semester.
There are several people in, or around the project team, who have expertise on different elements of the semester. They organize single or group sessions with tutors, such as on research abilities, or on how to coach student groups. The quality of the coaching itself is not being monitored. The amount of interdisciplinarity can be traced from the portfolios of the students. And they show some diversity from multidisciplinarity to interdisciplinarity.

Promoting (and participating in) teacher learning and development: All tutors attended three three-hour training sessions, that were focused on assessment, research abilities, and coaching. The training sessions consisted of knowledge transfer, as well as practice and inter-collegial coaching. According to the PL, the training sessions should be expanded, in order for tutors to be able to further develop their behavior as a coach. Building a learning community could be an option, as well as intervision. She acknowledges that half a day per student group is not too generous. The HT indicates that it is important for tutors to have a positive attitude towards learning. "*Tutors need to be willing to discuss their own frames of reference with each other and should embrace this as an opportunity for learning rather than framing it as an extra task".* He regards it as risky when tutors stop reflecting on their own behavior with colleagues.

5 DISCUSSION

In this exploratory study, we held interviews with 5 key stakeholders who were involved in the implementation of the interdisciplinary Smart Solutions Semester. We focused on two questions:

- Within the faculty of LED, how has interdisciplinary engineering education been implemented?
- Within the faculty of LED, what were leadership behaviors, practices and actions in this process?

Overall, in Saxion, this semester started as a bottom-up initiative, with a unique and shared vision, was implemented enthusiastically by the teachers involved because they saw a real need for this type of education, and its implementation was judged as being successful by them. Other programs see its relevance and want to join. This matches with theory, indicating that bottom-up initiatives are more likely to succeed.
Now that the number of programs joining the semester is growing, the university board has appointed a special project manager to let it run smoothly, and is stimulating more programs to participate. With this upscaling, for the new programs, the semester has elements of a top-down initiative.
The interviews gave us detailed and in-depth information on current leadership practices. Activities were reported in all of the integrated leadership practices -though not equally- and we gathered information about challenges and successes, according to the stakeholders. In order to get a better understanding of the results, we conducted a short additional literature study. A comparison of our practice and the literature leads to several conclusions to be discussed in this paragraph.

5.1 Interdisciplinary education

The results show through the growth of the semester, that the idea of interdisciplinary education is attractive to an increasing number of programs. Since the number of people who were not involved in the original implementation is growing, it is time to rethink the concept of interdisciplinarity. The respondents concluded that not all of the project statements already invoke the body of knowledge from several disciplines. And, even when they do, some of the student portfolios show that they have worked as professionals, side by side, analyzing and solving the challenge without integrating the different perspectives. At the same time, there are examples of real interdisciplinary projects. So, it could be concluded that the semester is well under way, but further steps towards more interdisciplinarity can be taken. Since tutors, from the perspective of distributed leadership, have such an important role in living the vision and in implementing the concept, we searched in literature for cues. Here, we found that tutor behavior is crucial, in helping students to get to know each other's discipline.

The importance of getting to know each other's discipline: As the results show, in this interdisciplinary semester, tutors primarily coach students on process, rather than on content. Boon and van Baalen [12] came to similar findings, concluding that the focus in interdisciplinary projects is often on collaboration and communicative skills. As the student portfolios show, the outcomes of the projects can be called interdisciplinary but also multidisciplinary. It can be questioned whether coaching on only the project process is yielding optimal results. The core of interdisciplinary education is the integration of knowledge [12]. Reflective and metacognitive skills are important to understand each other's discipline, including the structure of underlying knowledge. Coaching students on these reflective and metacognitive skills might be more worthwhile, since it will help them understand the way in which knowledge in the different disciplines is being constructed, which is a first step towards integration of knowledge of interdisciplinary education.

The importance of the coaching role by teachers: Interdisciplinary learning can only be realized when learning is scaffolded adequately [5]. In the coaching role, tutors can question students, facilitate them, set boundaries between disciplines, and can help students formulate a good problem definition. Although tutors should -ideally- steer the process as little as possible, in this study there were reported to be large differences between tutors, ranging from directing strictly to letting students take control. At the same time, there is hardly any real-life information available about the tutoring behavior. Our respondents showed that teachers are not being observed and -thus- do not get feedback on their tutoring, and that there leaders do not seem to set examples by themselves. Other research on the semester shows [1] that teachers are indecisive about their role as coach, expert, or tutor. Currently, in a related research project, we are conducting a small study in which we observe ten tutors of the Smart Solution Semester in order to collect inside information about their tutoring behavior. It is an obvious suggestion to management to invest in tutor development, focusing on coaching skills, and maybe also on developing the right attitude for such activities, such as having a basic openness, willingness to work across boundaries themselves, etc. An important element in this could be the formulation of a clear HR-policy which is currently missing.

5.2 Educational leadership

Generally, we see that activities are being performed in all leadership practices, which lays the basis for success [8]. At the same time, apart from putting the vision to paper, the primary focus seems to have been put on formalizing the program and creating organizational conditions. In the process of scaling-up the semester, managerial and organizational aspects have prevailed. The leadership practice ‘developing and understanding people’ seems to have gotten less attention. Tutors have been offered a short training program, but more steps are needed with respect to providing tutors with good examples, setting up HR-policy, inspiring and helping them in their further development. There are poor insights into what is really happening in the sessions with students.
In the data, we see signs of distributed leadership, at least amongst the project team. Team members have different responsibilities in fostering the development of the semester. Teachers are then trusted to take over responsibilities during implementation, but interaction between tutors seems to be poor, and data on how the vision is being practiced is lacking.

The importance of a shared vision: Respondents indicated the importance of having a shared vision. This is congruent with findings from other research [13]. Whereas forming and practicing this vision was a bottom-up initiative at the start of the semester, now that is has grown, a steering committee has formulated the vision on paper for new tutors and programs. For some of them, this could feel like a top-down initiative. West (2014) indicates that it is important that the vision is clear and understandable, and shared by the teachers. Also, individual, professional relationships between teachers are crucial for the success of interdisciplinary education. In these interviews, it was reported that it is not natural for teachers to meet each other and it is also a challenge to get teachers with different interests and backgrounds in agreement. This aligns with others [13]. It is, thus recommended to the project team to invest in sharing, discussing and reliving the vision with new tutors. In our second phase of the research, we will more closely investige this process in those faculties where new programs are joining the semester.
Since the development of the vision has such a central role in improving education, we adhere to Leithwood et al [8], who deliberately formulate the development of a vision as a separate leadership practice, rather than integrate it as one sub activity in the leadership practice of ‘developing the organization’, as Muilenburg et al [11] do.

The importance of developing the organization: Universities are complex organizations with several faculties and departments. They are often housed in different buildings. The physical location can thus be a natural barrier for people to meet. Moreoever, implementing interdisciplinary education requires several managers or supervisors to support and approve the concept. As such, the formal organizational structure could be hindering the organization of interdisciplinary education [13]. Our semester is in a transition from being organized by its founding fathers to being organized by a central team, making choices that -naturally- canot please every single person. The focus seems to have been on making central rules and arrangements. It is a general experience that the management of the participating progams is very supportive. As such, this part of the organization is not hindering the implementation. Where it becomes difficult, is the next step, spreading it to the teachers. Because, even when there are opportunities to meet, work and learn together, this does not happen automatically [13]. Also our results do not show such natural inclination of tutors. This finding is congruent with findings by Busscher [1], who shows that tutors do not work together often. It was agreed upon by several respondents that the available time for teachers is scarce. This may be a hindering factor. Also, the (un)willingness of teachers to learn and reflect with each other might be hindering. From the concept of distributed leadership it could be argued that it is now up to teachers and their team leaders to make the next move.

6 RECOMMENDATIONS

This study has provided insights into the level of implementation of interdisciplinary education in the Smart Solutions Semester. Factors that were hindering or supporting implementation were detected and they were aligned with new and existing theory. Below, we end with several recommendations, derived from this study and its results. They might be of help for those who want to develop and implement interdisciplinary education.

6.1 Interdisciplinary education

- Interdisciplinary learning is often connected to working on real life projects. It requires not only coaching of students on the project process, but also on reflective and metacognitive skills, which are important to understand each other's discipline and to integrate interdisciplinary knowledge.
- A focus on interdisciplinary learning becomes more smoothly, when students are already familiar with working on projects in project teams in former parts of the curriculum.

6.2 Leadership practices

- All leadership practices need to be in place in order to realize a successful and sustainable implementation of interdisciplinary education. These may be distributed amongst different persons.
- Reserve ample of time and opportunity for teachers to discuss and share the vision in connection to their own views of interdisciplinary education. It increases the feeling of a bottom-up process, and its impact, even in a top-down situation. The key to success is to ask the professional how the education should be shaped. Creating the curriculum together is fundamental to success.
- Create opportunities for teachers to meet, work and learn together, in terms of sufficient non-teaching time or space (working space in the same building or on the same floor).
- At the same time, create an atmosphere that invites and stimulates teachers to build professional relationships with their colleagues, since teachers seem not to have a natural inclination to do so. An open culture, in which it is utterly normal for teachers to meet, observe each other and discuss their behaviors.
- Invest in teacher development through teacher training and intervision. The focus of teacher development should be on coaching skills for both process and knowledge (e.g. questioning students, facilitating them, setting boundaries between disciplines, and helping students formulate a good problem definition).
- Embed the teacher development in formal Human Resource Policy.

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Interdisciplinary project-led engineering education
The coaching role of the tutor

J.I.A. Visscher-Voerman [1]
Saxion University of Applied Sciences
Deventer, the Netherlands

E. van Harmelen
Saxion University of Applied Sciences
Deventer, the Netherlands

Sharon Holterman-Nijenhuis
Saxion University of Applied Sciences
Deventer, the Netherlands

Conference Key Areas: New Notions of Interdisciplinarity in Engineering Education

Keywords: Teacher as coach, interdisciplinary education, authentic projects, learner-oriented teaching

ABSTRACT

Professionals are increasingly expected to collaborate in interdisciplinary settings. Higher education institutes offer students opportunities to develop necessary skills, often in the context of project-led education. In such types of education, the role of the tutor is changing, from a focus on teacher-oriented teaching towards learner-oriented coaching, facilitating students' knowledge construction. Hardly any research focuses on how teachers apply this new didactical approach and how it impacts student learning.

In our research, we study how tutors in interdisciplinary engineering education take on the coaching role and how tutors and students value this coaching behavior as beneficial for student learning.

Context is the interdisciplinary semester in Saxion University of Applied Sciences, where third-year bachelor students from three or more (engineering) disciplines work together in project teams on large (25 ECTS) projects, provided by research groups and business partners.

Ten tutors were filmed during a one-hour tutoring session. From each film, six fragments were selected as input for semi-structured interviews fostering reflection with the tutor and with students. The results were connected to teacher beliefs and to students' evaluation and interpretation of the tutor behavior. Result are presented with respect to interdisciplinarity, and to tutoring behavior, and how students appreciate it.

[1] Corresponding Author: J. Irene A. Visscher-Voerman
e-mail address: i.visscher@saxion.nl

1 INTRODUCTION

Professionals are increasingly expected to collaborate in interdisciplinary settings. Higher education institutes offer students opportunities to develop necessary skills, through project-led education, offering contexts in which teachers and workforce professionals may have a shared responsibility for student learning. Such 'hybrid learning configurations' can be defined as "*a social practice around ill-defined, authentic tasks or issues whose resolution requires transboundary learning (e.g. by transcending disciplines, traditional structures and sectors, and forms of learning*)" [1 pp. 310]. While researching and solving the challenges posed, students -as future professionals- develop competencies and attitudes, such as being inquisitive, entrepreneurial, adaptive and flexible, being able to collaborate in teams with people from different disciplines, and (interdisciplinary) knowledge development.

In such types of education, the role of the tutor is changing, from a focus on teacher-oriented teaching towards learner-oriented coaching, facilitating students' knowledge construction. Students are expected to take responsibility for their learning, act independently, and show self-directed behavior [2]. It is often assumed falsely that students have mastered these self-directed skills, but the reality is that they have not. It is, therefore important for tutors to provide enough scaffolding and support [3]. Hardly any research focuses on how teachers in higher education apply this new didactical approach and how it impacts student learning. The primary goal of this exploratory research project is to visualize tutor behavior, and how it is perceived by students to be beneficial for their learning on areas of (interdisciplinary) knowledge development, research abilities and professional skills.

2 THEORETICAL FRAMEWORK

2.1 Interdisciplinary project-led education

In the third-year semester, students work together in project teams. The pedagogy that is being used has elements from both problem-based and project-led education. A main difference between the two lies in the question whether the product to be delivered is the ultimate goal of the learning trajectory (for example the design of an app, project-led education) or whether the route and knowledge to be gained is central (for example a research paper, problem-based education) [4]. In the semester, students are expected to show and develop research capabilities and professional skills while working on an authentic task from a client. These clients can either be researchers or professionals from industry. Students are also expected to apply and deepen their knowledge. This has reference with problem-based education. At the same time, they are expected to end up with products that adhere to the wishes and needs of the client, conform the focus on products in project-led education [e.g. 3, 5].

The project settings and the challenges in the semester are interdisciplinary. In interdisciplinary project-led education, students use and apply knowledge from two or more disciplines [e.g. 6, 7]. Interdisciplinary challenges do not only require the mere application of knowledge from different disciplines, but also an integrated synthesis of that knowledge. The combination and integration of new knowledge and innovative approaches can evolve, leading to a more adequate and effective solutions to challenges [8].

2.2 Teacher-oriented versus learner-oriented education

The focus of the semester is on the development of self-directed learning skills, knowledge construction, and collaborative learning and working. The tutor is learner-oriented and has a facilitating and a coaching role. Their role is opposite to teacher-oriented behavior, which is characterized by sharing their knowledge through direct instruction, and by a focus on individual learning [9].
The change from teacher-oriented to learner-oriented behavior can be difficult for teachers. In recent research, for example [10], the teaching style of seven tutors working in a problem-based curriculum was studied, focusing on the nature of their interventions, either aimed at content/knowledge or at the process. The researchers distinguished between a directive (teacher-oriented) and supportive (learner-oriented) style (*Table 1*). They also interviewed the tutors, on their believes about learner-oriented education. They found that -even when their believes matched the underlying assumptions of this type of education- most of the tutors still primarily showed teacher-oriented behavior.

Table 1. Teacher-oriented and learner-oriented interventions [10]

Intervention: Process/ Content	Teaching style: Directive/ Supportive	Category	Teaching Activities
Content	Directive	Teacher-oriented *Content Instructor*	Transmitting, teaching, informing, explaining, instructing, defining, checking, answering
	Supportive	Learner-oriented *Content Activator*	Challenging, questioning, activating, motivating, encouraging, exploring, connecting, elaborating
Process	Directive	Teacher-oriented *Process Organiser*	Directing, structuring, leading, chairing, focusing, inciting, addressing, reassuring
	Supportive	Learner-oriented *Process Observer*	Observing, evaluating, diagnosing, monitoring, scaffolding, modelling, reflecting

2.3 Tutor competencies

From literature, several competencies can be derived, that are necessary for tutors as coaches in learner-oriented education. These are: modeling, scaffolding, asking the right questions [e.g. 3, 4], monitoring the learning process and formative evaluation of process and product [e.g. 3, 5, 11].
By asking in-depth and supportive questions, tutors activate students' prior knowledge, question their motives and reasoning, elicit students' self-reflection, and support students' self-direct learning (e.g. 11, 12]. In addition, it is important that tutors can listen well. An active listening position is desirable, which means that tutors respond verbally or non-verbally to students, summarize what has been said, and have an open, unbiased view during the conversation [13]. In the interaction within a project group, it is also important that tutors show modelling behavior. Tutors set a good example of how to act and interact as a professional [12]. Tutors should also demonstrate empathy, for example through expressing positive expectations and avoiding prejudices, and through encouraging and complimenting students [12].
Tutors should also empathize with the students' thinking and perception world [14]. In addition, a good tutor is able to reflect on his own actions and asks students to provide feedback on his performance. In addition, giving constructive feedback and encouragement increases students' willingness to remain actively involved in the group and the learning process [15]. Finally, tutors can give students scope for their own

learning [14]. They do not dictate students what to do, they try to place the responsibility for choices in the process with the student as much as possible [11].

3 RESEARCH APPROACH

3.1 Context

The context of the research is the interdisciplinary semester in Saxion University of Applied Science, in which currently 22 bachelor programs participate. This Smart Solutions Semester initiated within the faculty of Life Sciences, Engineering and Design (LED), which houses 11 different bachelor programs. Faculty (LED) started the design of the interdisciplinary semester in 2013. Third-year students from three or more disciplines work together in project teams on large (25 ECTS) projects, provided by research groups and business partners. The number of programs participating in the semester is growing, from eleven in September 2018 (750 students and 95 tutors) to 22 programs September 2019. The tasks students work on are complex, authentic, interdisciplinary, and require students to apply a creative and inquisitive approach. Although the type and domain of the projects differ, technology always is a central component. Throughout the 20-week semester, students are supposed to develop their competencies in three areas: professional behavior; application and development of research capabilities; and application and development of knowledge from their own discipline and other disciplines.
The size of a student project team varies from 4-8 students. They are supervised by a tutor. Students work on this project, almost full-time. They meet with their tutor and client regularly, about once a week. In the meantime, students work on their projects wherever they want. They may ask their tutor for support or advice in-between sessions, or they may ask the instructor or another teacher to give a masterclass on a specific subject. Tutors are expected to encourage, question and support students in order to help them grow in these three areas and develop the necessary competences.

3.2 Research questions and data collection

The previous paragraphs show that specific, learner oriented-tutoring behavior, is assumed to be beneficial for student learning. It was also indicated that, in our institution, this type of tutoring behavior is expected from tutors. At the same time, we know from research elsewhere [10] that it is not obvious for every tutor to show this type of behavior. This leads to the question what type of behavior tutors in our organization demonstrate.

Consequently, the following research questions have been formulated:

1. How do tutors shape their tutoring role while coaching students in interdisciplinary project-led education within the Smart Solutions Semester?
2. To what extent do students experience this tutoring behavior as beneficial for their learning?

We broke down this question into several sub questions (*Table 2*). For the purpose of this paper, we focus on answering sub questions 1, 2, 5, and 6. Data has been collected by observing and filming a one-hour tutor meeting with students, of 10 different tutors, within the first 6 till 10 weeks of the semester. From this film, 6 segments were selected, as input for a semi-structured interview fostering reflection with the tutor, and one with the student group. For both interviews, an instrument template was created, containing the same types of questions, so that results from teacher and students could be contrasted.

Data collection was divided between three researchers. The interview sessions were recorded. In the interviews, the observation results were connected to teacher beliefs and students' evaluation and interpretation of the tutor behavior.
After the session, the researcher summarized the information in the interview template after which the recording was erased.

Table 2. Overview of research questions and data collection methods

Research questions	Data collection		
	Obs	Interv. Tutor	Interv. Students
1. What behavior do tutors show during a contact moment with a group of students?	X		
2. To what extent can this behavior be labeled as student-oriented or teacher-oriented, according to theory?	X		
3. To which of the three learning areas is this behavior related (e.g. professional behavior, research capabilities, interdisciplinary knowledge and learning)?		X	X
4. How student-oriented or teacher-oriented do students label the tutor behavior?			X
5. What tutor behavior do students experience to be supportive or hindering for their learning?			X
6. What is students' attitude towards student-oriented, interdisciplinary education?			X
7. What is the teacher's attitude towards student-oriented education?		X	
8. How student-oriented or teacher-oriented does the tutor label his own behavior?		X	

3.3 Respondents

The tutors in the Smart Solution Semester are teachers from regular bachelor programs, who have affinity with interdisciplinary education. There is no selection. Most of them have received a small training (3 half-day sessions). Most tutors supervise one or two student groups. They get 4 hours a week per student group (to be spent on student meetings, tutor meetings and intervision, assessment, etc). Ten tutors participated in the study. Since the aim was to explore in general how the tutor role is being shaped, representativeness of respondents was not the main concern in this phase of the study. Therefore, during a tutor training, a general announcement of the research project was made. Six tutors indicated to be available and willing to participate. Four others were deliberately invited since they were regarded by the semester project team to be good tutors.
Condition for joining was the willingness of a few students of their group to participate in the student interview. In total, nine groups were interviewed, 36 students in total. In one case, students did not find time for an interview.
Most of the tutors have a background in science and engineering/technology (*Table* 3). Interviewed students come from the following programs: Applied Physics; Biology and Medical Laboratory Research; Chemical Engineering; Creative Business and Media Information and Communication, Creative Media & Game Technology, Fashion Textile and Technology; Forensic Research, Industrial Product Design; Mechanical Engineering, Nursing, Health & Technology; Entrepreneurship & Retail Management; Software Engineering.

3.4 Criteria for selection of segments

The goal is to get a broad perspective on tutor behavior, the underlying motivation and values for this behavior, on what learning areas tutors focus (interdisciplinary) knowledge development, research abilities and professional skills), and how beneficial this behavior is, according to students. Therefore, we decided to select -per tutor- three segments of supportive behavior and three segments of directive behavior. In both areas, we strove for diversification, by selecting behavior aimed at different learning areas or different types of behavior (such as modelling, questioning, or hints, etc.). This would lead to a broad view of tutor behavior, and the underlying motivation [16].

Table 3: Overview of background of the participating tutors

Background	#
• Biology and Medical Laboratory Research	2
• Chemical engineering	2
• Creative Business - Media, information & Communication	1
• Entrepreneurship & Retail Management	2
• Fashion & Textile Technology	1
• Mechanical engineering	1
• Software Engineering	1

3.5 Data analysis

The analysis was done jointly by the three researchers. First step in the data analysis was to make 2 fact sheets per tutor observation (within-case analysis). One fact sheet contains an overview of the 6 film segments chosen, followed by the researcher’s selection criterion (indicating directive or supportive behavior, the tutor reflection, and students’ reflection. Also, it was indicated per segment to what extent tutor and students were consistent in their observation and reflection of the tutor behavior.
In the second sheet the tutor interview and students’ interview results are summarized and contrasted, on four main themes: 1) vision on the interdisciplinary semester; 2) vision on the tutor role, 3) reflection on the role and value of the tutor sessions in general, and 4) possible needs for further (professional) development or support they have. On this second fact sheet, the researchers finally formulated main conclusions regarding the tutor behavior. The researcher also listed the segments that could serve as good examples of directive and supportive behavior, which could serve as input for professional development activities. These within-case fact sheets were used for further cross-case analyses.

