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Blended Learning in Engineering Education:

challenging, enlightening – and lasting?

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SEFI – EUROPEAN SOCIETY FOR ENGINEERING EDUCATION

SEFI is the largest network of higher engineering education institutions (HEIs) and educators in Europe. Created in 1973, SEFI is an international non-profit organisation aimingto support, promote and improve European higher engineering education, enhancing thestatus of both engineering education and engineering in society