4 RESULTS

4.1 Interdisciplinary education

Students were asked how they experience interdisciplinary work within the Smart Solutions Semester. Six of the nine groups state to find it positive to work together with students from other disciplines, as can be illustrated with this quotation: *“Interdisciplinarity gives a nice view on the projects, a different perspective. Projects in which you work together with several people is positive".*
Three of the nine groups indicate that they pay attention to and make use of each other's discipline. *"Collaboration is going well. We try to use each other's expertise to arrive at one solution together. It probably makes it easier that we all have a technical background.”* Five of the nine groups indicate that they broke down the product to be developed into sub-products, organized mainly around the individual disciplines. These groups state that for them this is the most logical way of working, and they argue

that interdisciplinary work is a challenge due to the limited knowledge of each other's field of study. “*The work is multidisciplinary, which is much more practical. The division of labor is logically linked to the disciplines. There is little contact with the students from the other disciplines of the group, in the context of the project/ assignment*”. Others say: “*the mix between disciplines difficult to integrate, we have not yet learned much about other disciplines.*”

4.2 Student-oriented education

When asked what they think about student-oriented education, most student groups address the degree of freedom (eight of the nine groups).] to make their own choices in the process. Five groups identify this freedom as a positive aspect and indicate that their tutors do provide them ample freedom. However, two of these groups also have reservations, as can be seen from the following quotes: *"We are confident to be self-directed, but stakeholders also give us too much freedom; we actually have no guidelines*" and "*we get freedom, but also lack of clarity and insecurity*". One group states explicitly that the tutor does want to offer them sufficient freedom, but that the client, on the other hand, directs the assignment. One group of students who does not address the degree of freedom in the answer expresses concerns about the learning efficiency of student-oriented education compared to more traditional education.

4.3 Directive and supportive tutor behavior

In order to get insights into the behaviors of tutors during a contact moment with a group of students, the researchers selected 6 segments per case, 60 in total. Two of these were excluded from the interviews since they reflected the researcher’s general observation of the tutor behavior. Out of the 58 fragments, 25 were labeled as directive, 28 as supportive and 5 as directive/supportive. Table 4 shows how often which behaviors were observed in the selected fragments.

Table 4: Directive and supportive tutor behavior within 58 segments

Directive behavior (25)	**Supportive behavior (28)**	**Directive/supportive (5)**
• Tutor opens the meeting (7) • Questioning the process (5) • Informing about the assessment criteria (portfolio) (4) • Providing suggestions regarding the research approach (3) • Providing suggestions regarding the process (3) • Instructing to use a specific research method (1) • Transmitting content knowledge (1) • Informing about deadlines (1)	• Asking questions about the general process (6) • Asking questions about knowledge (5) • Observing (3) • Reflecting with students (3) • Asking questions regarding assignment (3) • Asking questions regarding research (2) • Asking questions about the groups process (2) • Scaffolding (hint) (1) • Encouraging students to take initiative (1) • Reassuring (1) • Monitoring process with respect to deadlines (1)	• Directing students to reflect, followed by mirroring students (1) • Asking questions, followed by instruction (1), • Instructing through compelling questions (1) • Asking feedback on behavior and informing about criteria (1) • Through chairing encouraging students to discuss topics (1)

The results from the interviews were connected to the fragments, reflecting to what extent the tutor behaviors are supposed to be supportive for student learning. Out of 58 fragments, 9 were left out (not discussed with students). Out of the remaining 49

segments, in 10 fragments, students find the tutor behavior NOT SUPPORTIVE for their learning (3/21 directive; 5/24 supportive; 2/4 directive/supportive).
For 7/10 segments, this relates to students and tutors having different expectations of the tutor role for the meeting. Tutors intend to have a discussion on content, whereas students only want to inform the tutor about their progress, since they already have their discussions in between tutor sessions. Students expect the tutor to monitor deadlines and support their progress.
For 39/48 segments students find tutor behavior SUPPORTIVE (18/21 directive; 19/24 supportive; 2/4 directive/supportive). For this paper, we chose 8 examples of tutor behavior that both tutor and students find supportive for student learning. We chose an example from the four most frequently selected directive (*Table 5*) and supportive behaviors (*Table 6*).

Table 5. Four segments of directive tutor behavior

1	***Opening the meeting*** T: "*Ok, let's get started, with some general stuff. Last week there were concerns about the project. I asked you to write an email with suggestions for improvement. I would like to discuss these with you [=client], to see what we could do. After this meeting I would like to discuss with two students about your personal portfolios and I would like to plan a session on presentations of the portfolio.*"	
	<u>*Reflection tutor*</u> It was a deliberate choice to take the lead, after the struggles with the client last week. Main goal of the meeting is to get informed by the students.	<u>*Reflection students*</u> This was a supportive action. T. gives good tips and asks questions. T. takes the lead in an empathic way.
2	**Questioning the process** T*: "is there anything else to discuss? How do you work together? Does all go well? No fights?"* S*: it goes well, there are no conflits* S*: "it goes fine"* S*: "not yet".* T*: "Let's wait and see, probably in the final week, just before the deadline"*	
	<u>Reflection tutor</u> I find it important to know how they collaborate. In a previous project the group had a conflict which I found out too late	<u>Reflection students</u> This action does not bother the students much. They know that their collaboration is fine. It is, however, important that T refers to it.
3	**Informing about the assessment criteria** T: *"I am thinking, let's tell per assessment criterion what seems to you to be a good piece of evidence. And in particular, how do you demonstrate it. What argumentation is relevant, because I think that this is still difficult."*	
	<u>Reflection tutor</u> S. find working with a portfolio difficult. T. can add value here, by helping them how to collect evidence for the portfolio.	<u>Reflection students</u> We find the portfolio difficult. Some elements are difficult to prove. It is nice that T addresses this explicitly.
4	**Providing suggestions regarding the research approach** *T: "My interpretation, actually, is that you work according to design thinking. What your group is doing, is design thinking. This is a method that you can use to make a product."*	
	<u>Reflection tutor</u> Design thinking is an often used method. T wanted to provide students with insights into where they are in their process and what the next steps are according to this model.	<u>Reflection students</u> S find the tutor behavior not at all annoying. Actually very pleasant. It was his observation. Through asking questions and through observations he knows where we stand as a group.

5 DISCUSSION

The research questions guiding this study were: How do tutors shape their tutoring role while coaching students in interdisciplinary project-led education within the Smart Solutions Semester? And to what extent do students experience this tutoring behavior as beneficial for their learning?

5.1 With respect to interdisciplinary project-led education

For the 10 projects in this study, it could be concluded that the type of learning outcomes might be multidisciplinary rather than interdisciplinary in at least half of the cases. This could be due to the fact that the data was collected in the first period of the semester in which students were still starting up. One could argue that there might be a possibility that the nature of the collaboration would change towards more interdisciplinarity during the course of the semester, when students have become

Table 6. Four segments of supportive tutor behavior

<table>
<tr><td>1</td><td colspan="2">Asking questions about the general process
T: “Furthermore, I would like to hear from you what you are all doing and what you are going to do. I don't want to interfere in that conversation, so I'm just listening to your exchange.”
S: “We were actually a bit stuck last week.”
T: “Hmhm”
S: “We need to select substances and substantiate why we are going to choose that substance. We didn't get out of this very well. So, we wanted to ask experts from the research group to help organize a focus group.”
T: “Oh, how good!”</td></tr>
<tr><td></td><td><u>Reflection tutor</u>
T. always asks about the state of affairs, has previously aimed for more exchange between students and now, T. is more listener. T. thinks it is important to know the content of the project.</td><td><u>Reflection students</u>
S are fine with T asking about it. S see that T. hopes that there will be an exchange between us.</td></tr>
<tr><td>2</td><td colspan="2">Asking questions about knowledge
T: “Do I understand you're going to make the substance X with an extra molecule on it or something?”
S: “Yes, the idea is to make it with an extra molecule, which is allowed, and if that is done enough we take the molecule off”.
S: “And then we have what we need.”
T: “So, you end up with a detour to get where you need to be?”
S: “Right”</td></tr>
</table>

	<u>Reflection tutor</u> T. thinks it's fun and important to be up to date on the content as well. T. also believes that S. should be able to communicate about content in layman's terms.	<u>Reflection students</u> Very positive; these questions show T's involvement. The question shows that T. knows what is crucial for the project.
3	**Reflecting with students** [Because of the length of this segment, we provide a summary] In this fragment, students reflect on the contact and the relationship with the client. They state that the client provides contradictory information to students and that, in the opinion of the students, there will be no confirmation from the client. Tutor listens attentively during this segment and asks reflective questions.	
	<u>Reflection tutor</u> During a former progress meeting with the client, S. felt overwhelmed by the client T. mentioned this on their behalf and reflected on it with S. Ideally, S. do this themselves, supported by T. But S also need to learn how to have such a conversation, so then an example will help.	<u>Reflection students</u> The client was very directive. T stood up for us during the conversation with the client, and reflected on this with us. This was very instructive. Now, we dare to be more explicit to the client.
4	**Providing suggestions regarding the assignment** *During this fragment, students are talking to each other in terms of content. Tutor observes during this fragment and does not intervene in the discussion.*	
	<u>Reflection tutor</u> I let students direct from the beginning. Students conduct the conversation and I occasionally mix in.	<u>Reflection students</u> We conducted the conversation and T supervised our agreements and structure, so that it does not go in all directions.

acquainted with each other. But given the answers of several respondents, it is more likely to assume that a mere interdisciplinary goal is not being reached yet. One hindering factor might be the choice by management that tutors should only supervise the process, rather than the content. As such, the focus seems to be more on the working process rather than on the underlying learning process. Recent literature shows that in order to reach interdisciplinarity, students should be guided on this learning process [17]. In general, in many education programs the main focus is on process organization (how to get people together, how to communicate), rather than on getting to know each other's discipline. This is supported by the data of these 10 tutors. In order to become really interdisciplinary, it may ask more supervision by tutors in this respect.
Students also differ in the amount of experience with working in project teams when they start the semester. It is a recommendation for the programs to give them that experience earlier in the curriculum. A curriculum structure of moving from multidisciplinarity to interdisciplinarity might be useful.

5.2 With respect to tutor behavior

We started the research with the idea that supportive behavior should be preferred above directive behavior. In our study, all tutors showed both directive and supportive behaviors during the tutoring sessions. Strikingly, students are generally satisfied with the tutor behavior, either directive or supportive, and they are not able to identify many explicit points which behavior is counterproductive for their learning process. It could be that there are really no behaviors that are counterproductive to the learning process. However, this is not plausible. It is more likely that students are still insufficiently able to reflect on their own learning process and what is counterproductive in this respect.

Especially when we assume that a number of students are not used to giving shape to their own learning in this way during the first part of their program. The method of data collection may also have had an influence on these results. Although anonymity has been promised in the report, it is possible that students do not dare to be critical of the tutor, who will keep supervising them during the process and who is also an assessor in the semester.

It is thus up to tutors to look for a good balance between the two behaviors, which makes it possible for students to experience a growth in the skills that are central, without the students drowning or swimming. It is important for tutors to make a diagnosis that focuses on where the students stand in their learning process, what their skills are in the area of collaborative and reflective learning, and to what extent they are already self-directed, by, for example, properly assessing the level and needs of the students and, on this basis, making appropriate interventions as a tutor [18].

There might even be a danger in preferring supportive behavior as such to directive behavior. With tutors who are not yet competent in the skills that fit in with student-oriented education, it is possible that students will enter a kind of discovery-learning setting, which researchers have described as ineffective in the past [19]. The tutor then keeps himself on the plane to such an extent that he adds relatively little depth to the learning process that the students are forced to keep on messing around themselves.

5.3 With respect to the research approach chosen

Although it was not object of study, several tutors indicated to value the use of video fragments as a basis for the interviews as a useful vehicle for their own learning process. This was nicely reflected by one of the respondents: "*Those segments are useful. Now, I see things I do wrongly, or things I would like to do in a different way. It is useful to observe yourself. It would be good to do that more often. It is more useful than intervision with colleagues, especially because now you see yourself-in-action. Only from these few fragments, I already see several things that I would like to improve. What I see is that I am sitting in the wrong chair too often, e.g. I am steering the team, rather than letting students steer their process].*"

A nice outcome of this study is that we have 60 segments as examples of specific tutoring behavior. These examples could be used as practical input for a tutor training. Rather than speaking about tutoring, we could show concrete examples to help tutors discuss what are good and weak tutoring behaviors, and to help them reflect on their own behavior as well as their own underlying assumptions. It can build up to a more concrete list of supportive tutor behavior, as an inspiring tool for tutors, or feed the development of HR instruments within the organization.

We suggest, as the next phase in this research project, to select a few successful tutors and film all their sessions during the semester. This will give us more in-depth information about the way the sessions evolve. Whether or not there is a tendency to grow from multidisciplinarity to interdisciplinarity, or whether it really depends on the type of assignment. Whether the behavior of the tutor changes over the sessions towards more supportive behavior, since students are becoming more self-directed.
In the end, it will yield even more examples that can serve as inspiration and reflection for other tutors.

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Living labs: dealing with uncertainty in solving complex problems

C. Wehrmann [1]
Delft University of Technology
Delft, The Netherlands

M.E.D. van den Bogaard
Delft University of Technology
Delft, The Netherlands

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ABSTRACT

In engineering education students are increasingly challenged to solve complex socio-technological problems. However, there are many uncertainties in solving those 'ill-defined wicked problems'. For students, dealing with uncertainty is not easy to master.

In the minor and master programmes of Science Education and Communication at Delft University of Technology in the Netherlands, living Labs ('C-labs') are used to teach students to deal with real-life complex communication problems in technological innovation processes. Students collaborate in teams of four persons, all from different technological disciplines. Each team works closely with professionals who face the problem in practice. In the C-labs, design methodology is used to approach the problems in a structured way.

In this study we raise the question: how do students deal with uncertainties in solving complex problems in the C-labs? To answer this question we identified 3 sources of uncertainty: attributed to the individual, to the social context and to the task [7] and monitored the students during the design process by means of surveys and interviews.

Data analysis shows that students perceive all 3 kinds of uncertainty in the various stages of the design process. They use of a broad variety of responses to tackle uncertainty. The outcomes can be used to improve our ways to help students to deal with uncertainties.

[1] C.Wehrmann
c.wehrmann@tudelft.nl

1 INTRODUCTION

1.1 Problem and research question

In a report about the global state-of-the-art in engineering education Ruth Graham [1] identifies a move towards “socially relevant and outward facing engineering curricula” (p. III) that are characterized by student choice, multidisciplinary learning, and societal impact. Graham emphasises the importance of opportunities for students to gain experience outside the classroom, outside traditional engineering disciplines, and in international contexts. Overall, she anticipates a more connected curriculum for engineering students, delivered through a connected spine of design projects [1]. This is best done in dedicated learning environments that bring together social relevance, technical innovation, entrepreneurship, multi-disciplinarity, and collaboration[1] [2].

In the Netherlands, several universities have created these environments in the form of innovation spaces or living labs. In these innovation spaces projects are executed by students, together with external parties. The involvement of businesses and government, users, citizens and/or communities set living lab settings apart from regular learning environments in project-based education. Traditional academic teaching and learning is challenged by the way learning is organised in living labs [3].

In the minor and master program of Science Education and Communication at Delft University of Technology in the Netherlands, living Labs (‘C-labs’) are used to teach students to deal with real-life, complex communication problems in technological innovation processes. Students from different technological disciplines work together in teams to solve a real-life problem. Each team collaborates closely with the professionals who face the problem in practice.

In the C-labs, design methodology is used to approach the complex innovation problems. Design is seen as a creative, disciplined, and decision-oriented inquiry, carried out in iterative cycles [4]. During the cycles a design solution is developed by repeatedly exploring organized knowledge, intuition, experience and creativity as well as testing alternative solutions. This dynamic process goes on until the students developed confidence in the viability of one of the solution alternatives [5].

A crucial skill in designing is a capacity to cope with uncertainty. In dealing with complex problems, ignoring or avoiding the uncertainty leads to superficial solutions to non-existing problems rather than to making a real positive impact [6]. However, the capacity of dealing with uncertainty is actually difficult to master [7].

In this study the question is raised how students deal with uncertainties in solving complex problems in the C-labs. We investigated which uncertainties students experience at which stage of the design process, and which mechanisms they currently use to tackle them. The results can be used to form ideas about how we can teach students effectively how to deal with uncertainties in this context.

1.2 Case study: C-lab courses

The concept of the C-labs is based on authentic learning and design-based learning (DBL). Authentic learning is learning by being involved in real-world problem solving [8]. DBL is described by Gomez Punte, van Eijck, & Jochems [9] as “an educational approach where students gather and apply theoretical knowledge to solve design problems” and rooted in “active learning methods that facilitate students’ learning processes" (p.14). Designs can relate to products, tools, devices and strategies [9]. Basically, DBL is a teaching approach similar to, and often compared with, problem-based learning; however, in DBL the design process is pivotal.

Cases were submitted by government, industry and non-profit organizations. These clients were actively involved during the entire process, from problem definition to the presentation of the product. They were available for input and feedback; at set times and when students had specific questions.

Students worked in teams of 4 and each team focused on a different case; all complex socio-technical problems from practice. Criteria for group composition were students' fields, varying from computer science, mechanical engineering to architecture and industrial design; student preferences for a specific case; and scores on the DISC test for personality types (DISC stands for Dominance, Influence, Steadiness & Conscientiousness [10]).

The C-lab courses took one semester. Students worked on the case from day 1. The lectures and supervision by the teacher and student assistants were aimed at getting students to go through the design process in a systematic way, based on the double diamond model of the British Design Council [11], see figure 2.

2 THEORETICAL FRAMEWORK

2.1 Uncertainty

In this study the different types of uncertainty we discern between are derived from Daalhuizen et al. [7]. They mention that designers who work on innovations "have to deal with uncertainty associated with complexity, multi-disciplinarity and outcomes that in early phases are not – and are not supposed to be – foreseeable" (p.147). They stress that "design methodology aims to support the designer by providing structure and thus assist in dealing with uncertainty", but in practice "design methodology often does not provide methodological support that is adaptable to the individual's needs in situations of unusual or high uncertainty". They call these situations 'non-routine' situations, in which the designer does not know how to proceed.

"In routine situations, designers will either directly release a pre-set response, called skill-based behaviour. Or when features of a familiar situation are recognized, they make short-cuts within the model called rule-based behaviour (p.148-149). In non-routine situations designers go through several steps to make a decision and define a course of action. As a consequence of the frequent occurrence of non-routine situations in design processes, it is expected that the designer often performs on a knowledge-based level. In these situations, the designer will have to focus his attention on the situation and analyse and develop an understanding of the situation at an increasingly abstract level in order to develop an appropriate course of action" (see figure 1).

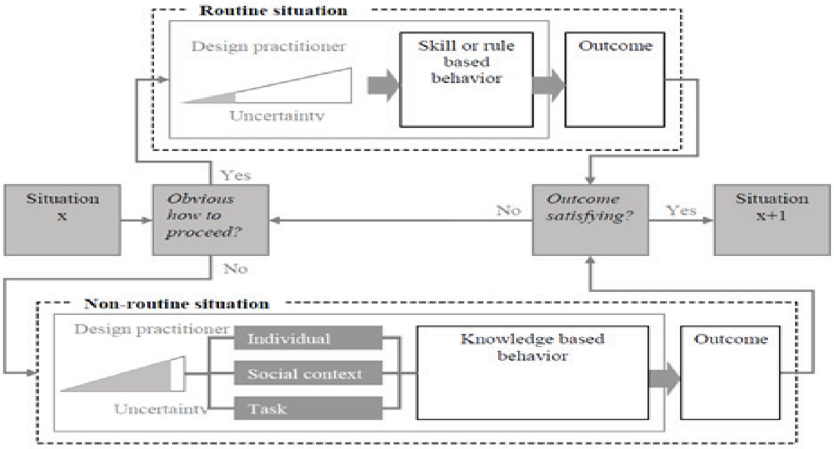

Fig.1. Sources of uncertainty leading to non-routine situations and knowledge based action. Source: Daalhuizen et al. (2009), p 150.

Almost all students who participate in the C-labs have some experience with designing and design methodology; it is incorporated in their programmes. However, none of them have any experience in designing solutions to complex socio-technical problems. In comparison with the practitioners in the study of Daalhuizen et al. [7] the students have less routine in designing and dealing with uncertainties. Still, we think the model of Daalhuizen et al. is a good starting point in our study. Daalhuizen et al. describe three sources of uncertainty: uncertainty attributed to the individual, to the social context and to the task. We tuned these definitions of the sources of uncertainty to the situation in this case-study:

1. Uncertainty attributed to the individual is caused by the absence of having the required knowledge, rules or skills to proceed in a way that is appropriate for the problem at hand. In these situations, uncertainty is perceived to be associated with the person him/herself.
2. Uncertainty attributed to the social context is perceived to be associated with the interaction between the student or team of students with the commissioners. Issues as trust and shared understanding play a crucial role.
3. Uncertainty attributed to the task in the design process, is caused by a lack of understanding of the current status or the complexity of the task necessary to proceed in a way that is appropriate for the problem at hand. In these situations uncertainty is perceived to be associated with the task itself.

2.2 Design methodology

The Double Diamond model of the British Design Council (figure 2) was used to visualise the design process in the C-lab course. In this case-study we used this model to indicate at what moment in the design process uncertainties were perceived by the students and the lecturer. The model is divided into four distinct phases – Discover, Define, Develop and Deliver. These four stages were used to indicate at what moments which uncertainties were most present.

Starting point of the model is that in all creative processes a number of possible ideas are created (‘divergent thinking’) before refining and narrowing down to the best idea (‘convergent thinking’), and this can be represented by a diamond shape. But the Double Diamond indicates that this happens twice – once to confirm the problem definition and once to create the solution. In order to discover which ideas are best, the creative process is iterative. This means that ideas are developed, tested and refined a number of times, with weak ideas dropped in the process. Practical design methods – like user diaries, journey mapping and character profiles – move a project through the four phases of the Double Diamond.

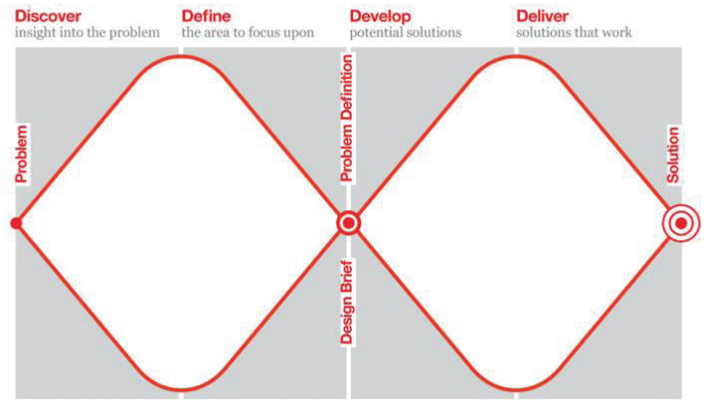

Fig. 2: The Double Diamond model of the British Design Council [10].

3 METHODOLOGY

In this study, we focus on one C-lab course in 2017-2018, attended by 36 students, who were divided into 9 teams. The students were monitored during the entire design project. *At the start* of the course they were asked to fill out a questionnaire individually, with open questions about their expectations of the course, their experience with designing, the challenges they were looking forward to and were fearing most, and their preferred way of working (with strict guidelines versus with a lot of autonomy). *During the course* they were asked every week to reflect on the past days and to note for every day what kind of activities they performed, what insights they obtained from the activities (both positive and negative), and how (un)certain they felt. They were asked to respectively visualise the activities, insights and uncertainties on three similar timelines, which made the connection between an activity, insight and uncertainty visible. *At the end of the C-lab* two students per team took part in semi-structured interviews. They were asked to consider the design process in retrospect, and share the insights they obtained during the course; the uncertainties they dealt with and the mechanisms they used to overcome the uncertainties.

Students participated on a voluntary basis. They all signed a consent form, stating that the researcher would carry out the research independently; answers would not be shared with the teacher of the C-lab, and results would be made anonymous. Students were asked to fill in the weekly surveys at set times when they worked independently on their case. They were free not to answer questions. In general, they were willing to participate in the research. However, in the final stage of their project, most students were less extensive in their answers than at the beginning. Each team decided in consultation which team members would participate in the interviews. Participants could sign up for a specific time slot in which the interview would be held. Generally they were open and answered questions in detail.

In the data-analyses the weekly surveys formed the starting point. First, it was decided which weeks corresponded with what phases of the design process (discover, define, develop & deliver). The mentioned uncertainties per design phase were coded via open coding and divided into three categories: uncertainty attributed to the individual, the social context and the task. The 18 interviews with students were transcribed, and again, the uncertainties mentioned were coded. The ways students said to cope with the uncertainties were related to the types of uncertainties. The data from the surveys at the start of the course were used to see whether the expectations of individual students matched their experiences.

In a similar course in 2018, the lecturer was interviewed on a weekly basis. He was asked to reflect on the progress of teams, his perception of the uncertainty of the students in the particular stage of the design project and the way he anticipated and / or reacted on their uncertainty in his lectures and in his supervision. The interviews with the lecturer were transcribed and used to interpret the outcomes of the student-data of the course described in this case study. They were especially of help to interpret students' uncertainties related to the social context.

Below we present the results of the study per source of uncertainty.

4 RESULTS

4.1 Uncertainty attributed to the individual

Uncertainties attributed to the individual were not often mentioned in the weekly surveys, but were discussed in the surveys at the start of the project and in the interviews at the end. Some students indicated that thinking 'outside the box' was not one of their core competences, they were afraid not being creative enough. Others feared the converging phase: "making choices from endless possibilities". Various students indicated that they were unsure whether they could provide sufficient motivation for the project, given the iterating nature of the design process ("start over when reaching a dead end", or "go through to trial and error, over and over again"). A number of students were also uncertain about making decisions, but for another reason. They claimed to be perfectionists and found it difficult to decide 'when is something good enough'. Others indicated that they worked hard to achieve high marks in their study programmes. For them it was difficult if the lecturer did not indicate to what extent he agreed with the decisions made by the team, or if the client did not seem to understand the team's decisions.

Depending on the nature of the uncertainty, these 'individual' uncertainties related to a certain stage of the design process. In the interviews at the end of the project, some students indicated that their experience with this design process already made them feel less insecure. This was particularly the case with uncertainties about lack of creativity. Providing focus and staying motivated when iterations proved necessary were not mentioned in this context.

4.2 Uncertainties attributed to the social context

Analysis of uncertainties attributed to the social context revealed an interesting development, that was also recognised by the lecturer. At the start of the project (discover phase), most students felt insecure towards the client. They felt like having little control over the problem and thought the client would expect output in an early stage. In the next phase (define), students seemed to feel a little more secure about their own decisions, - they gained substantive and contextual knowledge - but were afraid that the client would not (fully) endorse their problem statement. In the third phase (develop) the uncertainty about the content was less prominent than in previous phases; some students even indicated that they felt more like being an expert than the client, in certain respects. What they were uncertain about is how they should 'take along' the client in their decisions. In the final phase, most students were proud of the product of their design, but some felt uncertain about the appreciation of the client and the lecturer.

Patterns of uncertainty in the collaboration within the teams are much less clearly recognizable. Three students reported feeling insecure on the team. Two of them already indicated in the questionnaire before the start of the project that they were not looking forward to cooperating in a team for an entire semester. Most of students' reflection about team collaboration related to a specific situation ("preparing a presentation together went badly") and seemed to be rather insights about what went well or not in the collaboration than an indication of uncertainties.

Various students who indicated in the initial survey that they were anticipating problems in the diverging phase or students who had difficulty converging, indicated in the interviews that due to the cooperation in the teams, these potential shortcomings proved not to be a problem.

4.3 Uncertainties attributed to the task

Most of the uncertainties mentioned by the students in their weekly survey were uncertainties attributed to the task. Especially in the discover and define stage, many uncertainties were reported, due to the complexity of the task. Students did not know where to start, how to get grip on the problem. In retrospect however, students mentioned that they had gained a lot of insights in these first stages and learned quickly.

In every stage of the design project students were asked to apply particular tools, like a causal diagram, a theoretical framework or a customer journey. A lot of the uncertainties had to do with these methods: “What do we exactly have to do; How do we have to interpret the assignment; Are we on the right track?”.

Another important source of uncertainty was (in the students' perception) ‘the long absence’ of feedback or getting negative feedback.

Each team had the feeling to be 'stuck' one or more times during the design process, which forced them to iterate and to revise their principles. These situations created uncertainty for many members of the teams. However, students who had indicated in the first survey to prefer to take a lot of their own initiative in the process, reported fewer uncertainties than other students. Most students were hesitant to actively approach the client, especially when they didn't have a well-defined question. Initially this also applied to approaching the lecturer, but to a lesser extent.

In the perception of the lecturer, student uncertainty especially arises during the transition from one phase in the design process to the other. In the analysis this was not quite visible, due to the fact that for every team the transition took place on another moment. However, during the interviews, this finding was confirmed by some students.

4.4 Copings mechanisms: responses to non-routine situations

What are the copings mechanisms reported by the students? Related to the task the most mentioned mechanisms were: to take ownership of the project (take initiative and rely on the intuition and expertise of the team members), dare to ask and to involve others, and especially: to keep going. Some students emphasized however, that it helped them not to stick to the problem but to focus on something else for a while. Several students mentioned that using theory helped them to make decisions. The student interviews at the end of the project showed that their uncertainty with regard to the application of a certain tool diminished when it turned out that others in the team could handle the tool well: they learned from their team mates.

Related to the social context, students did not mention many coping mechanisms. Some mentioned that they would like to get some training in managing expectations of the clients, especially in the last two phases of the design process. The lecturer noted in an interview that the lack of prior knowledge about the context of a problem and the actors involved, makes students often ask very basic questions that often surprise clients in a positive way. Clients themselves are often so deeply involved that they find it difficult to approach a problem from a different perspective. The lecturer indicated that this aspect could be emphasized more in the living lab, in the hope of reducing uncertainty of students in the discover and define phase.

Students who struggled with uncertainties with regard to their position in the team and the collaboration with other students, did not come up with clear ideas for solutions or coping strategies. They responded moderately positive to the interviewer's suggestion that more attention to personal professional development in the living labs might help.

Regarding the individual uncertainties, some students who participated in the interviews indicated that keeping a log helped them to reflect and to see their uncertainties in proportion. In their opinion, addressing their uncertainties proved to be helpful. One student remarked that the survey at the start of the living lab made her aware of her uncertainties. She decided to formulate personal learning goals to overcome those.

5 CONCLUSION

The main question of this paper was: how students deal with uncertainties in solving complex problems in the C-labs?

Students identified uncertainties in the three categories of Daalhuizen et al. [7]. Especially in the discover and define phase, students experienced a lot of task-oriented uncertainties, which partly arose from the complexity of the problems. Context-related uncertainties with regard to the role of clients changed during the various phases of the design process. Some students also experienced uncertainties regarding their role and position in the team. Individual uncertainties are less tied to certain phases.

Students mentioned various coping mechanisms with regard to uncertainties attributed to the tasks: to take initiative and rely on the intuition and expertise of the team members, to dare to ask and to involve others, to keep going, or to focus on something else for a while. Several students noted that using theory helped them to make decisions. Only a few solutions were mentioned for handling individual uncertainties: keeping a log and addressing their uncertainties. Dealing with social uncertainties related to client expectations and participation in the team were issues that some students could not deal with properly.

6 DISCUSSION

6.1 Methodology

The methods used in this study: the distinction between the three types of uncertainty; the four design phases, and the fact that we have questioned students at different times and in different ways, has yielded a varied picture of the uncertainties that students experience. In this paper we have limited ourselves to giving global results, without going into detail, which we believe is most relevant in the context of the SEFI conference.

All reported uncertainties in this study could be categorized into the three types of uncertainty. However, it might be useful to add a fourth category ‘technological uncertainties’ in cases in which substantive knowledge of a technology is of great importance.

6.2 Lessons learned

In their paper Daalhuizen et al. [7] mention that “designers focus primarily on issues related to the task and to the social context” (p. 9-157). The authors stress that there is a need to encourage professional designers to reflect on their own contribution to non-routine situations.

In this study we learned that students within the C-lab were (still?) open to express their individual uncertainties. The lesson we take from this, is to pay attention to those individual uncertainties in an early stage: to address the individual uncertainties in engineering education and teach students how to reflect. This made us decide to add a module Personal Professional Development to our C- labs at Delft University of Technology.

In addition, we would like to add a masterclass about dealing with client expectations as well. After all, students were unable to indicate how they could deal with social uncertainties.

In the context of lifelong learning it could be valuable to include the uncertainties and copings mechanisms of clients and other stakeholders in our investigation into living labs as well: it could benefit cooperation between all parties in the living labs.

So, investigating our engineering education in detail offers us concrete starting points for improving education in living labs.

6.3 Relevance for Engineering Education

Until now, there has been little research into living labs. There is still much to discover. If we want to apply this type of education more frequently, we must ensure that sufficient attention is paid to students’ uncertainties, in order to prepare future engineers better for the problems they will encounter in practice. Dealing with uncertainties is relevant for gaining adaptive expertise; a competence we will all need in our rapidly changing society.

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Design Methods for ICT-Supported Courses:
A Literature Review

H J Ylinen[1]
Lecturer/Doctoral Student
Seinäjoki University of Applied Sciences
Seinäjoki, Finland

T Juuti
Associate Professor
Tampere University
Tampere, Finland

Conference Key Areas: new notions of interdisciplinarity in engineering education; new complexity quest in engineering sciences

Keywords: engineering education research; course design; educational technology; integrative literature review

ABSTRACT

In engineering education research, many methods have been presented to support curriculum design. Courses, however, need to be designed as well. While designing a course, attention must be paid to the subject matter, pedagogical aspects and technological factors, for example. New teaching technologies further widen the potential solution space. This results in a complex design challenge for the teacher. The teacher's ability to design the courses has a direct impact on how successful learning will be.

The purpose of this literature review is to clarify what methods currently exist for the systematic design of courses in engineering education. We focus on the following research questions: 1) What methods, tools and processes currently exist to support the design of courses? 2) What are the key concepts, models or theories they are based on? 3) What is the role of information and communications technology (ICT) in these methods?

The literature review shows general instructions, with central affecting factors, are available. Current approaches present some aspects—for example, student motivational factors or the role of teacher instructional skills. However, the systematic or more holistic method, which supports a study module design including ICT aspects, is not currently available. This study's results contribute to an educational design research project that is aimed at developing a systematic design method for ICT-supported courses within the engineering education context.

[1] Corresponding Author
H J Ylinen
hannu.ylinen@seamk.fi

1 INTRODUCTION

'We will not meet the needs for more and better higher education until professors become designers of learning experiences and not teachers' [1]. The students often live in the moment; the studying process will become concrete through the courses taught at each stage of the study. Hence, courses are key elements employed to prepare students for the demands of workplaces. While students study using the courses, the know-how will cumulate and be fully effective with the accomplishment of all the courses related to the degree. So the teacher constantly acts the crucial role when designing courses. However, should this design be made?

Knowledge about course design is the most significant bottleneck in better teaching and learning in higher education [2]. In light of current research information, the teacher is often seen as a designer of learning, where the design methods and the control of design tools are emphasised. The traditional approach to the planning of the course, in which the contents to be taught direct the planning, has been found to be inadequate [2]. In addition, constructivist-oriented teaching has added challenges to the design of courses. Many teachers experience difficulties with constructivist-oriented pedagogies because they tend to be in conflict with their pedagogical practices [3]. The use of technology on campuses has been one of the most significant movements in higher education over the last decade [4]. Advanced teaching technologies have, however, brought not only more possibilities but also challenges to the design, and integrating information and communications technology (ICT) into classroom teaching and learning continues to be a challenging task for many teachers [5].

To address the challenges, a recently developed theoretical framework designed to guide research in teachers' use of ICT is the technological pedagogical content knowledge [6]. For teachers, the design of ICT-integrated lessons for 21st-century learners can be challenging, as they need to keep up with the rapid proliferation of ICT tools [3].

Different methods have been developed to support the course design. Newell (1983) describes the method with four statements [7]:

1. It is a specific way to proceed.
2. It is a rational way to proceed.
3. It involves subgoals and subplans.
4. Its occurrence is observable.

The objectives of these methods have been to intensify designing and help align teaching according to the theoretical premises of the methods. Learning outcomes, teaching and learning activities and assessment are seen as sections which are tightly intertwined and not as unconnected pieces of the design of courses [6]. It is a challenging task to fit educational principles and contents into the design so the learning outcomes, which are the starting point for the design, can be reached.

The purpose of this literature review is to clarify what methods exist for the systematic design of courses in engineering education. We focus on the following research questions: 1) What methods, tools and processes currently exist to support the design of courses? 2) What are the key concepts, models or theories they are based on? 3) What is the role of ICT in these methods? The point of view regarding ICT concerns its possibilities to support teacher and student work before, during and after the teaching and learning activities.

The rest of the paper is structured as follows: Section 2 discusses the research method used, focusing on the search strategy and data sources. Section 3 introduces the results of the literature review. Section 4 discusses the findings and validity of the study. Finally, Section 5 concludes the paper with future directions and final remarks.

2 RESEARCH METHOD

The amount of research information in the world is constantly increasing; this is especially true for the field of engineering education. If an engineering education researcher (or a teacher as a researcher) wants to be conscious of the present state of relevant research, he or she must continuously follow new research results.

The research method of this study is a literature review. The purpose of a review is to provide a holistic understanding of the topic of interest [8]. An integrative literature review is used in this paper. Integrating literature review is a good research method when one wants to describe all the aspects of a phenomenon [9]. Using this approach, it is possible to combine different methodologies to review the literature and provide a summary for a more holistic understanding of the phenomenon [9]. Integrative literature reviews represent the broadest type of research review methods, and they are distinctive for combining diverse data sources, such as experimental and nonexperimental research or theoretical and empirical literature [10]. Integrative literature review neither selects nor separates a research material as carefully as a systematic literature review, but if well done, it is able to present the state of the science and contribute to theory development [10]. An integrative literature review entails problem identification, formulation of inclusion and exclusion criteria, literature research and evaluation and analysis of data [11].

2.1 Search strategy and data sources

Searches were conducted in March and April 2019 using electronic database search engines (Scopus, EBSCOhost and Wiley Online Library) to find literature which could answer the research questions. Attention was focused on books, specific book chapters, PhD theses and peer-reviewed articles, but all scientific accepted forms of literature were considered. The first method used was searches with phrases connected with Boolean terms. After these basic searches, the amount of relevant literature was rather small, so we used a snowballing method to supplement results. Snowballing refers to using the reference list or citations of a paper to identify additional literature [12].

2.2 Inclusion criteria

In the first inclusion stage, the aim was to find books, book chapters and PhD theses of good quality that answer the research questions. Because engineering education is part of a higher education field, we decided to accept literature from an area of higher education if it contributed to course design. The search criteria included the literature was published after the year 1999 and the language of the publication being English. The main reason for limiting the search by year is outcome-based education became more common in this century, and this form of education has significant effects on course design. The search words were a combination of the main concepts of course design. Many test searches were required to find a suitable combination of terms. The keyword combinations always included the word ‘design’ to direct the searches to the right content. The word ‘course’ has many synonyms, so it was necessary to use all possible alternatives. Word searches including ‘study module design’, ‘course design’ and ‘teaching strategy design’ were used in combination with the term ‘higher education'. These searches often led to many duplicates. Examples of the results of the first stage of the literature research process are presented in *Table 1*.

Table 1. First-stage search results (examples)

Date	Search engine	Search words	Restrictions	Keyword hits in search
4.3.2019	EBSCOhost	'Course design' AND 'higher education'	2000–; Books	33
11.3.2019	Wiley Online Library	'Course design' and 'higher education'	2000–; Books	112

In the second inclusion stage, the aim was to find articles of good quality that answer the research questions, focusing on only engineering education. The search criteria included the study was published after 2013, with the full text available, the study was peer-reviewed, and the language of the publication being English. Hence, it was possible to ensure that the information was up to date. Examples of results from the second stage of the literature research process are presented in *Table 2*.

Table 2. Article search results (example)

Date	Search engine	Search words	Restrictions	Keyword hits in search
2.4.2019	Scopus	'Course design' OR 'study module design' AND 'engineering education'	2013–; peer-reviewed articles	478

2.3 Exclusion criteria

The inclusion stage led to an extensive amount of literature. During this stage of the literature review, the aim was to delimit the literature to only studies which have relevant content. For that purpose, titles, abstracts and tables of contents were examined, and the studies that did not meet the criteria were ignored. Only the books which processed the design of the courses in higher education were accepted to the final review. If the focus was on curriculum design, the book was rejected. After this exclusion process, six books were accepted. In the case of articles, only those which processed the design of the courses in engineering education were accepted to the extension. Articles focusing on curriculum development or innovation in classroom instruction were not included since these topics were out of the scope of this research. After this exclusion process, nine articles were accepted. Using these 15 sources for the snowballing method, we added two books and two articles to the final analysis. Overall, after all searches and the inclusion/exclusion stage, we accepted 8 books and 11 articles for the purpose of a detailed analysis.

3 RESULTS

To get the answers to the research questions, the accepted literature was carefully analysed. An important focus was to find out what role ICT plays in the selected design methods. The role was divided into three stages: before, during and after course implementation. This role was evaluated from the perspectives of the teacher and the students. Simultaneously, it was possible to notice what main tools and processes were used and what kind of theoretical foundations or models were present in the background. This analysis was mainly performed by the first author. An overview of the results of the analysis is presented in *Table 3*.

Table 3. Overview of design methods, tools, processes and the role of ICT

Method	Main tool(s)/process(es)	Theoretical foundation/model	Role of ICT			Context
			Design	Action	Asses.	
Traditional course design [13]	Content sequencing	Behaviourist	-	-	-	HE
Integrated course design [2]	Course development worksheet; taxonomy of significant learning	Constructive	-	T+S	-	HE
Constructive alignment [14]	Structure of the observed learning outcome taxonomy	Constructive	-	T+S	T+S	HE
Backwards course design [15]	Content priorities; diagram clarification	Constructive	-	-	-	HE
Idea-based learning [13]	Course design document template	Constructive	-	T+S	-	HE
Designing and assessing courses and curricula [4]	Form for establishing the need for the course design process	Constructive	-	T+S	-	HE
Course design [16]	Flexible modes of content delivery	Constructive	-	-	-	HE
Content assessment pedagogy model [17]	Concept map; assessment triangle	Constructive	-	-	-	EE
Effective course model [18]	Course assessment matrix	Constructive	-	-	-	EE
Product development model [19]	Stage-gate process diagram	Constructive/ product development	-	-	-	EE

Method	Main tool(s)/process(es)	Theoretical foundation/model	Role of ICT			Context
			Design	Action	Asses.	
Intrinsic-motivation course design [20]	Intrinsic-motivation process diagram	Self-determination motivation theory	-	T	T	EE
Design thinking in course design [21]	Evolution 6^2 model adapted for instructional design	Design thinking	-	-	-	EE
Competence-oriented didactics [22]	Competence-oriented didactic course flowchart	Klafki's theory of education	-	-	-	EE
Gathering feedback [23]	Conflict cards	Constructive	-	-	-	EE
Theory-based course design [24]	Process with focus on engineering sciences and employed learners	Constructive/motivation	-	-	-	EE
Consensus-based course design [25]	Fishbone diagram integrating the rule for implementing cat	Consensus-oriented decision	-	-	-	EE
Working process course design [26]	Six steps to organising teaching	Constructive	-	-	-	EE
Gamifying educational process [27]	Gamification methodology algorithm diagram	Gamification	T+S	S	-	EE
Lean principles course design [28]	Value stream mapping; Kaizen; 5 Whys; quality function deployment	Continuous improvement	-	-	-	EE

*Abbreviations: Asses. = assessment, T = teacher, S = student, HE = higher education, EE = engineering education.

3.1 Research question 1

What methods, tools and processes currently exist to support the design of courses?

We can argue that there are many methods which support course design. The first column of *Table 3* gives a basic illustration of founded methods. All the theories include different kinds of tools and processes. The main tools and/or processes are illustrated in the second column of *Table 3*.

3.2 Research question 2

What are the key concepts, models or theories they are based on?

Every design method uses concepts when constructing the structure of the design process. The main concepts are learning objectives/goals, instruction/delivery and assessment. Under these main concepts, there are several method-specific subconcepts. The most used theoretical foundation for the design of courses is constructive learning theory (*Table 3*, third column). The other theories or models originate from industrial backgrounds or design research. For course design, it is possible to categorise the relevant theories into three types: learning theory, assessment theory and instructional theory. However, a more exact analysis is not the goal of this research.

3.3 Research question 3

What is the role of ICT in these methods?

In *Table 3* (fourth column), there is an illustration of the role of ICT in the methods. A few of the methods emphasise the possibilities of using ICT to support the teacher and the students' teaching and learning activities (T+S in the 'Action' cells). However, the design and the assessment phase are mostly abandoned. Some guidelines are presented on how to implement ICT in teaching processes, but there are no specified directives on how to take educational technology into account when it is time to make design decisions.

4 DISCUSSION

Research on engineering education course design are characterised by a relatively small number of studies that provide a general overview and a large number of works, mainly articles that focus on specific elements of study module design. A short article or report which describes and evaluates the effectiveness of innovation in course design is one of the standards of higher education literature [29]. Several higher education research projects and publications include evaluations of innovations introduced at the course level. Not surprisingly, these appear far more frequently in the form of journal articles than books [29].

One can argue that in the literature on course design in engineering education, the most used design methods are based on constructive alignment. The fundamental starting point for this principle is intended learning outcomes [14]. There are several iterations of this principle, but the fundamental thought is the alignment of the assessment and the teaching and learning activities to support the learning outcomes. Methods such as backwards design and effective course model emphasise the stages of the planning process in a different manner and offer different tools for design. It is recognised that courses are designed by and for people, and the process is more of a holistic and organic one than is usually acknowledged [16].

It is important to notice that the design of courses can be divided into three elements: the design of learning objectives (learning outcomes and core content), the design of assessment (assessment techniques, tests and surveys) and the design of instructions (lectures, laboratory assignments and used instructional technology) [18]. These elements comprise the core of the design. Elements are intertwined and affected by many situational factors—for example, the number of students who will participate in the course, knowledge level of the students, status of the students (full time or part time) and the teacher's prior experience in the subject matter and knowledge and skills of the teaching process [2]. Attention must be paid at a very early stage to instructional techniques because they affect, in many ways, the student assessment procedures.

How student learning is designed, assessed and delivered immediately impacts one of the main ‘customers’, the students [29]. Nevaranta (2012) emphasised a course as a modular service product of which its customers are students [30]. It is possible to approach design tasks as a product development job and use widely adopted product development methods from the industry [19].

The impact of technology on teaching and learning is widely recognised. Technology significantly not only increases the instructional options available to faculties but also has a negative impact on two areas that are often neglected: institutional budgets and the ways in which students study and learn [4]. Technology has an impact on how students approach the entire learning experience. Currently, faculties are reporting decreasing attendance in classes, more students multitasking during lectures and difficulty in getting students to devote to their assignments the amount of effort and time required for quality work [4].

The theoretical framework designed to guide research in teachers’ use of ICT is the technological pedagogical content knowledge [6]. However, it seems that the framework is not applied in connection with course design systematics at the moment.

Similar to all studies, this study has certain limitations. The number of articles related to general course design, in the context of engineering education, turned out to be small. Studies focusing primarily on course design are rare. However, this study managed to capture the representative sample of the relevant literature and, consequently, synthesised the form of the big picture.

5 CONCLUSIONS

Many distinguished researchers have thought about the complex challenge of course design. Methods and tools developed during research aim to facilitate and systematise design. In the background, there are many limiting factors. These are, for example, the researcher’s view of life, teaching and learning theory and the context for which the model has been developed. Due to many variables, it is probably impractical to develop a universally applicable method. Every study, however, has its own value. The methods and tools, at best, bring systematics to design and make repeatable, efficient processes and the constant improvement of quality possible.

The constraining time resource drives teachers into a situation where it is not possible to maintain present learning results without efficiently utilising technology. Particularly assessment is a time-consuming stage of course implementation. Using technology to help formative and summative assessment is one promising application area. Students receiving instant feedback on their progress will provide good support for learning and make assessment more sustainable and instructive.

A design method for course design which pays attention to the efficient use of technology is not currently available. In light of this fact, more attention must be paid to the systematic design methods which offer practical tools for the intensification of teaching and learning processes with educational technology. The results would contribute to an educational design research project that is aimed at developing a systematic design method for ICT-supported courses within the engineering education context.

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WORKSHOP

ORDERED ALPHABETICALLY
BY LEADING AUTHOR

HUNGARIAN INDUSTRY-UNIVERSITY SHOWCASES

L. Cs. Ábrahám
NI Hungary Kft., Hungary

Topics: New Notions of Interdisciplinarity in Engineering Education

Keywords: cooperation between academia and industry

The topic of the round-table discussion is cooperation between universities and industrial companies.

During the discussion we would like to highlight some good examples, how industry and universities can make joint project successfully.

Why is the session relevant?

Working together is not always easy as the two different types of organizations have different structure and different goals. The round-table will honestly talk about the challenges what we have and how we manage to overcome the difficulties.

How are session participants activated?

The participants of the round-table will discuss together the topic according to the next comments:

Szilasi Péter Tamás, head of Public Relations section, NEMAK:

The cooperation between NEMAK Győr and the Faculty of Material Science of the Miskolc University can be truly characterized as symbiotic.

It is not only about educational, scientific and research cooperation, but lot more saving a profession together.

It has an eight years history, when with the lead of Nemak, the Hungarian Association of Foudries ran a survey on the needs of the companies in the field of metal casting. The survey was on the research needs, and demand on highly trained professionals, engineers specialized on the metal casting and material science.

At that time secondary vocational training was fully missing, while the university level education was close to being extinct. Only one part time professor dealt with the topic. Research capacities were also almost close to none.

Based on the results the companies of the sector aligned their forces. They agreed to provide financial support to the Miskolc University, to help building up human capacities of the faculty and especially its institute focusing on automotive casting.

They also joined their forces to start dual education.

As a result of this program by now a small, but powerful institute is built up, with significant doctoral program, and 20-25 students enrolling to this highly specialized training on BSc level every year. The first dual training students had graduated this year. NEMAK have 2-4 dual training students every year, being the biggest dual training partner of the faculty.

There is a continuous and open discussion on the educational program and the execution of dual training. Starting the 5th year we are going to launch the 5th or 6th evolution of the training program. It is an ongoing joint learning.

There are also frequent occasions where we can feed our experiences back to the university as well as the other companies being involved in dual training.

NEMAK and Miskolc University also intensively join their forces in student recruitment, mutually helping in each other’s activities.

NEMAK Győr highly depends on the scientific knowledge base of Miskolc University. Based on a yearly research contract usually 5-6 topics are worked out by the University. More and more the dual training students are joined in these researches. Giving them a real life topic for their studies and thesis work, but also providing extra research capacity to the University.

Frank Péter R&D Director, Knorr-Bremse:

Knorr-Bremse’s Research & Development Center cooperates with universities since its founding in 1995. Our primary partners are among others, Budapest University of Technology (BME) and John von Neumannn University Kecskemét.

We drive common research projects with universities and other research places, such as SZTAKI since the beginning. A special question here is the IP protection that can be resolved.

Knorr-Bremse together with its partners Mercedes and Kecskemét College launched Dual Education system in Kecskemét in 2012 as first in Hungary. Our extensive Student Program is a win-win-win for the student, university and the company. Besides that, Knorr-Bremse operates a PhD program.

Ács János, Manager, Partnering & Operations LEGO:

LEGO Manufacturing Kft. and BME Faculty of Logistics hosted a lesson for automatized logistics processes as joint venture. The lesson aimed to introduce a fully-automated high bay warehouse operations and a manufacturing site designed for material flow to university students while gather logistics related observations from them (external eyes and minds). Through this shared operations I can reflect on the pros and cons of collaboration between industrial and educational institutes.

Szűcs Lajos, Move Coordinator, Schaeffler:

Most of our new engineers are coming from the Faculty of Mechanical Engineering as fresh from college. However, in the technical training, the training material related to bearing manufacture has an insignificant part. To compensate for this - thanks to the good relationship with the Faculty of Engineering in Debrecen - the lecturers are constantly working with our engineers to improve the practical training. To strenghten the process we set up the Schaeffler optional course, where the students can gain a higher level of practical knowledge by solving project tasks. In addition, there has been an other possibility in the training of lecturers, which is focusing on the education with more practical part, we have also had a practical lesson for economists, the results of that must be presented in their portfolio.

Pék Zoltán, Head of Sensor Development, Continental:

Cooperation of Pannonia University and Continental Veszprém

In the recent years we had few common activities with the university however they were more like ad-hoc organised. We have been giving few lectures on Engineering faculty and also on Informatics faculty. This was not real help for the university and it had not given high value for the UNI students too.

In 2017 we decided to work out a complete unit called „ automotive software development in practice" for the Informatics faculty. The unit is organised for two semesters, consists of theoretical part and practice as well.

Continental nominated a team for giving the lectures and the practice furthermore the unit responsibility was taken by one of our engineers having PhD.

The theoretic part consists of methodologic part starting from requirement elicitation requirement decomposition, development, integration till verification. The theory also touches automotive standards especially Functional safety furthermore we give general introduction of the control functions like ABS, AYC, ACC and so on..

The practical part is building a robot vehicle and implementing one control function like Traction Control or A tempomat. The practice also covers the testing of the robot car in different conditions.

Our target with the unit is to get connected to the students and give them the chance to understand development process and methodology of safety critical items.

Today we offer the unit on Informatics and also on Engineering faculty. This semester 17 students signed in the unit.

This way we can contribute in the education of the students widening their view on product development getting more valuable knowledge with their degree. Furthermore we can increase our chance to welcome them on board at continental as employee.

Jakab Roland, Regional Director, ERICSSON:

Ericsson opened a complex hardware design research lab at the Budapest University of Technology and Economics a few years ago.

The cooperation has been working successfully, giving perfect place for the education as well as for PhD and diploma works. Once students approached us and asked whether they could use the Lab facilities when there is no education there. We said of course and as a result of this the lab contributed at large to the born of the first satellite of Hungary - MASAT.

The members of the round table session will share their experiences and explain why university and company relations getting more and more important:

1. companies can find the best and most talented students,
2. they can make important projects together (R&D)
3. the verve of the industry can teach students to be committed to deadlines, quality, responsibility and real solutions.

DIGITAL LEARNING MANAGEMENT SYSTEMS TO RAISE ENGINEERING STUDENTS' ACTIVE PARTICIPATION AND UNDERSTANDING: USE CASES OF SOCRATIVE, MATLAB GRADER, AND KAHOOT SOFTWARE IN MECHATRONICS EDUCATION

A. Aslan
Fontys University of Applied Sciences, Netherlands

Topics*:* Diversity in Engineering Education, Integrated learning environments for the digital native learners

Keywords*:* digital learning environment, Kahoot, Socrative, Matlab Grader, Homework

In the Mechatronics department of Fontys University of Applied Sciences in the Netherlands, the problem exists that the students do not do their homeworks that are given during the lectures. This constitutes a setback when the teachers want to continue their lectures covering new topics, especially when these new topics are linked to the previous topics. Interaction with the students during the lectures becomes inefficient too, because they lack the previous knowledge. This kind of a problem is often seen in Engineering Education and the participants of the workshop have experienced that in some way. A simple solution would be to divide a bigger course into several parts, where each part has to be finalized with an exam (summative examination), before the new part starts. The alternative of it (formative examination) which purely aims for indicating the current learning outcome of the students without the exam being officially graded. Homework and lecture interaction are good examples of formative exam if the student gets feedback on his/her answers.

In this workshop the use cases, tips and tricks will be presented using some online tools that are experimented with in Control Engineering lectures. These software tools called Kahoot, Socrative, and Matlab Grader will be compared with each other and examples will be presented from Control Engineering lectures that are applicable to other disciplines. The participants will use those tools and they are expected to solve mini-quizzes using these tools as if they are the students. This will follow to brainstorm and discussion sessions on how should the questions be formulated by the teacher so that the students get the maximum understanding out of it. Below is a summary of the three tools that will be covered during the workshop.

Socrative is an online quiz tool with handy options to summarize the results if the homework assignments are implemented in a closed-ended question form (i.e. multiple choice) in this tool. The teachers will be encouraged to put their homeworks into this system and copy the students' results each week into a logbook which is shown to the class in the beginning of the lecture to trigger the competition feeling besides accentuating how important the homework is. As an exercise the participants will be set in groups to formulate a mathematical problem into a closed-ended homework question making sure that the students follow the steps to solve the mathematical problem from A to Z instead of coming up with the correct answer in any other alternative (easier) way.

However, Engineering courses have often open-ended final exam questions and that’s why the homework assignments which should support the examination type are also expected to be open-ended. Matlab Grader is an automatic student work grader that provides feedback on the code that students submit. This tool requires more development time before first time use during the course period but saves much time when implemented once, compared to manually grading the programming assignments. Use cases will be presented on how to convert from easy mathematical operations to difficult Control Engineering homework material to Matlab Grader assignments that are automatically graded by the tool and sends feedback to the students on which part their implementation has failed. The software checks the code on the basis of functional programming where each functions’ input must yield a certain output. For example if the student needs to write a function (an algorithm) for the mathematical operation ‘addition’, a test case would be inputting 3 and 5 to check if the outcome is 8. If the outcome is not 8, the student is informed that 3+5 does not yield 8 in his implementation. This presentation will be followed by a work session where more complex problems are worked out into test cases where the participants aim to cover the possible alternative algorithms a student can come up with.

As a third browser-based software, Kahoot is a more informal and fun quiz tool to be used at the end of the lectures when students are tired of being exposed to new information. It creates a competition environment where students strive for answering fast and correctly at the same time. The participants are first going to get a feeling of a Kahoot quiz as if they were students and striving for the highest point in the competition. Then an interactive discussion will follow where in Engineering Education can Kahoot fit in order to add more activating work forms in the courses.

The participants will be encouraged to use them via demonstrations to show that these tools require little time during the lecture period if set up once.

As a take-home message, examples, digital attachments and tips will be given based on my own experience on how to construct such homework systems and which tool is suitable for what type of education. A discussion about how to define some additional homework rules to increase student participation in the lectures is relevant and will be held if time permits. It is expected that the participants go back to their school with new ideas and motivation to make their courses more fun, activating and diverse. That’s why the topic suits to the conference theme ‘Diversity in Engineering Education’ to great extent.

MAKING THE CULTURALLY DIVERSE CLASSROOM WORK: ACTIVITIES FOR SUCCESSFUL GROUPS

B. Bergman
A. Norman
Chalmers University of Technology, Sweden

Topics: Diversity in Engineering Education; Gender, Inclusion and Ethics

Keywords: internationalisation; diversity; intercultural cooperation; group work

Motivation for attending and learning outcomes of the sessions

As universities become increasingly internationalized, many lecturers will meet students from diverse cultural backgrounds (OECD, 2014). There are many advantages with a culturally diverse environment, not least that it reflects the nature of the global engineering workplace and that students broaden their perspectives but at the same time, lecturers need to take a critical look at their own material and approaches to best utilize this environment. This workshop is aimed predominantly at lecturers and administration and will discuss useful strategies for working with these students, with a focus on group work in engineering projects.

Learning outcomes:

- an increased awareness of the benefits and challenges of a culturally diverse work environment
- a toolbox of activities to facilitate groupwork in culturally diverse student groups

Background and rationale of the session

Internationalisation is a key goal at many universities. This goal can be measured quantitatively, for example, achieving a critical number of international students across Master programs; however, counting numbers does not address what international students actually experience at the university. Neither does it address home students' experiences of cultural diversity within the university setting.

Recently, a number of initiatives to work with intercultural awareness at all levels have taken place at Chalmers University of Technology in Sweden, driven by the goal, decided in June 2016, to create global perspectives and foster intercultural cooperation across all Master's programs. Since project and group work is common in the workplace and subsequently in our educational structure, our initiatives have focused on groups in project courses. This is also where students are brought into closer contact with one another, yet this way of working may be unfamiliar for some students.

Engaging session design, aligned with the learning outcomes

Maximum number of participants: 30

The workshop will provide a sample of activities which have been implemented with culturally diverse groups. A key theoretical foundation for these activities is a non-essentialist, experience-driven approach to teaching intercultural communication (Van Maele and Mertens, 2009), which is discourse based, theory referenced and interaction oriented.

The activities chosen for the workshop are those experienced as most effective by students (shown through student interviews and reflective texts), such as working with case studies and models for dealing with critical situations that arise (Bergman et al, 2017). The workshop's discussions will be documented and made available to participants after the workshop. Participants will also receive copies of activities to take away with them.

Activities in relation to learning outcomes:

1. the benefits and challenges of this environment: shared practice through discussion (approx. 20 mins)

2. a toolbox of activities (1): participants will experience some activities for inclusive group work as described above (approx. 45 mins). This will include:

   - strategies for forming teams with culturally diverse students

   - activities for the start, middle and finish of the project to encourage openness, trust and reflection

3. a toolbox of activities (2): participants will reflect on and share their own experiences (approx. 20 mins)

Significance for Engineering Education

As outlined in the SEFI position paper, "Substantial progress must still be made to achieve the SEFI vision: a state where engineering education is safe, inclusive and fully empowered by all segments of our societies - globally." This workshop is a step towards that vision and towards internationalisation in practice to fully utilize the potential in culturally diverse teams (Freeman and Huang 2014).

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CASE STUDIES IN ENGINEERING ETHICS EDUCATION

G. Bombaerts
Technische Universiteit Eindhoven, The Netherlands

D. A. Martin
Technological University Dublin, Ireland

Topics: Gender, Inclusion and Ethics

Keywords: ethics education, case studies

Background and Rationale

Case studies are the prevalent teaching method employed in engineering ethics education, but despite their popularity, there is little or no empirical evidence supporting their effectiveness (Colby and Sullivan 2008; Yadav and Barry 2009). The most common use of case studies focuses on individual dilemmas set in scenarios of crisis (Haws 2001). There is less concern with incorporating realistic professional settings and topics such as public policy or the broader social mission of engineering (Colby and Sullivan 2008; Bielefeldt *et al* 2016). While students do show an ability to recognize obvious black and white ethical dilemmas, they fail to do so for “more subtle but possibly more serious dilemmas” (Schuman *et al* 2004, p 11).

Significance

The growing criticism of individualistic engineering ethics case studies highlights the need to develop and use case studies that can capture the complexity of the profession and realistic features of the professional environment (Lynch and Kline 2000; Bucciarelli 2007; Conlon and Zandvoort 2011).

Motivation and learning outcomes

The workshop aims to respond to the need for more complex ethics case studies and to facilitate the participants’ use of the method in their own teaching. The workshop has two major outcomes. First, participants will gain an enhanced awareness of different approaches to case studies. The second expected outcome is facilitating the development of case studies by participants themselves, based on the workshop exercises. The case studies developed can be incorporated by the participants in their teaching, and can deliver input to the SEFI ethics working group.

Participant engagement

The session is highly interactive. It follows a constructivist approach of introducing first a short case study exercise to make the participants experience strengths and weaknesses of the method and by facilitating discussions in small groups and with the entire audience. Participants will thus be divided into small groups, meant to foster a reflective dialogue on their experience using case studies, as well as providing clarity about relevant outputs such as the drafting of new case studies and providing input for the SEFI Ethics working group.

Agenda

1. welcome, introduction and overview
2. short case study exercise and debriefing on strengths and weaknesses
3. small group discussions guided by the following questions:
    - Q1: what are your (own, students', university's) expectations from the use of ethics case studies?
    - Q2: how do you choose case studies in your teaching?
    - Q3: which learning objectives or what characteristics of the engineering profession and work environment do you hope to convey to students through your choice?
    - Q4: what are the challenges encountered and your success stories?
4. Each group reports back, leading to an engaged dialogue with other participants.

    Exercise

    - Groups can be reorganized according to common themes identified in the previous exercise. Each group is invited to draft answers to the formulated questions. This can serve as an initial approach for developing a case study which is in tune with their expectations from the method or the particular features of their module or geographic region. After the completion of the exercise, groups will report back. Tips and tricks to collaborate with real engineering stakeholders on the ethics case studies drafted will also be considered, based on the experience of the Author with engaging stakeholders in ethics case study instruction.
5. wrap up and concluding discussion on follow up strategies and initiatives

Takeaway

Participants will receive samples of ethical case studies and a list of references. Given that the workshop offers a platform to initiate the development of new case studies, participants also have the opportunity to follow up and finalize the case studies drafted, which in the future can be used in their own teaching.

Acknowledgements

We thank our colleagues for the continuous feedback on the research on case based learning and on the design of case-based ethics courses, as well as to our students who took part over the years in the exercise. Participation of Gunter Bombaerts is supported by the H2020 SCALINGS project on scaling up co-creation. This project has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 788359.

RECENT REFERENCES IN ENGINEERING EDUCATION RESEARCH

T. De Laet
KU Leuven, Belgium

Topics: another topic relevant to the conference but not listed above

Keywords: engineering education research

Rationale

Although engineering education research (EER) has been evolving and expanding significantly in recent years, it is still a relatively new field in the European context. As a result, those with an interest in EER and particularly those entering the field, frequently report challenges in gaining an overall sense of existing EER scholarship. The workshop aims to broaden participants' knowledge of important publications within the field by analyzing and discussing a small number of recent publications selected by the SEFI Working Group on Engineering Education Research as being recent, high quality work, in the field.

Participant engagement

The very successful workshop format of the SEFI 2018 workshop will be repeated.

After a short introduction and mingling exercise, heterogeneous groups will be composed that allow for small group discussions. In addition to analyzing specific publications, participants will have opportunities to discuss with Working Group members the selection of these particular publications as key works.

Takeaway

The attendees will have gained insight in recent European Engineering Education publications as they will receive a list of recent recommended publications from the field. Participant conclusions will be made available online after the session, on the website of the working group.

DEVELOPING HANDS-ON LEARNING APPROACHES TO MATH AND PHYSICS IN K-12 LEVEL LEARNING

J. Diaz
C. Urrea
A. Bagiati
MIT, United States of America

Topics: Fundaments of Engineering Education: Mathematics and Physics

Keywords: K-12, STEAM, sustainable, development, goals

What are session participants expected to learn? How are session participants activated?

This is a workshop focusing on the development of K-12 hands-on activities situated within the United Nations' Sustainable Development Goals (SDGs) as well as an authentic problem-solving framework. In our workshop, we will discuss our approach for how to create opportunities for both students and educators by making connections between the topics covered in the classroom, their communities, and the environments they live in. Expected learning outcomes for our workshop participants will include learning about our framework for creating hands-on learning activities situated within local contexts.

Approximate Schedule:

- Introductions to understand where participants are joining from both regionally and professionally.
- Review of the SDGs and identification of challenges that participants' local regions face.
- Discussion of the difference between problem-based and project-based learning pedagogies.
- Participants presented with an example activity about Ocean Acidification and then will be asked to construct activities of their own inspired by their local challenges while working in small groups.

Why is the session relevant?

This work is based on two years of summer engagements that the Massachusetts Institute of Technology (MIT) has held with its STEAM Camp in Hong Kong. Seeking to enhance existing summer offerings for middle school-aged students (ages 10-14) and local teachers, a two-week experience was developed to give participants the opportunity to engage with a broad range of advanced STEAM content taught in MIT "Mens et Manus"-style with hands-on, learning by doing activities, while being exposed to fundamental math and physics concepts. Using MIT content and inspiration from the United Nations Sustainable Development Goals, students cover these activities during their first week. These were developed for the program to not only be relevant to the students ages but also to encourage thought about challenges they face within their own communities. The community that would be best served by our workshop will be K-12 educators as well as those scholars interested in the development of K-12 STEAM outreach programs and making the UN SDGs more accessible to younger populations; however, all are welcome.

How is this work significant for Engineering Education?

For the purpose of this workshop, the beneficial impacts of this work on Engineering Education can be observed through two lenses: The effect on K-12 STEM, and the effect on higher education individuals and on the groups who support them.

With regards to the effect on K-12, our approach to engineering education is that it can be used as a pathway for teaching fundamental STEM concepts. While there are already ongoing discussions about the best way to approach K-12 STEM, in many cases, engineering is still the “silent partner”. Through our work, we are trying to highlight the engineering component and show that it can be a pathway to teach fundamental concepts like math and physics while at the same time using the principles of hands-on, design-based learning as a framework to teach a variety of STEM related concepts. Furthermore, we are also showing how the SDGs can also be introduced at the K-12 educational level, starting even at very young ages.

Regarding the implications for higher education, more and more universities are currently trying to build a deeper connection with the local and international K-12 systems, and participation in our workshop would enhance the participants’ “know how” on how to develop and implement K-12 STEM outreach programs. Regarding more direct benefits to the higher education level, our current experience shows that as university faculty, students, and staff get involved with the development of such STEAM modules, they have been given the opportunity to further explore and understand international contexts and to get exposed to global STEAM-related challenges, information that can be used to further drive their personal research on campus. Beyond STEAM-related challenges, those involved are also expected to understand a new and different educational system that can possibly alter or enhance their perceptions regarding education. Moreover, when university students get involved with content development, they are also given the opportunity to enhance their own teaching experience by exploring education within a new cultural context and also further enhance their teaching skills by collaborating with experienced local K-12 teachers while also learning from them.

Last but not least, as many engineering schools are interested in globally enhancing student understanding of and attraction to STEAM professions, and these local or international K-12 experiences can provide a new test-bed in regards to understanding global perceptions and challenges on that matter, that can further guide STEAM education related research. We imagine that many institutions around the globe will also share these aspirations.

How will results be summarized?

Descriptions of the modified activities will be recorded and summarized for viewing after the conference ends.

REVIEWING FOR ENGINEERING EDUCATION JOURNALS

K. Edström
KTH Royal Institute of Technology, Sweden;

L. Benson
Clemson University, USA;

J. Mitchell
University College London, UK;

J. Bernhard
Linköping University, Sweden;

M. van den Bogaard
TU Delft, The Netherlands;

A. Carberry
Arizona State University, USA;

S. Chance
University College London, UK; TU Dublin, Ireland

Topics: another topic relevant to the conference but not listed above

Keywords: engineering education research, manuscript review, review criteria, engineering education journals

Reviewers are the unsung heroes of any research field, volunteering their time and receiving recognition or acknowledgement only occasionally and anonymously:

"The authors would like to express our sincere gratitude to the three anonymous referees for their suggestions on how to improve the scholarship of this paper."

Behind the scenes of the review process, in which authors submit their manuscripts to the editors of journals, are reviewers who engage deeply in advising authors on how to improve their manuscripts. It is a process that often involves multiple iterations over many months. A reviewer who is willing and able to write thorough, constructive, and thoughtful comments is an asset for the journals and editors, and by extension for the whole field. A fact that is often overlooked is that without the work of reviewers, there would be no journals and no scholarly field.

It is also true that reviewing can be rewarding. First, reviewers are often authors as well and benefit from having their own manuscripts reviewed. Second, the review process is often intellectually stimulating in and of itself. This stimulus often leads to insights that help in the development of our own research and writing.

This workshop welcomes those who are interested in taking on review assignments, as well as experienced reviewers willing to share their best practices. Our primary purpose is to develop an understanding of the review process and further our skills in the art of reviewing. The aim is to help the engineering education community to develop manuscripts effectively, while minimising unnecessary agony. All actors – authors, editors, and reviewers – need to recognize that we are on the same side, sharing a common interest in taking the quality of manuscripts to a new level that makes us all proud and furthers the field of engineering education.

Participants will also gain inside information on the editorial process of three well-established engineering education journals. The workshop leaders are editors of:

- *European Journal of Engineering Education (SEFI)*
- *Journal of Engineering Education (ASEE)*
- *IEEE Transactions on Education (IEEE)*

Expected outcomes

As a result of the workshop, we will all be able to:

- Describe the role of peer review for a journal and a scholarly field
- Explain different quality criteria for scholarship in engineering education and their application in the peer review process
- Consider how reviews can help editors make fair decisions
- Consider how reviews can support and challenge authors to improve their manuscripts, by expressing critiques/feedback clearly, constructively and respectfully
- Give examples of particular aspects of a manuscript that a review could bring up

Workshop Outline

INTRODUCTIONS

- Participants and workshop leaders [10 minutes]
- About the Journals [15 minutes]

    where they stand today

    aims and scope

    review criteria and review process

GROUP EXERCISE

- Form teams of 4 and make a mini-poster: “Characteristics of helpful reviews” [30 minutes]

- Vernissage (hanging and sharing of posters)

PLENARY DISCUSSIONS

- Results from group exercise [30 minutes]

FINISH

- Photographing the posters and signing up to volunteer as reviewers for the various journals [5 minutes]

LIFE-CYCLE ENGINEERING AND SUSTAINABILITY IN THE CLASSROOM: TACKLING THE ISSUE OF PLASTIC WASTE

C. Fredriksson
A. Fung
Granta Design, United Kingdom

Topics: Sustainability reflecting the complexity of modern society

Keywords: Life-cycle, Eco design, Eco Audit, Plastic, Practical

This workshop will focus on using data and tools for sustainability and lifecycle investigations in design and materials-related courses. It is important that material life-cycles are discussed in such courses, to encourage future generations of product developers to consider long-term effects. The specific problem that will be tackled in this workshop is the urgent issue of plastic waste and the case of PET water bottles. The Enhanced Eco Audit tool will be utilized as a means of developing critical thinking and awareness in product development and design.

The challenge of plastic waste accumulating in landfills, on beaches and in the sea has many dimensions – economic, social and environmental. Public campaigns, government initiatives, and global media coverage contribute to the growing awareness of this type of material life-cycle problem. Real-world concerns like this are a powerful way of engaging students on engineering and design courses, and encouraging them to consider the (sometimes unintended) consequences arising from materials decisions.

During the decision-making process, different materials need to be considered along with alternative concepts which minimize negative environmental (and social) impact. In a hands-on, practical group exercise that makes use of the Eco Audit tool, we show that CES EduPack can be used to aid discussion and help informed decision-making in product development. We provide a life-cycle investigation of PET bottles and some alternative water containers using the tool, and demonstrate a problem-based activity that can be directly used in your classroom together with the software. Workshop participants will also explore the Sustainability Database of CES EduPack to analyze and discuss broader environmental and socioeconomic issues related to material use.

In the workshop you will:

- Learn about a problem-based approach to assessing the sustainability of products and technological developments
- Gain practical knowledge and skills regarding eco-data and eco-informed materials selection in life-cycle engineering and eco design

- Experience a practical and hands-on example of how to use the Eco Audit Tool to explore the issue of plastic waste
- Find out about case studies, exercises, lecture units, and other teaching resources available for educators.

At the conclusion of the workshop, you should be able to:

- Confidently know how to use CES EduPack to teach students sustainability concepts
- Implement a problem-based system approach in your design or materials-related teaching
- Gain a practical example with templates and a fully developed case study to use in your teaching
- Get one-month access to the test license of CES EduPack to try out with your students.

GROUP FORMATION PROCESSES IN LARGE CLASSES WITH FOCUS ON STUDENT MOTIVATION AND OWNERSHIP

S. Grex
H. Løje
DTU, Denmark

Topics: another topic relevant to the conference but not listed above

Keywords: Group-formation, student-centered learning, motivation, 21st century skills

Background and rationale

Group work is important for learning at all levels in many educational systems, as group work can support a positive learning outcome for the students. When the teacher assign group projects, it requires the students to work together with other students to promote academic achievement and at the same time to learn about cooperation and teamwork [1]. Groups can be formed in different ways. One common way of forming groups is to allow the students to self-select into the groups. Another way is instructor based where the teacher form the groups based on for example backgrounds and academic level. Group work can be key component of student-centered learning, but the student-learning outcome can depend on the formation of the groups. The evidence is mixed about the effects of self-selected groups on student learning compared with instructor-formed groups. Groups can be heterogeneous or homogenous and there is no consensus which one of these are better for students. Donovan et al. [2] found in their study that the low competence students had higher learning outcome when they were in heterogeneous groups while mid- and high competences students performed well in both group types. Students of all competence types had better attitudes toward group work in heterogeneous groups. How to structure the group formation process to maximize the learning outcome is not clear.

This workshop is about how to organize large class group formation processes where students self-select into groups. We will introduce a group formation concept developed for a 3rd year bachelor course on innovation, and cross-disciplinary teamwork, as well as real-life company challenges [3], [4]. Teamwork and cross-disciplinary group work is an opportunity for the students to develop collaborative skills which are part of the 21st century skill-set [5] and the report “The Global State of Engineering Education” [6] also highlights the importance of team work and cross-disciplinary activities in engineering education.

The group formation concept focus on activating the students’ motivation and ownership, by emphasizing the students’ personal and professional competences and interests as well as their expectations to themselves and their teammates. Central elements in the concept are therefore to talk with many other students before teaming up through speed dating, to balance cross-disciplinarity and expectations regarding ambitions, motivation, working hours, personal and professional interests/competences etc. and to form a group contract. To facilitate the group formation process, a number og guides and templates have been developed, such as a question guide for the speed-dating process and a template for the groups to map and discuss their skills and competences.

Results show a low break-up rate for the groups, awareness of own and others' competences in the groups as well as awareness of own and others' role in the team. Attributes that are relevant when preparing students for 21st century skills and todays labour market.

Workshop session

Introduction

The group formation process will be introduced including a presentation of templates and instructions that are used to scaffold and guide the students during the group formation process (e.g. Templates for competence mapping, group contract, speed dating processes etc.) (20 minutes).

Hands-on activity

The next step will be to try out the concept for the group formation process. The workshop authors will facilitate the process and participants will engage in forming fictive groups with each other. At the end of the session, there will be a common reflection on the group formation process including feedback on the experience. (50 minutes)

Discussion and conclusion

In the last part of the session, the participants will discuss the result of the hands-on activity. For this part workshop, participants are also invited to share their challenges and experiences on group-formation. (20 minutes)

Expected outcomes/results

The expected outcome from the hands–on session is creation of new experiences for workshop participants on how to organise group formation processes and sharing of experiences. The participants will be provided with ideas to use in their own teaching and the applied guides and templates will be shared with workshop participants.

References:

[1] Chiriac, E. H. (2014) Group work as an incentive for learning – students experiences of group work. Frontiers in Phychology, 5, 1-10

[2] Donovan, D. A., Connell, G. L. & Grunspan, D. Z. (2018) Student Learning Outcomes and Attitudes Using Three Methods of Group Formation in a Nonmajors Biology Class. CBE—Life Sciences Education Vol. 17, No. 4

[3] By authors.

[4] By authors.

[5] OECD (2018) The Future of Education and Skills. Education 2030. www.OECD.org

[6] Graham, R. (2018) The Global State of the Art of Engineering Education. Massachusetts Institute of Technology (MIT)

THE FUTURE ENGINEER

L. Gumaelius
Royal Institute of Technology, Sweden

A. Kolmos
Aalborg University, Denmark

Topics: Sustainability reflecting the complexity of modern society

Keywords: sustainability, digitalization, employability, education

What will Engineering Education look like in 2030? Do you want to take part in the visionary work on future engineering education?

A growing gap between education and societal needs is reported, and it is imperative to close this gap to respond to todays and future challenges. The challenges that need to be met to enable tomorrow’s engineers to meet society’s needs are many, but the three challenges mentioned below that have been chosen to frame this study on the future development of engineering education.

A. The need to integrate sustainable development as a red thread through all education has existed for a long time, and with the formation of the 17 sustainability development goals (SDGs) in combination with the contemporary climate debate, this need is even more obvious regarding engineering education in 2030 than it is now.

B. Another challenge is posed by the industry demand for engineers who are experienced in project management and who have the ability to learn and adapt quickly, given that career paths will change more rapidly in the near future Therefore, these future requirements for employability, including innovativeness and entrepreneurialism, constitute an important second challenge.

C. A third major challenge is digitalisation, which comprises the increased system understanding and process skills that are integral parts of the fourth industrial revolution with an expected increase in the use of new technologies, like the Internet of Things (IoT), artificial intelligence (AI), robotics, etc. Digitalisation will saturate the entire society and affect all the engineering disciplines.

The workshop is based on a “Nordic Engineering Hub” established in 2018 with the objective to empower the Nordic region when it comes to STEM education and in particular to address these three challenges. One projects within the hub are on engineering education 2030 for which experts in various engineering subjects are interviewed.

What is seen during a first step of analysis is that the expectations seem to be quite contradictory, and variations are found to be dependent on what engineering discipline you belong to. The more science-based engineers, such as chemical-engineers or physics-engineers seem to have a different picture on what will be important for the future than engineering disciplines that are more closely related to production, like mechanical or civil engineering. It is therefore very interesting for us and the participants in this workshop to see whether we find a consensus on how engineering education needs to be developed in order to meet future challenges.

Similar questions will form the basis for guided discussion in teams formed by the workshop leaders. With the reference to the three challenges, we ask the following main questions to the participants:

- How do think these challenges affect the development of your discipline and the educational program you are involved in?
- How would this look in 10 years time from now?
- Are your students are prepared for the future with the existing education?
- How will the students learn engineering in the future?
- Are there other challenges that we have not mentioned?

The workshop participants will be asked to establish teams around their subjects. Each team will be given a set of cards with possible directions of engineering education 2030 for each of the challenges. The participants will then have to choose three cards for each of the challenges and discuss how this will influence the direction of the curriculum.

The participants will have to sum up their work on a poster which they will present in a final poster session at the workshop. The results from the workshop will be compared to results from interviews with experts from Nordic universities on how they expect the future to look like.

Discussions on the challenges engineering education will have to address and how engineering 2030 could be imagined is of vital importance for both researchers and practitioners working with development of European engineering education.

The results will be summarized and spread to the SEFI forum, and may also be the base for further investigations on future Engineering Education.

Physical Computing: A low-cost project-based approach to engineering education

P. K. Hannon
TU Dublin, Ireland

D. Berry
TU Dublin, Ireland

S. Chance
TU Dublin, Ireland; UCL, United Kingdom

M. Core
TU Dublin, Ireland

F. Duignan
TU Dublin, Ireland

Topics: Integrated learning environments for the digital native learners, 4th Industrial Revolution

Keywords: computing, PBL, practice, affordable, IoT, technology

One of the current trends in engineering education, often due to costs, is to use simulation software for the design and analysis of systems. However, using simulation packages as an alternative to real-world equipment may lead to a lack of student engagement and confidence, thereby reducing the impact of learning. This workshop presents an alternative mode of module delivery that facilitates practice-based learning, where students get hands-on practical computing using inexpensive, yet real-world equipment and technologies that can help transform notional self-directed learning to actual learning.

In this workshop, participants will discuss the philosophy, rationale, and techniques used to teach Physical Computing at one Technological University. The workshop will be broken into 5 sections, a timeline for which is presented below.

Suggested timeline for each section of the workshop

1. Philosophy & example modules (10 minutes)
2. Case study module details (10 minutes)
3. Walkthrough implementation (30 minutes)
4. Breakout discussion with participants (30 minutes)
5. Summary of results from section 4 (10 minutes)

Section 1: Philosophy & example modules delivered using the approach

To begin, workshop facilitators will introduce their project-based philosophy and approach to teaching Physical Computing by briefly describing a range of modules delivered using the approach in their school: **Robo Sumo/RoboSlam** (a robot-building challenge); **Build a PC** (a highly practical introduction to computer architecture); **Embedded Systems** (a highly practical look at microprocessor and microcontroller systems).

Section 2: Case study module details

During this section the facilitators will describe in more detail how they conceived, reconfigured, and redeployed a conventional undergraduate **Internet of Things** (**IoT**) module using the problem based approach to reach a broader and more diverse audience using the four design principles outlined in [1] to:

a) eliminate barriers—often encountered when delivering modules that involve the integration of several hardware, software and communication components;

b) achieve critical affect—by removing the frustrations involved in significant management overhead of configuration and maintenance involved when using open-source software;

c) guide towards independence—by providing prescriptive instructions for a sample application and guides towards further expansion for continued self-directed learning; and

d) ensure scalability—by publishing detailed instructions on-line and providing sample inexpensive project kits to workshop participants in order to facilitate the delivery of the material by third parties outside specialised laboratory environments.

Section 3: Walkthrough implementation of the proposed approach

In this section, the participants will be guided through a practical implementation of a case study that uses the proposed approach for teaching a physical computing module in order to gain hands on experience of the approach. The participants will be guided through the design and implementation approach used to build a series of structured mini projects, involving the integration of inexpensive but disparate, real-world hardware, communications and open-source software components, building to a complete end to end solution for a real world IoT application. Assessments methods used in the module and the level of student engagement with the approach will be presented as part of this section.

Section 4: Breakout discussion with participants

During this section, participants will be asked to:

- Describe cost-effective ways to balance value and overhead associated with a problem-based engineering approach
- Identify and evaluate mechanisms for using real-world technologies for module delivery as opposed to the more de facto approach of using simulation software
- Discuss their hands-on experience of using the approach to develop a real world IoT application involving the integration of several disparate hardware and software components
- Discuss assessments methods and tools suitable when using this teaching approach
- Appraise the merits of the approach to facilitate building students' competence and confidence with using real world technologies
- Discuss the merits of the approach for removing the barriers to entry for learners in engaging with new technologies and for inspiring further self-directed learning.
- Discuss the impact of some teaching and learning "patterns" used in delivering the pilot module such as: "Repeat after me"; "Here's a solution for 'X'. Please use the approach to solve 'Y'"; "Here's a worked example A and some similar problems. Keep trying until you get all the correct answers."; "Change this and see what happens"; "This is broken in this way - fix it"; "This is broken in some way, find the problem and fix it"
- Identify implications of the overall approach for teaching and learning in engineering education

Section 5: Summary of results from section 4

A summary of the results from section 4 will be compiled in this section. This will serve as a foundation for the further development and assessment of the approach.

Overall, this workshop provides the rationale for "holding the line" against the *de facto* approach of using simulation software at the expense of practical and problem-based engineering activities. The approach is particularly relevant for modules that involve the integration of several hardware, software and communication components.

[1] T. Burke, D. Berry, and S. Chance, Reaching new audiences through "RoboSlam!" workshops, 2013

THE *MEDVEMATEK* PROJECT AND THE SMART TRAILS APPLICATION

P. Kovács
Budapest University of Technology and Economics, Hungary
A Matematika Összeköt Egyesület, Hungary
MTA-BME Information Systems Research Group

Topics: How to detect and attract talents with new generations of learning technologies and networks; Fundaments of Engineering Education: Mathematics and Physics

Keywords: talent development, gamification, mobile application, mathematics

In our modern times there are a couple of core skills, namely problem solving skills, capability for teamwork, adaptiblity etc., which every engineer needs throughout their life. Some of these skills have to be nurtured from a young age, especially since the necessity of complex and scientific thinking scares many teenagers away from an engineering career. The prejudice against school subjects that develop logical and solution-based thinking (such as mathematics) poses a real problem, as it limits the number of capable students, even against the goals of the industry and the actors of higher education, who seek to train ever more professionals in these fields.

The *Medvematek* Project aims to address these issues by a comprehensive program that gets children involved as early as the age of 10, and follows their development into their university studies. Through innovative tools we engage teenagers with outside the school activities that build upon positive experiences, thus catching their interest and raising the likeliness that they will later choose a path in higher education related to mathematics, engineering or similar fields. At the same time we nurture their core skills and develop a community among them, which can form the basis of a professional network in the future. The *Medvematek* Project reaches around 15000 students annually at its outdoor problem-solving competitions, a series of maths camps and other innovative community-building events.

The most successful of these events are the outdoor problem-solving competitions, during which teams compete against each other, while trying to navigate a map at the same time. These take place in public parks, where we set up a set of stations. Each team is given a starting station, where they need to solve a puzzle and depending on the outcome (i.e. whether the solution is correct), they are sent to a next station. Once they solve enough problems correctly, they complete the track. However incorrect solutions lead to penalties, increasing both the distance needed to walk and the number of problems needed to solve. These rules, combined with the fact that good solutions lead to rewards along the way, keep the teenagers engaged and apply the pedagogical mindset of gamification to build a fun activity.

The Smart Trails application is a mobile app developed by the same team responsible for the *Medvematek* Project. It was designed to provide an experience in the same mold as the outdoors competitions. The application replicates the playful activity of completing tracks by problem-solving for the students or the teams of students using it, without the necessity of volunteers manning the stations along the way. The application allows for the creation of the trails teams need to follow with a varying complexity of the graph structure behind the (possibly virtual) maps. It also provides QR-codes which can be printed out to create an actual, physical track as well as the possibility of logging the results from the teachers' side. For the teams the application reveals the problems needed to solve at every station after reading the QR-codes and directions to the next waypoint.

At the beginning of the workshop we will introduce the *Medvematek* Project shortly, in order to allow participants to discover the pedagogical and methodological benefits of our approach. The introduction will be extended to the Smart Trails application, discussing how it enables the same concepts to emerge in teaching practice. During the workshop participants will get a chance to familiarize themselves with the application, both by trying out an exhibition track which we will prepare and by getting to design tracks of their own. Volunteers from the *Medvematek* Project will help them out in these activities, opening the possibility to discuss questions which might emerge during the time. Therefore, along the way the participants will get a chance to learn the capabilities of an application that can serve as an out-of-the-box examination tool or applied to organize fun events, which engage possible future students. We welcome everybody to the session, who is interested in new ways to raise the interest of students in the fields of STEM.

TEACHING PROBLEM SOLVING TO ENGINEERS IN THE ERA OF BIG DATA AND INDUSTRY 4.0

V. Kraft
JMP, Germany

Topics: 4th Industrial Revolution

Keywords: Industry 4.0, Big Data Analytics, machine learning, scientific method, problem solving, statistical thinking.

Industry 4.0 promises a fourth industrial revolution to better manage the way value is produced. One enabler of I4.0 is Big Data Analytics, which is often embraced as a panacea. In fact, the complexity of processing higher volume, more frequent, more diverse and more messy data makes things worse for engineers aiming to build, deploy and maintain processes to drive a 'smart factory'. Engineers in industry are often swamped and ill-equipped to handle these challenges, particularly when the application domain is growing fast.

One problem with Big Data Analytics (especially in teaching!) is that it often bypasses the methods and best practices of statistical thinking developed and proven over many decades. In many one-shot studies, machine learning algorithms are applied looking for highest prediction accuracy, sometimes without due regard for the pedigree of the data used. Furthermore, most data scientists are neither interested in learning more about the process or system under study nor in validating their findings with subject matter experts. In contrast, an engineer does not just want to predict future defect rates, but also to develop a long-term strategy to understand root causes and reduce defects further through process improvement.

During the workshop participants will see live demonstrations of a holistic approach to Big Data Analytics, which reflect some essential elements of Statistical Engineering. Key concepts covered include:

- Design of Experiments and data quality (to address the pedigree of the data)
- Visualization to explore data and models ("You can see a lot just by looking")
- Advanced analytics (beyond machine learning methods)

Our holistic approach helps to showcase how statistical thinking works with Engineering to drive process understanding and innovation. The demonstrations will feature JMP Pro, which offers the most complete support for real-world applications of Industry 4.0. No prior familiarity with JMP is required. All workshop content will be shared with participants.

ENGINEERING OUR WAY TO A SUSTAINABLE FUTURE TOGETHER

E. la Grange
Cahoot Learning

A. Smith
University of Tasmania, Australia

S. Chakrabarti
ANSYS Granta, United Kingdom

Topics: Lifelong Learning, Sustainability reflecting the complexity of modern society

Keywords: Sustainability, SERINA, Continuing Engineering Education, UN Goals, Training, World Future

Learning outcomes (motivation & learning outcomes)

One of the outcomes of the workshop will be the creation of an ongoing community of practice in relation to engineering education and research and the United Nations Sustainable Development Goals (UNSDG).

A further outcome is that participants will improve insights into the UNSDG and their application to engineering education, research and active practice.

A third expected outcome will be acquaintance with sustainability initiatives and the use in their respective organisation and community.

A fourth outcome may be the involvement by each participant to contribute to the UNSDG repository of training materials in the SERINA initiative. Thereby having a relevant role in the creation of a better world.

Relevance

The motivation for this workshop was the IACEE Porto Declaration of 2016 and the related SERINA initiative concerning world sustainability (http://serina.iacee.org/). A partial transcription of the declaration says:

"...Now therefore in keeping with its dedication to leading lifelong learning, the IACEE will develop global initiatives to address those 21st century challenges threatening the survival of human kind through collaboration, design, creative thinking and engineering....".

It is sought that engineering can help significantly to address the challenge of a sustainable world. SERINA is a promising and reliable approach to promote sustainability UN Goals among the engineering community. It is crucial to utilise in full capacity the active engineers´ competencies and influence enabling better sustainable decisions.

Participants role

Participants will be asked to establish and consider one sustainability initiative example taking place within their organisation or community relating to the UN SDGs. This example may also be chosen from the examples shared by the organisers. The active practice of engineers related with each example (projects, organisation or community) will be shared and discussed in small groups. The role of engineering education will be discussed and analysed in terms of benefits and implementation in a large scale.

Participants of the workshop will be introduced to and invited to be part of IACEE's Global Sustainability Initiative, SERINA, Sustainability Education and Research in Action. The role of the education initiative of SERINA, which is about highlighting and encouraging the work being done in organisations and communities around the world in sustainability, will be analysed. The SERINA initiative can be viewed and liked on Facebook… @serina.iacee, at the website serina.iacee.org or join the LinkedIn SERINA IACEE group.

Results summary

The structure of the workshop is composed by a brief presentation of United Nations Sustainable Development Goals, IACEE Porto Declaration and the SERINA initiative. Related copies of documents and web-links will be provided. Groups will be formed to address the questions presented. There will be in each group a member of IACEE and active in SERINA. There will be discussion among groups and proposals will be presented using digital support. Opinions of participants and answers to concrete questions will be recorded and shared using group digital communication tools. It is expected that there will be a set of proposals about next steps from the Engineering community to handle the challenge of a more effective participation.

Significance for Engineering Education

Engineering Education (EE) and Continuing Engineering Education (CEE) are crucial to handle the scale and complexity of the gap between existing solutions and the needs facing our planet. Engineers are uniquely placed to act on this opportunity. Through initiatives like SERINA it is possible to connect individuals, universities, industry, government and NGO organisations to meet the grand challenges facing humanity and the world.

Lifelong learning has developed and can continue to develop global initiatives to address those twenty-one century challenges threatening the survival of human kind through collaboration, design, creative thinking and engineering. The Porto Declaration (www.iacee.org) may motivate the engineering community and influence a majority of stakeholders to comply with a framework of global sustainable development.

EE and CEE can influence on short term the pledge of the engineering community and of related sectors to a global commitment in implementing this call to service. This change and improvement can be obtained mostly by education and training of the engineering community around the world. Engineers and related stakeholders have a major influence in the world development. It is crucial that within a global and international arena the engineers take charge of the sustainable measures to ensure a future for the world. SERINA and the Porto Declaration can act as beacon and motivation for all and especially for active engineers and for future engineers. The contribution of these initiatives can arise from examples of related activities, the role of online learning in CEE sustainable courses, some guidelines for online sustainable courses and the provision of training and education for a sustainable world.

FINDING COMMON GROUND IN CROSS-BOUNDARY COLLABORATION

Laperrouza, Marc
EPFL, Switzerland

Topics: New Notions of Interdisciplinarity in Engineering Education

Keywords: interdisciplinarity, active learning, teamwork

What are session participants expected to learn?

The workshop aims to:

- Describe and improve an existing pedagogical scenario to establish common ground in a project-based/interdisciplinary program
- Explore alternative scenarios to establish common ground in cross-boundary collaboration

Why is the session relevant?

Students need to cope with multiple perspectives to address problems as a system and solve them comprehensively [1]. At the same time team diversity is also associated with higher levels of dissatisfaction, turnover, … and stress [2]. Collaboration is difficult because each profession has its own language, terminology, beliefs about relative importance of performance attributes, approaches to learning, mechanisms for information exchange, goals, and reward structure. In other words, the promises of cross-boundary collaboration are as large as the perils [3].

How are session participants activated?

In the first part of the workshop participants will be asked to discuss the strengths and weaknesses of an existing scenario with the aim to improve it. In the second part they will be asked to explore alternative scenarios to foster cross-boundary collaboration.

How will results be summarized?

Participants will receive a description of the existing pedagogical scenario as well as the suggested improvements. In addition, a synthesis of the alternative scenarios wil be provided.

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Teaching other Communication Skills than Writing and Presenting – A Take Home Workshop created as part of the PREFER Project

M. Leandro Cruz
TU Delft
Delft, The Netherlands

G. N. Saunders-Smits
TU Delft
Delft, The Netherlands

Conference key areas: curriculum development, engineering skills

Keywords: communication skills, verbal and visual communication, active learning

Motivation: Participants will be able to test-drive a new curriculum element developed to have engineering students experience and reflect on the importance of effective verbal and visual communication.

Rationale: Although engineering education has been engaged to stimulate students communication skills, it is still very focused on oral presentations and written reports. For this reason, a new 1h communication activity was developed as part of the PREFER Project, an Erasmus+ Knowledge Alliance. This activity is called *Chinese Whisper with a Twist* because it is based on the Chinese Whisper game which aims at passing around a message. However, a Twist was applied to this activity and participants are constrained to either describe an image provided, listen and reply, or ask questions to draw the image. Thus, this activity allows participants to experience a wide spectrum of ways to communicate, such as describing, listening, questioning, answering, and drawing, as well as to create awareness and reflect on effective communication. More information about the activity can be found in [1].

Participant engagement: In this session, participants will be immersed in a hands-on experience of the communication activity. As such, they will be invited to work in small groups and challenged to play the *Chinese Whisper with a Twist*, i.e. to communicate effectively to reconstruct an image.
In the final part of the workshop, we will jointly reflect on how valuable this activity was for the participants, how it can be used to develop students communication skills and how participants could integrate it into their engineering courses.
The participation is limited to a maximum number of 30 people.

Takeaway: The attendees will gain a curriculum element, ready for implementation in their own courses. Not only will they have the opportunity to experience the education activity, but also obtain practical suggestions to integrate the activity from its creators. Participants will be given access to the full teaching implementation kit after the workshop as an Open Educational Resource.

Significance for engineering education: This workshop will provide educators with a short 1h practical educational curriculum element to enhance students' communication skills that can be applied in almost any course in any engineering degree programme.

Reference:

[1] Leandro Cruz, M., and G.N. Saunders-Smits, "Design and Implementation of New Communication and Lifelong Learning elements in a Master Engineering Course", 46th SEFI Annual Conference, 2018.

RESEARCH IN (INTER)ACTION. COLLABORATIVELY EXPLORING THE POTENTIAL OF THE "ACTION RESEARCH" FRAMEWORK FOR ENGINEERING EDUCATION

J. Lievens

University of Leuven, Belgium

Topics: Gender, Inclusion and Ethics, Sustainability reflecting the complexity of modern society

Keywords: Action Research, Exploratory Action Research, Participatory Action Research, Curriculum Design

As social, civic, corporate, industrial, educational and environmental standards and customs are evolving at an ever-increasing pace, so the claims made to curricula of 21st-century engineering education are becoming, at once, more diverse, urgent and complex. The challenges that institutions of higher engineering education face include, but are not limited to: enabling transitions from traditional teaching based on knowledge transfer and “canned engineering” exemplars to problem-based and competency-oriented modes of teaching and learning stimulating creativity and critical thinking; from entrenched conceptions of the engineer as a technological specialist towards educating “T-shaped engineers”, who are also proficient in communication, teamwork and project management; from immediate-return presuppositions to a (global and local) community-oriented focus on sustainability and social equity. In short: if the catchword of the today’s age is “disruption”, then how can Engineering Education prepare its graduates for recognizing and welcoming the new as it emerges, and harnessing it as a socially and environmentally benevolent force?

One part of the answer is that Engineering Education is to look beyond the confines of the institution. What the stock-taking MIT report “The global state of the art in engineering education” (2018) identifies as one of the main trends in leading engineering curricula around the world is “a move towards socially-relevant and outward-facing engineering curricula” (p.iii). It is, at least partly, by reaching out towards the (local and global) communities in which they are embedded that institutions of Engineering Education will be able to develop an agenda for new learning.

What this workshop explores is the extent to which the inherently outward-oriented framework of Action Research (AR) opens up pathways towards successfully and comprehensively coping with the complex and diverse demands on contemporary engineering curricula. Action Research refers to a “family” of approaches that share a dedication to improving immediate, real-world situations by well-planned actions based on a rigorous practice of inquiry (mixed method data gathering, analysis, and reflection). Typical of this systems-oriented, post-positivist approach is that the researcher is not a detached observer (in the dominant objectivist, hypothetico-deductive tradition) but an openly biased participant-collaborator, who actively - but always critically and reflectively - strives towards enhancing the real-world conditions of a “community”, however defined.

The promises of AR to be critically and practically explored in this workshop are:

- that it breaks open the walls of academia and inspires projects with a societal impact;
- that it has the potential of uniting technical or technological challenges with a modus operandi that requires social, communicative, ethical and research skills and attitudes;
- that it stimulates students of Engineering Education to “explore the future by doing” (p. 11) rather than “downloading patterns from the past” - to use terminology by Otto Scharmer, whose Theory U is directly informed by AR – and thus prepares them for the disruptive innovations yet to come;
- that it provides at once a methodology and a praxeology for engaging engineering education stakeholders into cycles of progressive transformation.

In this workshop, participants first acquaint themselves with some definitions of Action Research, the different perspectives, and approaches within the Action Research family, and some examples. After this introductory part, the participants explore what Action Research could potentially mean in the context of their courses, curricula, and communities – whether educational, institutional, professional, regional or otherwise. Working together in small groups, participants are guided along a typical Action Research, first-cycle trajectory, including steps to:

a) identify a need, a problem, a question or challenge;

b) envision a desirable future or solution;

c) map the key actors, stakeholders and/or communities and their relationships;

d) identify suitable ways of gathering data (by exploring a “toolbox” with typical Action Research research tools);

e) consider possible actions or interventions;

f) consider ways of evaluating the process, the actions, and the results;

g) consider ways of assessing learning outcomes;

h) consider how this AR project could connect to other curricular components;

i) consider obstacles to be overcome.

Participants are seated together at 4 to 6 person tables. In the introductory section, participants at each table explore, compare and discuss AR definitions and examples and distill essential characteristics. In the next phase, participants individually or in pairs execute steps a), b) and c) from the above scenario, using a paper or online canvas for documentation. Then, participants present their AR “germ” to the table. After discussion, coalitions are formed so that each table develops a selection of AR scenarios more fully, by going through stages e)-i). Each scenario is documented using an online canvas (a rubricated Padlet), which is shared with the other group tables. These canvasses provide a tangible, take-home report that can provide inspiration for curricular efforts in the future. In the final stage of the workshop, participants debate on whether, or to which extent, the AR framework succeeds in following through on the above-listed promises.

Participants take home a theoretical and practical understanding of what Action Research means and what it can signify in the attempt at coping with the many challenges that institutions and curricula of engineering education currently face.

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Exploring the future of digital testing: How can multiple-choice and closed questions play a role in engineering education?

A. J. Lochner
M. Luttikhuis
University of Twente, The Netherlands

Topics: Fundaments of Engineering Education: Mathematics and Physics

Keywords: digital testing, mathematics, multiple-choice, learning goals

Digitisation of learning also involves the digitisation of testing. With this comes certain challenges in terms of facilities, logistics, but most importantly, setting good testing items that align with curriculum goals. This is especially challenging in Mathematics (Sangwin and Köcher, 2016) and other application-based education that is foundational in Engineering Education.

At the end of the workshop, participants will be able to outline and contrast the different possibilities within digital testing. This will be achieved through the workshop sketching the background to why a technical university has decided to undertake digital testing in its current flexible Chromebook format ("Digital testing with chromebooks", n.d.), an interactive quiz regarding common misconceptions and truths about digital testing and two case studies of courses that use digital testing at the university. This includes a case study which combines classroom software and digital testing questions in order to facilitate authentic testing ("Digital assessment in Remindo", n.d.).

This information will be the foundation of the second half of the workshop, where participants will analyse and criticise undergraduate Mathematics multiple choice questions in terms of their learning goals, difficulty, and the effectiveness of the distractors (Anonymous, 2019). Participants will then be given guidelines to create and evaluate their own multiple-choice items for their own subject area. Participants will be able to have informed discussions and ideas regarding digital testing for their own specific education and have started creating items for their own subject areas.

Outline of Workshop (Max 50 participants):

1. **General Introduction to Digital Testing (20 min)**
    a. *Know:* What is meant by Digital Testing: Possibilities and question types.
    b. *Analyse:* Top 10 misconceptions and concerns quiz about digital testing.
    c. *Discuss:* Between presenters and participants
        i. Why digital testing is done.
        ii. Address concerns of digital testing.
        iii. Present advantages of digital testing.

d. *Understand:* Digital Testing at the university

i. When it started.

ii. Why Flexible model.

iii. Using Remindo for general testing and MyLabsPlus for Math.

2. Two examples (case studies) for digital testing (15min)

a. *Understand:* Authentic testing using SPSS and Multiple Choice (Remindo)

i. How the cloud-computer solution can run both pieces of software in a secure environment, allowing for "open book" exams that uses Remindo in for the automatic assessment.

b. *Understand:* MyLabsPlus

i. What content it has.

ii. Homework sessions and feedback to students, as well as video support.

iii. Allows for digital testing as it has mathematical equivalence reasoning.

3. Evaluation of MCQ in Mathematics – What makes a good distractor (20 min)

a. *Know:* MCQ jargon.

b. *Analyse:* Test validity and reliability: What are you testing, with focus on distractors.

c. *Evaluation:* questions using rubric on thinking skills and difficulty.

4. Make your own item (25min)

a. Participants make teams.

b. *Create:* Participants are given a checklist to assist in creating items of their own.

5. Summarize and wrap-up (10 min)

a. *Present:* Ideas of the future of digital testing.

b. *Discuss:* Participants view of future of digital testing.

Understanding qualitatively different experiences of learning in Engineering: Variation as a learning tool

M. Miminiris
Anglia Ruskin University, United Kingdom

S. M. Chance
UCL Centre for Engineering Education, United Kingdom; TU Dublin, Ireland

Direito, Inês
UCL Centre for Engineering Education, United Kingdom

Keywords: research methods, phenomenography, methodologies, engineering education research

What are session participants expected to learn?

Students experience and understand engineering curricula and education in qualitatively different ways; such differences often lead to qualitatively different outcomes. The aim of the session is to introduce phenomenography, a qualitative research approach that aims to identify these qualitative differences and shed light into how engineering students understand aspects of teaching, learning and assessment in the discipline. This research approach is widely known by the concepts of “deep” and “surface” approach and seeks to identify different conceptions of a phenomenon held by individuals within and across a group (Marton and Booth, 1997). The methodology helps researchers identify shared conceptions among group members and describe relationships among the various conceptions held. This can consequently allow educators to work towards the advancement of such conceptions from limited, less advanced to more advanced understandings of a phenomenon, concept, idea, taught topic, method etc.

The workshop adopts a hands-on approach; participants will therefore become familiar with the purpose and methods of phenomenographic research by analysing a dataset themselves. This is an effective pedagogical approach considering the workshop time constraints. The dataset will be selected extracts from a recent study of how engineering and architecture students understand design and knowledge creation in their disciplines, how this varies by professional degree program (architecture vs. civil engineering), and how student conceptualisations change over time. Participants will benefit from engagement with data and exposure to a ‘real’ research problem, i.e. how to provide an account of qualitative differences in engineering students conceptions of design and knowledge creation. Facilitators will provide guidance and support through the development of the group work and clarify points of contention or address misconceptions about the methodology.

This workshop has four expected learning outcomes (LO):

1. Describe aspects of the theories underpinning the phenomenographic approach to generating and analysing qualitative interview data.
2. Identify implications of variation for teaching and learning in Engineering Education.
3. Work effectively and efficiently within the time constraints of the workshop to analyse data and present results of phenomenographic analysis.
4. Discuss variation as a tool for enhancing student learning and pedagogical outcomes.

Why is the session relevant?

Phenomenography is a research methodology well suited to exploring how engineering students and academics experience engineering education. The significance of phenomenography to engineering education research (EER) and practice lies in its potential to account for differences and changes in meanings individuals hold about concepts and practices in their discipline. By emphasizing variation, this methodology highlights that existing forms of knowledge are not fixed and therefore these are possible to change.

How are session participants activated?

This workshop is limited to 20 participants. At the beginning of the workshop, they will be invited to introduce themselves by giving their affiliation, professional background and motivation for attending the workshop. Therefore, they will be involved from the outset and this approach is intended to be maintained throughout the workshop through regular questions to the audience. Following the assignment of the group work, participants will be asked to individually read the selected transcripts and collaboratively work on the identification of the emerging differences in engineering students' conceptions of design and knowledge creation.

Introduction to phenomenography [20 minutes]

In this workshop, participants will be introduced to the historical development of phenomenography and will examine its position within the wider qualitative paradigm (LO1).

Potential implications for Engineering Education [10 minutes] Group discussion

Participants are likely to have prior understanding of issues explored in the interview transcripts and will feel motivated to contribute to group work, discussing their research interests with facilitators and other participants (LO2).

Data analyses and presentation [50 minutes] Group work

Participants will discover and practice using this methodology in conducting engineering education research, applying phenomenographic approaches to generating and analysing data. They will work in groups to undertake their own analysis of interview data from a study with architecture and engineering students exploring how they understand design creation. At the end of the hands-on data analysis activity, workshop participants will discuss their approaches to analysing the data and compare their findings (LO3).

Closing remarks [10 minutes] Group discussion

Ultimately, participants will discuss how the results of phenomenographic studies might contribute to more meaningful engagement in engineering education and research (LO4).

How will results be summarized?

Each group will give a very brief presentation of a visual representation of their findings. Participants will be invited to comment other groups' findings and the facilitator will summarize the discuss by offering an overview of the final results of the study.

How is this work significant for Engineering Education?

Case and Light (2011) identified phenomenography as one of the emerging qualitative methodologies in EER, as it can contribute to broadening the type of research questions and ways of thinking about engineering education. Variation is important to highlight how students understand important concepts of the engineering curriculum such as energy in solution processes (Ebenezer & Fraser, 2001) or how to enrich the curriculum with new concepts such as enterpreneurship (Täks, Tynjälä, & Kukemelk, 2016). It can also be helpful in identifying troublesome aspects of problem-solving processes in the engineering workplace and enhance how engineering curricula equip graduates for the workplace. Phenomenography can therefore support the design of engineering curricula, pedagogical approaches, and assessment methods as well as enhance aspects of the overall student experiences and how students meaningfully engage with the discipline and the profession.

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STUDENTS' INVOLVEMENT IN ENGINEERING EDUCATION DEVELOPMENT

J. M. Moita
BEST, Portugal

Topics: Diversity in Engineering Education, Strong demand for democratic involvement in educational processes

Keywords: BEST, Students' opinions, Teaching methods, Democratic involvement in educational processes, Assessment

The proposed workshop has the following main goals: first of all, demonstrating to professors, researchers and experts why it is relevant to gather the students' input regarding educational matters; secondly, presenting the work developed by BEST in order to close the feedback-loop between education providers and students; and finally, understanding the way lecturers could be key players in the process of implementing the proposed changes. Participants will have the opportunity to think critically about their own teaching and evaluation practices, reflect on the main challenges faced when trying to implement changes and understand how their peers and students perceive them. By doing so, participants are expected to become more aware of existing flaws, both in their work and the current teaching and evaluation practices, and increase their openness towards actively gathering and implementing feedback from the relevant stakeholders.

Board of European Students of Technology (BEST) is a European non-profit organisation celebrating, in 2019, three decades of a history full of continuous efforts to involve students in the improvement of STEM Education. With the vision of Empowering Diversity, which is closely connected with the conference thematic "Diversity in Engineering Education", BEST has been involving students in Engineering Education and actively disseminating their opinions to relevant stakeholders. With 23 years of experience in participating in European projects and attending international Education conferences, BEST wants to bring forward the perspectives of students as a key element in educational decision making and also to understand how professors, researchers and experts perceive this demand.

In terms of format and dynamics, the workshop will be similar to the sessions held in BEST Symposia on Education (BSEs), so that participants will experience the methodology used by BEST to gather the students' opinions in these events. After the introduction, self and hetero-evaluation exercises will be conducted, in order to identify problems and improvement points in teaching methods and practices. Divided into groups, participants will be brainstorming and discussing possible solutions to the identified problems. Later on, the solutions found during the previous exercise will be discussed and worked upon by all the participants together, in order to reach outcomes that all professors can implement in their own classrooms.

To finalise the workshop, the problems found by professors will be compared to the ones identified by students from different European countries. Through this exercise, professors will understand whether their self-assessment diverges from students' views. It will be a way to increase their motivation and interest in understanding and fulfilling students' needs and expectations, and a chance to take action towards this. The workshop impact on the participants will be assessed, as the participants are expected to better understand how they can have an active role in involving students more effectively. After the conference, the workshop outcomes will be analysed and reported by BEST members in order to improve the way the organisation connects with experts.

DESIGN THINKING – THE WAY TO TEACH DESIGN IN ENGINEERING EDUCATION

L. Morell
InnovaHiEd

E. Vendrell-Vidal
Politécnica de Valencia, Spain

Keywords: engineering design, design thinking, user-centered design, engineering education

Introduction - Why is the session relevant?

Innovation is the engine of industry, and it can also make a better world. **Design Thinking** is a methodology that is fast becoming a mainstay in business strategy all around the world. Centered on creativity, empathy, and putting the user's needs as the heart of the problem, Design Thinking is seen as an important tool for driving innovation and sustained business growth. As the "business of innovation" becomes increasingly important to strategic decision makers in all sectors and industries, it is necessary for design thinking to become ingrained in the engineer's mindset. Design thinking culture must be integrated across the engineering curriculum beyond the capstone design experience.

What are session participants expected to learn?

Engineering professors need to understand how traditional design differs from the design thinking approach in order to integrate this design method into the curriculum. At the end of this 90-hour workshop participants will have:

1) learned about design thinking, its history and implementation;
2) reflect on the design thinking implementation steps, and
3) brainstorm ways to infuse design thinking in the engineering curriculum.

How are session participants motivated?

In order to achieve desired learning outcomes, the workshop will be conducted utilizing a series of short presentations followed by exercises and design challenges, reflections and brainstorming done by participants in groups of 2 or 3 (like Think-Pair-Share). Due to the time limitations, one or two groups of participants will be asked to share their discussions/designs/reflections.

How will results be summarized?

Participants take home:

1) what is design thinking and why it is important in the 21st Century, and,
2) consider various ways to implement the design thinking method into the curriculum.

How is this work significant for Engineering Education?

This design approach is behind the success of Silicon Valley and other regional innovation hubs around the world. As the "business of innovation" becomes increasingly important to strategic decision makers in all sectors and industries in the 21st Century, and as the world increases to rely on green engineering for sustainability, it is necessary for design thinking to become ingrained in the engineer's mindset. Therefore, the design thinking culture must be integrated across the engineering curriculum beyond the capstone design experience, so that this approach (human centered design) is engrained in the engineer's mind. This workshop is designed for STEM deans and professors who wish to learn about design thinking and how to integrate it in the curriculum and is meant to give participants a full cycle through the design-thinking process in as short time as possible.

Workshop Agenda

Design Challenge 1 (activity)	10 minutes
What is Design Thinking and Why is it Important in the 21st Century?	20 minutes
What are the Design Thinking Steps?	10 minutes
Design Challenge 2 (activity)	10 minutes
Ways to Integrate Design Thinking into the Curricula	20 minutes
Brainstorming (activity)	10 minutes
Final Thoughts and Workshop Evaluation	10 minutes

GREEN LOGISTICS: ANOTHER ENGINEERING IS POSSIBLE

A. Queiruga-Dios
M. J. Santos Sánchez
A. Hernández Encinas
University of Salamanca, Spain

Topics: Open and Online Teaching and Learning, Lifelong Learning

Keywords: Green logistics, Learning methodologies, m-learning, game-based learning

One of the goals of an engineer is to solve problems, and a second one is to reduce costs. This is usually related to real life situations and daily life.

A team made of companies from different European countries started working with some universities in LOG-IN-GREEN project, for training green logistics managers to avoid the environmental effects of logistics. This project's aim is to improve green logistics skills in young workers. Once trained, young workers will become green logistics trainers, and this will help to the employability of young people. Logistics education and awareness require good knowledge of geography and also foreign languages and human relations skills as well as digital competences. There are standard trainings that are being used in the sector.

For doing this, we have discussed about some methodologies that will help students to acquire the competencies to become green logistics managers. Universities and companies can find together the way to teach young people. This workshop will deal with different methodologies that are proposed for engineers to train logistics leaders and future trainers.

The current situation in some European cities is that young people with migrant backgrounds, immigrants and refugees, young people at risk of marginalisation, or young people with fewer opportunities (including NEETs, not in education, employment or training) apply for a job and want to be integrated into the labour market.

Motivation and the use of technology are the key points to reach this target group. Youngsters like to be connected all day and they usually love playing games.

Keeping this in mind, we propose a practical session to teach and learn about different engineering topics. We will present a real scenario where participants will develop their engineering, social and team work skills to achieve the best results.

The use of games (game-based learning), design thinking, online learning, learning using mobile devices, or mental or conceptual maps, are some methodologies and tools that are currently being used in several educational contexts. The mobile phone (usually forbidden for teaching and learning) plays a key role in the process of training. Participants in this workshop will be encouraged to use their mobile phones and also to participate in a game and thereby test the possibilities of these methodologies. Escape rooms or Breakout EDU are becoming activities to motivate students, to make them work in teams, and to address real situations that must be solved finding clues and applying previously acquired knowledge.

We propose a session with speakers from different engineering areas with the common goal of engaging and training young people. The use of games or mobile devices in education of people over 15 is not very widespread. It is not common to use games for teaching Linear Algebra, Calculus, Mechanics, Logistics, Thermotechnics, or any other subject. Students must learn theoretical topics and how to solve several problems in a "classical" way, although these problems could be real-life problems. During recent years we are trying to make students apply what they learn while they try to solve engineering and scientific problems.

The participation in this session may provide ideas and tools for supporting trainers and trainees in the final goal of reaching the needs of young people. Furthermore, the development of a new approach is being demanded by engineers to motivate young workers, and also for youngsters to be motivated with learning.

We propose to play Angry Birds and not solve an interpolation problem, to find the key to open a padlocked box instead of listing ecolabels of a product, or decrypt an encrypted message to get the uses of ecological footprint. Young people would rather solve a puzzle, than memorize a list of polluting gases or solve an optimization problem.

During some undergraduate and master degrees we have implemented game-based learning with physics and maths topics. These activities engage students in learning contents and acquiring engineering competencies and skills. Gamers learn by doing and by experimenting, and they participate as part of a team. Their motivation is guaranteed as they like play games to win.

INCLUSIVENESS OF NEURODIVERSE STUDENTS IN ENGINEERING EDUCATION CURRICULUM DESIGN AND DELIVERY

G. N. Saunders-Smits

M. E. D. van den Bogaard

Delft University of Technology, The Netherlands

Topics: Diversity in Engineering Education, Talent Management

Keywords: inclusiveness in engineering education, neurodiversity, talent management

Motivation: Research shows that 15-20% of the population suffers from conditions that are classed as neurodiverse [1]. Wikipedia defines neurodiversity as “an approach to learning and mental health that argues various neurological conditions are the result of normal variations in the human genome” [2]. In this approach ADHD, Autism, Depression, and Dyslexia and other neurological conditions are framed as natural human variations and are an authentic form of diversity, self-expression and being with the rights to be allowed to live their lives as they are just like neurotypicals.

Evidence has showed that in engineering degrees neurodiverse students are overrepresented [3].

Neurodiverse people benefit from more awareness and support in their education. Their intellectual abilities are generally high to excellent. The problem in engineering education appears to occur in areas relating to transversal and organizational skills and the mismatched expectations of educational institutions. As a result, neurodiverse students are more likely to drop out [4] [5].

Rationale: The United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) [6], obliges universities to ensure a proactive, inclusive educational environment; a reactive support network is no longer sufficient. Many universities in Europe have support networks in place, but not many universities train education staff in how to take into accounts the needs of students in curriculum design and delivery. Yet lecturers and curricula developers must also play their part in inclusivity. However, there is a lack of awareness among lecturers and curricula developers what it means to be neurodiverse in a Higher Education environment, let alone that they are aware of the, often practical, needs of neurodiverse students in terms of course set up and delivery.

Participant engagement: Participants will debate statements on adaptation and inclusivity in curriculum design and delivery with aim to create awareness of the needs of neurodiverse students. After that, participants take part in brain storm session coming up with creative solutions to problems commonly experienced by neurodiverse students. The participants will be divided in smaller groups and discuss issues a neurodiverse student may run into. It is endeavored to introduce real problems from the perspective of real (anonymous) neurodiverse students. At the end of the workshop each group reports back with their solution which will also be included in the proceedings. There is no limit to the number of people that can take part. Everyone is welcome.

Takeaway: This workshop will provide educators with concrete information and inspiration to create a more inclusive engineering education for neurodiverse students. The results of the workshop will be included in the conference proceedings.

Significance for engineering education: By creating more neurodiverse friendly engineering education, overall student retention and success will go up, not only among neurodiverse students. This workshop will enhance understanding of the needs of neurodiverse students, the challenges they face and the importance of taking their needs into account when designing the inclusive engineering education.

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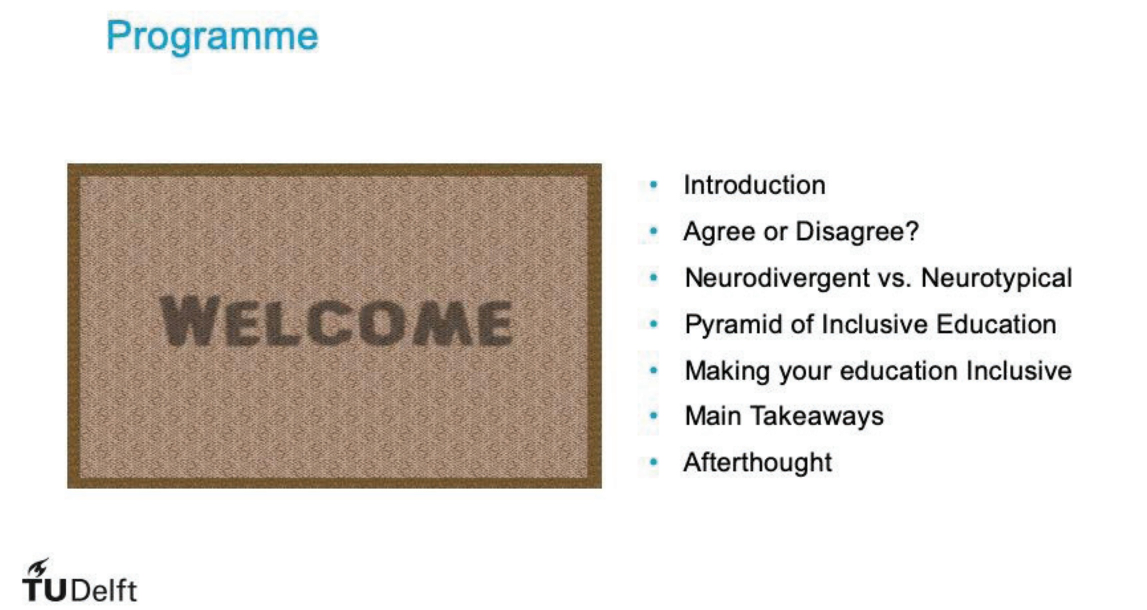
Inclusiveness of Neurodiverse Students in Engineering Education Curriculum Design and Delivery
Workshop
Gillian N. Saunders-Smits & Maartje E.D. van den Bogaard
Delft University of Technology
The Netherlands
TUDelft


Programme
WELCOME
Introduction
Agree or Disagree?
Neurodivergent vs. Neurotypical
Pyramid of Inclusive Education
Making your education Inclusive
Main Takeaways
Afterthought
TUDelft

Do you agree?

“A student cannot become an engineer if they cannot write a thesis without help.”

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Do you agree?

“A student won’t get half an hour extra in industry”

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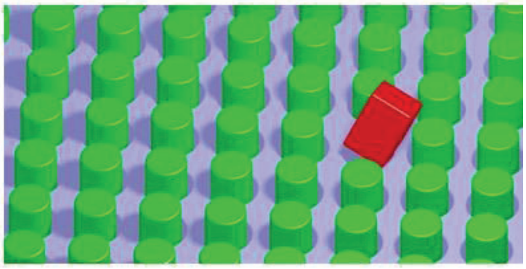
Do you agree?

"If a student cannot work in teams they can never be a good engineer."



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Do you agree?

" I don't want to supervise student who talk too much and go off on tangents all the time. They are so tiresome."

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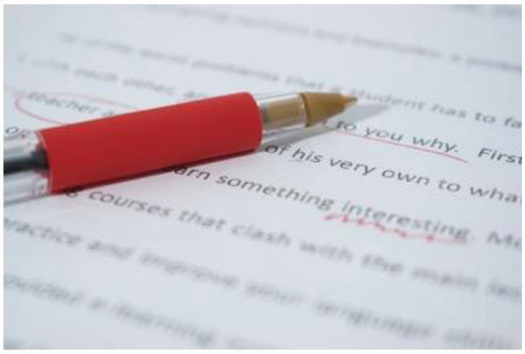
Do you agree?

"Students who cannot spell do not belong at university."



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What is Neurodiversity?

The diversity of human brains and minds – the infinite variation in neurocognitive functioning within our species.

[source: neurocosmopolitanism.com]

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What is Neurotypical?

Having a style of neurocognitive functioning that falls within the dominant societal standards of "normal".

[source: neurocosmopolitanism.com]

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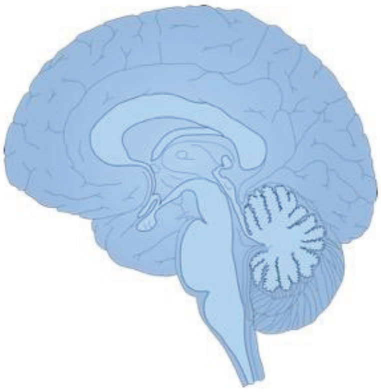
What is Neurodivergence?

Having a brain that functions in ways that diverge significantly from the dominant societal standards of "normal".



[source: neurocosmopolitanism.com]

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Some Possible Forms of Neurodivergence

[Source: suelarkey.com.au]

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Issues for Neurodivergent Students

First of all: Everyone's form of neurodivergence is **different**, however they do share **common problems** in education:

- Different way of processing -> Often require more time for processing,
- Losing sight of objective -> Do not finish, go off on tangents
- Time & Self Management -> Late, unstructured ways of working, can't synthesize
- Understanding Expectation -> Especially when requirements are very open
- Prioritizing -> Distinguishing between major and minor issues
- Interpreting differently-> Misinterpreting questions/explanation or social situation
- Sensory Overload -> Getting emotional or withdrawing
- Anxiety -> Unfamiliarity or unpredictability of situation/people

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As a result

Neurodivergent students have a high risk of dropping out in education due to low self confidence, fear of failure and anxiety

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In Engineering Education

Neurodivergent students are overrepresented:

Autism: 4 times more likely

Similar suspicions exist for ADHD and Dyslexia

[source: Meester & Draaijer, 2014]

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Why should we treasure neurodivergent students?

Why not?

- Everyone is entitled by law to the same chances for success regardless of their disability, based on the UN Convention for the Rights of People with a Disability
- But more importantly, we would be wasting enormous talents as neurodivergent students also bring many positive traits with them,

Such as:

- Creativity
- Analytical Skills
- Problem Solving Skills
- Thinking out-of-the box
- Enthusiasm, Drive and Passion
- Trouble shooting
- Ability to foresee problems
- Great eye for detail, etc..

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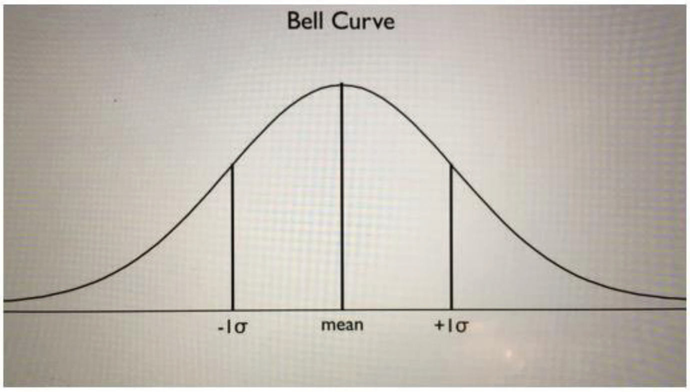
What is inclusive education?

Expressed scientifically:



When the Normalized Standard deviation: $\bar{\sigma} = 0{,}5$

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Pyramid of Inclusive Education

Universal Design for Learning

[source: www.ahead.ie]

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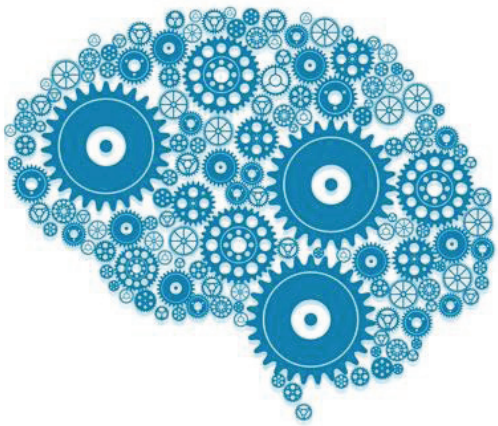
Your Assignment

In groups:

- Pick an issue a neurodivergent student may face in engineering education and brainstorm on possible solutions
- Report back to plenary with your issue and your possible solutions
- Feel free to include solutions already in place at your institution



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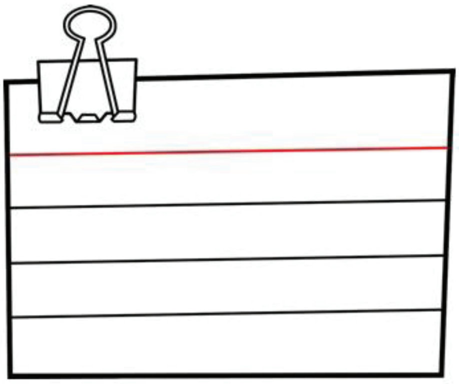
What is your Main Take Away for Today?

Please write on a card

- On one side: your main takeaway
- On the other side: what improvement you will make in the way you teach or interact with (neurodiverse) students

And take it with you!



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Main Outcomes

Based on Discussion during Workshop

- Neurodiversity is an important subfamily within diversity in engineering education
- The SEFI WG on Diversity will look at how they can also ensure neurodiversity is included in their WG topics
- It is important to understand that neurodiverse students (and staff) look at things differently and therefore it is important to check that teaching methods and the way information is shared does not hinder these students in their studies
- The pyramid of Inclusive Education can be a useful tool to raise awareness on why it is also beneficial for lecturers to create inclusive education
- Involve lecturers when provisions for neurodiversity and move away from just the academic counselling so that a suitable fit-for-purpose solution for possible challenges for neurodivergent students can be found in which the Learning Objectives combined with the students ability are leading.

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KATCH UP! INTEGRATING CIRCULAR ECONOMY IN ENGINEERING EDUCATION THROUGH PLAYING A BOARD GAME

K. Schmidt
Aalborg University, Denmark

A. Afonso
University of Aveiro

J. Sampaio
University of Aveiro

E. Mulet
University Jaume I.

M. Kalleitner-Huber
Austrian Institute of Ecology

Topics: New Notions of Interdisciplinarity in Engineering Education, Sustainability reflecting the complexity of modern society

Keywords: Circular economy, sustainability, Game-based learning, Problem Based Learning

The last 40 years' linear take-make-consume-dispose economic model creates fundamental challenges. The linear model is based on the assumption that natural resources are available, abundant, easy to source and cheap to dispose of, but it is not sustainable, and in some cases exceeding planetary boundaries. We need a fundamental transition into a more sustainable production and consumption system. In a circular model, waste and pollution are designed out, products and materials are kept in use and values sustained for as long as possible – lowering the stress on natural systems. Engineers will be asked to contribute to the transition towards circular economy (CE) on e.g. company and societal levels. To do so, they will need competences in co-creating new, multidisciplinary solutions.

The European KATCH_e project (Knowledge Alliance on Product-Service Development towards Circular Economy and Sustainability in Higher Education), develops training materials on CE, including both theoretical background materials and tools for practical implementation of CE solutions in organizations. One of the tools is the KATCH UP! board game. The game stimulates and guides the players in generating ideas on finding sustainable, circular solutions to a business challenge. It runs in six steps, from the definition of challenge, considering CE design strategies and CE business strategies, through development of business and market ideas and ending with the preparation of a CE Elevator Pitch for the idea. The main strength is that it guides the players to come up with unexpected ideas using both CE design and business strategy cards.

No previous knowledge of CE is required, however, having knowledge about CE design and business strategies is preferred, as the application of the tool will be more agile, efficient and effective, leading to better defined ideas. A maximum of 25 participants at the workshop will get a short introduction to the basics of Circular Economy, and then they form groups and play the game. Players start the game by drawing a card with a product category, a business challenge and an intended target group. Or, if they prefer, they can define their own example. Next, they draw a circular design strategy card and a couple of cards explaining circular business strategies of potential relevance for the design strategy. The task is to solve the initial business challenge through applying circular design and business model strategies. Players are also asked to consider how to implement and market the new solution. As an outcome of the game, the players fill in a CE Elevator Pitch formula, highlighting the essentials of their proposals. The pitches are put on the wall for sharing among the participants, and they will be included on the KATCH_e website from where there is free access to the game – as inspiration for teachers and future users of the game.

After playing the game, the participants will be asked to discuss which competences are needed to benefit from the game, and which competences are supported through the game. Followed by a plenum discussion, this will enhance our understanding on how, and under which conditions, the game can stimulate the development of building CE related competences in product and service development. These aspects will be added to the abstract after the conference.

There are several learning outcomes of playing the game. One is getting a systematic approach to reflecting on how to develop sustainable and circular solutions to business and market challenges. For teachers, it helps to deepen the understanding of the type of competences needed for the transition towards CE. The game is open source and thus free to use. It can be played with students in a learning environment, at seminars with participants from different organizations, or within a single company, which makes it a very flexible tool for learning about CE. As a part of a course on circular economy for engineering students, the game invites for applying the knowledge from the course, and the outcomes can serve as a background for preparing essays, exams, etc.

Engineers have an important role in the transition towards a more sustainable and circular societal model. However, even if technical skills and competences are very important, they cannot stand alone, and they should be combined with other competences to deliver the multidisciplinary solutions that are needed. Playing the game is a collaborative exercise through which engineering students can develop their understanding of the different types of knowledge and competences needed, and how they could be combined. And gaming as a way of learning through applying knowledge is known for it’s ability to stimulate students’ motivation and engagement.

In a class of students with more advanced knowledge on CE and/or on business perspectives, the teacher may ask the students to create relevant business challenge cards to include in the first step of the game. Or ask them to create cards with additional challenges that players will have to also consider while playing. In this way, students may be invited to not only develop solutions, but also to define relevant problems, which are central in a Problem Based Learning strategy.

ATTRACTIVENESS OF ENGINEERING SCHOOLS IN EUROPE

K. Schrey-Niemenmaa
Aalto University, Finland

K. Kövesi
Ensta-Bretagne, France

Topics: How to detect and attract talents with new generations of learning technologies and networks, Talent Management

Keywords: attractiveness, talent, engineering education, future needs

In this session, we would like to give an overview about the attractiveness of engineering schools in Europe and try to answer to the question how to make them more attractive. Participants of this workshop will learn the experience and point of view of their colleagues from diverse European countries, and be able to identify the main factors influencing engineering schools' attractiveness.

In a context where engineering schools in numerous European countries have difficulties to enrol talented and motivated students, an improvement in their attractiveness becomes a central challenge. Attracting and engaging future engineers has become a priority, not only for engineering schools but also for the whole of society, as the chronic shortage of engineers is likely to remain a persistent problem over the next decades. Especially important for the profession is to widen the profession for people from diverse background as the needed engineering solutions are for diverse customers and challenges.

Based on the two workshops in earlier SEFI conferences and outcomes of the Erasmus+ project A-STEP 2030, we will make a critical overview of this problem in an international and multicultural setting of engineering education professionals. The workshop will start with a short introductory case study to generate the discussion between participants about the attractiveness of their engineering school. Next, based on this discussion, participants will be divided into small groups to work on the question of what makes engineering schools attractive. Each group will present their results to the others in a short oral session by reflecting on their choice and decision making process. Finally, as a conclusion of our workshop we will organise an interactive session to engage a debate amongst participants. The workshop results will be summarized in this final step by asking participants to classify these influencing factors into institutional, national and international levels by giving examples from their institutions. Additionally, we will ask whether the attractiveness is considered to be connected to gender.

Attractiveness and especially the question of how to attract talented students into STEM education and more specifically in engineering schools is one of the important issues of Engineering Education. The importance of this question is illustrated by the fact that the attractiveness of Engineering Education is one of the top five priority themes of SEFI. This workshop will give a contribution to improve participants' understanding how to improve the current situation and attract gifted students with wide diversity.

Considering the available timeframe and to enable the active interaction with all the participants we would like to limit the amount of participants to 30 people.

GATHERING AND SHARING NEW METHODS AND TECHNIQUES TO APPLY 21ST CENTURY PEDAGOGY IN ENGINEERING EDUCATION

G. Tarján
Department of Structural Engineering
Budapest University of Technology and Economics, Hungary

A. Pluzsik
Department of Mechanics, Materials and Structures
Budapest University of Technology and Economics, Hungary

Topics: Open and Online Teaching and Learning, Integrated learning environments for the digital native learners

Keywords: interactivity, motivation, gamification, teamwork, real problem solving

Interactivity, motivation, gamification, teamwork, real problem solving are keywords to the 21st century pedagogy [1] and they were also the topics of the workshop. Regarding these topics many questions arise: How can new dimensions of teaching and learning be applied in the engineering education? How can the efficiency of contact hours at the university be increased to develop 21st century skills? Which new methods can be used on a lecture with more than a hundred students?

Theory and numerous new techniques are presented in literature [2] which are easy to use and ready to use in most of the subjects, however it still seems difficult to teach the mathematical and mechanical bases which require deep understanding and lots of practice. The traditional informational role of the teachers is changed [3, 4], hence lecturers and teachers face new challenges also in high education. They must not only motivate their students but also handle numerous consultations simultaneously, in order to fulfil their supporting and helping role.

The aim of this workshop was to gather and share innovative, new methodological techniques and ideas of the participants which have already been efficiently applied in engineering education all around the world. Recently, several interactive techniques and ICT based methods were built in the authors' subjects. The pilot programs proved to be successful both in moderate size practicals (about 30 students) and in large size lectures (more than 100 students).

The applied methods were presented through a real-life experience. The knowledge and feedbacks of the participants were collected by the innovative techniques used in the above subjects. During the workshop the participants were invited for a gamificated interactive teamwork, in which different (mostly ICT) methods served to gather information. Within the program the participants could:

- watch a short video (**motivation**)

- fill an interactive attendance sheet (to demonstrate **attitude change** [5])
- have a look inside an online escape room (test preparation practice in Base of Structural Design subject), and try to escape (**gamification** [6]),
- draw online diagrams together (**teamwork, collaborative learning**),
- vote online (methodological point of views: continuous **interaction**, feedback, effect on the teaching process),
- solve individual numerical problems (**flipped classroom** theory or hybrid methods [7], problem solving, differentiation),
- collect evaluation alternatives (motivation, gamification, **psychology of gift giving**).

During these activities a lot of information was collected about not only the presented but also all the other 21st century engineering educational techniques. As a result, a collection was draw up about which are the main trends in engineering education, at the time being, what are the pedagogical aims of the participants, and which innovative direction they are moving on. Participants could share their actually used and suggested teaching methods and technologies (devices, applications) on online surfaces. Ideas were gathered regarding to the evaluation and motivation techniques as well. With the help of the gathered information our questions were answered as it is given below.

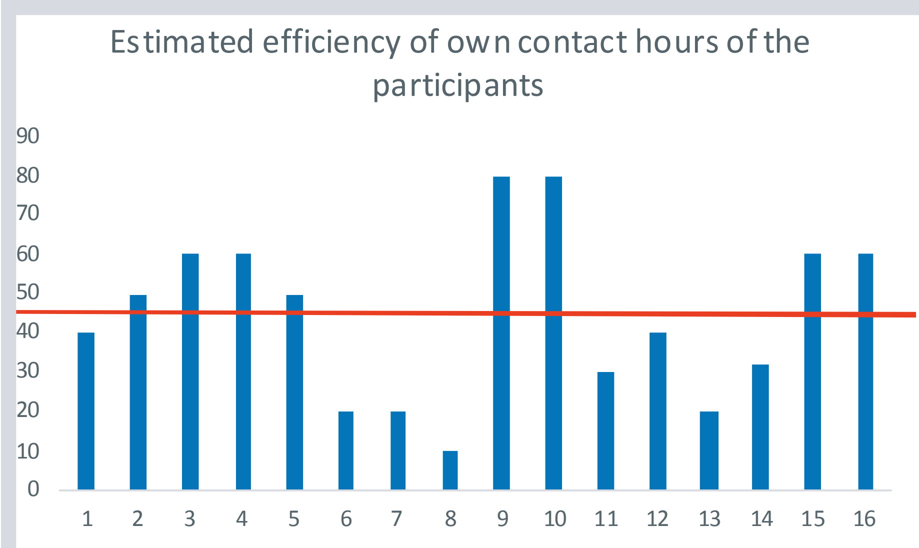
18 persons participated in the workshop.

Task 1.

By filling an interactive attendance sheet participants wrote their personal pedagogical aims, what they expect from this conference. According to the handwritten answers, participants aimed to get inspired by new teaching methods, to use new technological tools and to establish network with other colleagues.

Task 2.

Estimation the effectiveness of the traditional and the present teaching methods in percentage by the participants. Results: Participants estimated in average 44,5% the effectiveness of their own contact lessons.



Task 3.

Tendencies and directions of innovation in the 21st century according to the participants. Results: Most of the participants have already started to apply some new learner-centered teaching techniques. The next table contains the number of the participants voted for the different new tendencies as the most efficient way of modern teaching.

Tendencies in High Education			
Hibrid teaching	Collaborative learning	Growing Focus on Measuring Learning	Redesigning Learning Spaces
6	8	1	3

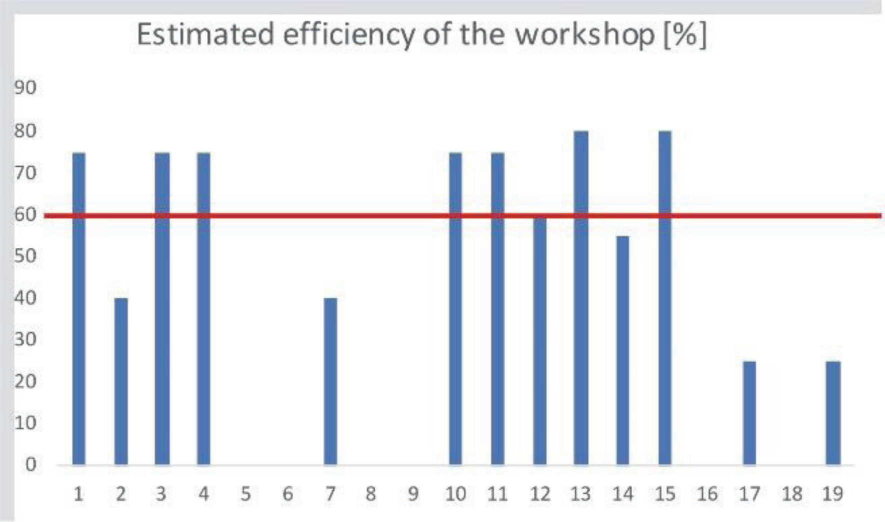
Task 4.

Collecting the actually used and suggested teaching methods, devices, technology, applications etc. from the participants in groupwork. Results can be found in the link below: https://docs.google.com/spreadsheets/d/1bfMEbfu0fgr1O-k0jLazibeM-K55EGEpWs1SQosq4CE/edit#gid=0

The table contains 16 different teaching technologies and methods gathered from the participants with the applied applications and tools, completed with a short description of the method, with important connected links and with notes why the participants suggest using them.

Task 5.

Evaluation of the workshop. Results: Participants estimated in average 60% the effectiveness of the common work and the present workshop.



EMPOWERING TEACHERS TO CLIMATE ACTION

J.-P. Teini
Academic Engineers and Architects in Finland TEK, Finland

E. Heikkilä
Aalto University Student Union (AYY), Finland

Topics: Sustainability reflecting the complexity of modern society

Keywords: climate change, global warming, climate action, climate impact, sustainability

Climate change (global warming) is the most urgent one of the wicked problems we face today. Europe has taken a strong stand in line with the Paris Agreement to limit global warming ”well below 2 °C, and pursue efforts to keep it to to 1,5 °C”. As we only have a few of decades to make radical changes to how much emissions we pollute to the atmosphere, every action for the benefit of the climate is important.

Students and young people in general are especially worried about the future of the planet and humankind. Engineering students are interested and willing to contribute to the subject with their professional competence, but tend to feel they do not get enough tools from education to channel their skills, competences and know-how in stopping climate change. This needs an urgent fix. To ensure that students get the skills and competences they aspire, the teachers need to improve their own understanding of climate change and how it relates to the subject at hand that they teach.

The workshop is aimed for

- Teachers interested in implementing climate change themes to their teaching,
- Teaching support personnel that wish to inspire teachers in their university to implementing climate solutions in their teaching, and
- Everyone interested in discussing and learning about implemeting climate solutions to engineering education

The workshop will start off with a short introduction to how different fields of technology contribute to causing and solving the climate crisis. After the introduction participants make their own plans for integrating climate solution themes in their own university curriculum or courses that they teach.

The participants will be provided with a canvas for planning their courses involving climate change themes. We will provide differentiated canvases for different fields of science and a general canvas for a more holistic approach. The participants from same fields of science are encouraged to collaborate on their planning to share their ideas and the facilitators of the workshop will provide constant support for the participants. As the end result of the workshop, all participants get to take their canvas plans home for further planning and implementation.

SHARING GOOD PRACTICES FOR ENHANCING INTRODUCTORY PHYSICS LEARNING

J. Tiili
Tampere University of Applied Sciences, Finland

Topics: Fundaments of Engineering Education: Mathematics and Physics

Keywords: Engineering physics

Introductory engineering physics is usually a part of the very first studies that engineering students encounter in their studies. Natural sciences and mathematics form the base of engineering and technology, but for some students these introductory courses can be a real threshold and a motivation killer to their studies. Most of the dropouts drop out at the beginning of studies. There are a lot of reasons why students drop out, but is there something that we as engineering educators are able to do in this very sensitive early part of students' studies? Do we already have some good practices to tackle the problem?

Expected learning outcomes of introductory engineering physics vary a lot depending on the degree program and the level of studies. Students entering the universities have very heterogeneous skills in physics, mathematics and other natural sciences.

Part 1:

In the workshop, the participants are first asked to recognize and describe the starting point and the goal of students' skills in physics. The variations of these skills (in the beginning and at the end of engineering physics) are discussed and compared among participants and some common conclusions are drawn out.

Part 2:

After the conclusions, participants are divided in small groups on basis of part 1 so that they are able to discuss with people with same kind of challenges. The second part of workshop is to share ideas and expeiences. What actions there have been made to enhance students' learning outcomes in introductory engineering physics in participants' universities? What kind of personal changes in teaching there have been made for the same goal? Is there still something that perticipants would like to try?

Part 3:

The good practices rising from these small groups are documented, collected and presented at the end of workshop.

AN ENGINEERING CURRICULUM OR A CURRICULUM TO SHAPE ENGINEERS?

N. van Hattum-Janssen
Saxion University of Applied Sciences, the Netherlands

M. Endedijk
University of Twente, the Netherlands

Topics: Diversity in Engineering Education?

Keywords: curriculum development, professional identity, curriculum analysis

How do we attract more students to engineering education and how do we keep them in the engineering field after their graduation? What makes them stay in engineering? In the project Mind the Gap we found that their professional identity is a key concept to understand the study and career choices they make. In the project Bridge the Gap, a continuation of Mind the Gap, we explore the development of professional identity over time and the contextual factors that influence the development of professional identity. Research on the formation of professional identity acknowledges a role of the educational context but is not explicit on how this process takes place (Trede, Macklin, & Bridges, 2012; Morelock, 2017). Abrandt Dahlgren et al. (2006) argue that professional learning contexts help students to identify the boundaries of their own professional context and to sharpen their professional identity. Through the contact of students with those from other disciplinary areas, for example in multi-disciplinary projects, students become more aware of their own identity as a professional from a specific field. Engineering curricula provide, to a greater or a lesser extent, experiences that shape the professional identity of a student. This workshop aimed to get a clear(er) picture of how curricula can influence professional identity and how a more focused approach to curriculum development can contribute to a stronger focus on the professional identity of engineering students, preparing them, as such, better for well-considered choices for study and career.

A framework was presented to analyse professional socialisation and the degree to which socialising experiences are provided in the curriculum. The framework consists of two dimensions: curriculum components and engagement levels. The curriculum components are based on Thijs and van den Akker (2009). The engagement levels are based on the levels of Weidman, Twale and Stein (2001). Their research starts from the experiences of the individual student and delineates the stages of development of professional identity that an individual goes through. The framework presented here uses these in order to establish the kind of experiences a curriculum needs to provide for a student that enable this development. The experiences stimulate transitions from early stage professional development, where role acquisition is starting, till a personalized stage, where the professional role is internalised and fused with personal and social roles.

The framework as presented was used to categorise the nature of the socialising experiences from less to more engagement of the individual student with the formation of his or her own professional identity, ranging from knowledge about, exposure to, interaction with to reflection on the (possible) professional context. The course rationale, learning goals of modules, teaching and learning methods and assessment methods were taken into account in this categorisation process, which left other relevant curriculum components like grouping, the role of the teacher, and time were left out of scope for the moment. Table 1 shows the framework for the analysis of experiences of professional socialisation.

Table 1. Framework for the analysis of experiences of professional socialisation in engineering curricula

Curriculum component	Level of engagement			
	Knowledge acquisition	Exposure	Interaction	Reflection
Rationale				
Aims & objectives				
Teaching & learning				
Assessment				
Teacher role*				
Role of professional*				
Facilities and resources*				
Grouping*				
Location*				
Time*				

*Not taken into account in the workshop

More than 30 participants used this trial version of the framework in the workshop. Before completing the form that was handed out, the participants went back to their personal professional socialisation process by identifying experiences that significantly contributed to their professional identity as an engineer or as another type of professional they most identify with. These experiences could be related to their degree programme or to their professional life after graduation. A number of different experiences were mentioned; company visits, study trips and internships, as well as specific events related to the first job after graduation. Participants then listed a number of possible socialising experiences in the curricula of their engineering degree programmes that may contribute to the professional identity of their students. The participants identified socialising experiences like excursions, graduation projects, internships in different professional contexts, a flexible curriculum, reflection, events to meet young professionals and the creation of start-ups by students. In order to better understand the impact of these experiences the participants used the framework to identify the nature of the experiences by placing the experiences in the framework as shown in Table 1.

The results of the participants show that the rationale of the programmes is mostly not mentioned by the participants. Socialising experiences are mentioned, but not directly related to the rationale of the degree programme. They did not refer to the inclusion of professional socialisation in the competencies of the programme or in general in documents on the programme outline. According to the participants, the learning goals of modules do sometimes refer to professional socialisation. Teaching and learning methods and assessment method were most frequently mentioned. The level of involvement of the students was often exposure or interaction. Knowledge on the professional field without exposure was specifically mentioned by two groups that referred to modules on engineering skills. In these modules, students are not yet exposed to the professional practice, but simulate it at their university. Reflection and the role of professionals in reflection was connected to assessment activities by several groups.

The findings of the groups were compared with the preliminary findings of the analysis of two comparable engineering curricula, one at a university and one at a university of applied sciences. Two degree programme documents and 38 module descriptions were analysed with Atlas.ti. Fragments that refer to professional socialisation were related, if applicable, to the curriculum components rationale, learning goals, teaching and learning methods, materials and resources, grouping and assessment. The remaining curriculum components will be explored by interviews. The fragments where then categorised as knowledge acquisition, exposure, interaction or reflection. The analysis showed that experiences of professional socialisation are clearly present in rationale and learning goals, as opposed to what the participants stated, but far less in teaching and learning methods and assessment. Furthermore, experiences aimed at reflection on professional socialisation at these institutions of higher education were not necessarily preceded by exposure or interaction, making the reflection on their professional socialisation a somewhat theoretical exercise for students.

Conclusions

The framework in its current version is a first step towards a more systematic curriculum analysis for experiences of professional socialisation of engineering curricula. By making a comprehensive overview of the curriculum and distinguishing levels of engagement in experiences of professional socialisation, the degree to which a curriculum potentially contributes to professional identity development can be explored. The analysis that was carried out in the workshop was based on important experiences as identified by the participant and revealed an incomplete coverage of the framework, focussing mainly on exposure and interaction as far as the levels of engagement are concerned and on teaching and learning methods and assessment as far as the curriculum components are concerned. The framework is expected to be helpful in curriculum design when aiming for more explicit attention for the professional identity of engineering students and the role of experiences of professional socialisation.

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EBCC MODEL: THE SUSTAINABLE PARTNERSHIP MODEL AMONG UNIVERSITIES, COMMUNITIES AND INDUSTRYCOMMUNITIES AND INDUSTRY

I. Viksne
Riga Technical University, Latvia

S. Puskarjova
Riga Technical University, Latvia

A. Lanthony
Institut Supérieur de Mécanique de Paris – Supméca, Saint-Ouen, France

M. El Idrissi
Institut Supérieur de Mécanique de Paris – Supméca, Saint-Ouen, France

A. Mihailidis
Aristotle University of Thessaloniki, Greece

F. Côme
European Society for Engineering Education, Belgium

M. Dunez-Simon
Établissement public territorial Plaine Commune, Saint-Ouen, France

T. Jouanlanne
Établissement public territorial Plaine Commune, Saint-Ouen, France

Topics: New Complexity Quest in Engineering Sciences, New Notions of Interdisciplinarity in Engineering Education

Keywords: sustainable partnership, real life cases, engineering education, community, local government

EBCC Model: The Sustainable Partnership Model among Universities

The workshop is organized in the framework of the Erasmus+ strategic partnership project No 2017-1-LV01-KA203-035426 “Education, Business and Community Cooperation Model for a Creative European Engineering Education” (EBCC Model). There are five partners in this project: Riga Technical University, Latvia (RTU), Institut Supérieur de Mécanique de Paris, France (SUPMECA), Aristotle University of Thessaloniki, Greece (AUTH), Établissement public territorial Plaine Commune, France (PLAINE COMMUNE), and the European Society for Engineering Education, Belgium (SEFI). The workshop is facilitated by 8 experienced faculty and administrative staff members from these organizations. They have experience in development and implementation of the curriculum for project-based engineering education.

Universities have established a network of partners, including regional government and other stakeholders, but often the cooperation with the regional government is implemented on an irregular basis case by case.

The objective of the workshop is to share ideas and knowledge how to build long-term and mutually comprehensible and desirable cooperation between universities and communities and industry.

Agenda

5 min.: Introduction. Moderated by RTU.

15 min.: The presentation of the guidelines for implementation of skills relevant to engineering design and development of innovative products in the engineering curriculum:

- case and/or innovative project idea creation model, moderated by RTU;
- student team building recommendations, moderated by SUPMECA;
- guidelines for integration of the selected skills into the curriculum and syllabus; moderated by SUPMECA.

25 min.: Round table discussion: Challenges and opportunities for the sustainable partnership model among universities, communities and industry, moderated by RTU.

10 min.: Creation of working groups of 5-7 persons and case study description. Moderated by PLAINE COMMUNE

25 min.: The practical exercise where the working groups will work to find the best cooperation model between university and local government or industry taking presented guidelines, case description and own experience. The participants will have roles of teachers and students, but RTU, SUPMECA, AUTH and PLAINE COMMUNE representatives will play roles of local government and community members. Moderated by SUPMECA.

15 min.: Feedback by each group and the final remarks. Moderated by RTU.

The participants will learn how to create advanced study curriculum based on real regional problems that would enhance students' practical experience, promote university involvement in resolving challenging issues of regional businesses as well as establish closer cooperation of the academic staff with the representatives of regional government. At the same time such cooperation should ensure high educational standards and meet the main educational objectives even if study courses include problems (projects) that are suggested by local government or industry.

The workshop has length 90 minutes and includes keynote presentations, discussions and practical case in working groups of 5-7 persons. There will be discussions on multidisciplinary approach, involvement of students from different universities and study levels (for example Master and Bachelor) national, cultural and societal differences within the EU, as well as potential gender-based issues. They will experience to work in small teams playing roles of academic staff and students. The groups will analyze the proposed cooperation model and create a blueprint of the model implementation for the presented case study description obeying facilitators'' guidelines. The participants will present the outcomes of the own workgroup and evaluate the results of others. There are expected 20 - 30 participants in total. Participants will receive a workshop booklet containing all presentations and reference materials.

EBCC MODEL: RAPID PROTOTYPING ROLE FOR ACQUIRING PRACTICAL SKILLS IN PRODUCT DESIGN ENGINEERING

I. Viksne
Riga Technical University, Latvia

S. Puskarjova
Riga Technical University, Latvia

A. Lanthony
Institut Supérieur de Mécanique de Paris – Supméca, Saint-Ouen, France

M. El Idrissi
Institut Supérieur de Mécanique de Paris – Supméca, Saint-Ouen, France

A. Mihailidis
Aristotle University of Thessaloniki, Greece

F. Côme
European Society for Engineering Education, Belgium

M. Dunez-Simon
Établissement public territorial Plaine Commune, Saint-Ouen, France

T. Jouanlanne
Établissement public territorial Plaine Commune, Saint-Ouen, France

Topics: New Complexity Quest in Engineering Sciences, New Notions of Interdisciplinarity in Engineering Education

Keywords: rapid prototyping, real life cases, engineering skills, community, product design

The workshop is organized in the framework of the Erasmus+ strategic partnership project No 2017-1-LV01-KA203-035426 "Education, Business and Community Cooperation Model for a Creative European Engineering Education" (EBCC Model). There are five partners in this project: Riga Technical University, Latvia (RTU), Institut Supérieur de Mécanique de Paris, France (SUPMECA), Aristotle University of Thessaloniki, Greece (AUTH), Établissement public territorial Plaine Commune, France (PLAINE COMMUNE), and the European Society for Engineering Education, Belgium (SEFI). The workshop is facilitated by 8 experienced faculty and administrative staff members from these organizations. They have experience in development and implementation of the curriculum for project-based engineering education.

The objective of the workshop to share knowledge and create a better understanding for educational efforts involving rapid prototyping as a modern learning tool in universities that develops students' capability to design and boosts their interest, motivation, creativity, decision making, communication and team working.

The workshop topics covers the main principles that govern the rapid prototyping technologies, design for manufacturing, and best practices. Participants will discuss teaching activities that combine theory and practice in a context of real engineering application challenges, available 3D modelling computer-aided design software and students' expectations.

Agenda

5 min.: Introduction. Moderated by RTU.

10 min.: The presentation the guidelines for using rapid prototyping to acquire practical skills in product design engineering. Moderated by AUTH.

20 min.: Round table discussion: Fostering students' active learning through the integration of rapid prototype into educational process provides (curriculum issues, topic selection, available infrastructure, teacher roles, teamwork, result evaluation a.o.). Moderated by AUTH.

10 min.: The presentation and discussions on skills linked to modelling, conception and rapid prototyping acquired during project-based learning and guidelines for a better integration of these skills in the curriculum. Moderated by SUPMECA.

10 min.: The demonstration of practical examples (cases) for application of rapid prototyping in engineering curriculum that allows students to acquire knowledge and skills creating real live models using different design and calculation tools. Moderated by AUTH.

5 min.: Creation of working groups of 5-7 persons and case study description. Moderated by AUTH.

20 min.: Case study where participants will create their own version for implementation of rapid prototyping into engineering education by selecting the most appropriate study course(s), study level, software, learning methods and evaluation of results. Moderated by AUTH and assisted by RTU, SUPMECA and PLAINE COMMUNE.

10 min.: Presentation of the case study results by working groups. Feedback and the final remarks. Moderated by RTU.

The participants will learn an integrated approach to the creation of study curriculum that includes project-oriented training on the basis of business problem solving stipulated by the regional government in combination with real solution prototyping. Integration of rapid prototype into educational process provides valuable feedback on both student acquired skills and the effectiveness of instruction.

The workshop has length 90 minutes and includes keynote presentations, round table discussions and case study exercise in working groups of 5-7 persons. They will experience to work in small teams to create their examples of application of rapid prototyping in the educational process by selecting the most appropriate study course, study level, software, learning methods and evaluation of results. The participants will present the outcomes of the own workgroup and evaluate the results of others. There are expected 20 - 30 participants in total. Participants will receive a workshop booklet containing all presentations and reference materials.

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Kálmán, Anikó, Co-chair	Associate Professor, Technical Education, BME
Froyen, Ludo	Professor, Materials Engineering, KU Leuven
Citterio, Linda	International Coordinator for SEFI 2018 and SEFI 2019, Directorate for International Relations, BME

Hungarian invited members

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Koltai, Tamás	Professor, Dean, Production Management, BME
László, Krisztina	Professor, Physical Chemistry and Materials Science, BME
Tóth, Péter	Director, Electrical Engineering, Obuda University
Zilahy, Gyula	Professor, Environmental Economics, BME

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Sjoer	Ellen	The Hague University of Applied Sciences

Skvor	Zbynek	Czech Technical University in Prague
Smink	Carla K.	Aalborg University
Soldatenko	Ilia	Tver State University
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Strauch	Carsten	TU Berlin
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Szilágyi	Brigitta	Budapest University of Technology and Economics
Szűts	Zoltán	Budapest University of Technology and Economics
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Tian	Huijun	International Centre for Engineering Education of UNESCO
Tiili	Juho	Tampere University
Torca	Ireneo	Mondragon Unibertsitatea
Tormey	Roland	Ecole polytechnique fédérale de Lausanne
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Zhang	Man	Tsinghua University
Zhang	Wei	Zhejiang University
Zilahy	Gyula	Budapest University of Technology and Economics


MŰEGYETEM 1782
SEFI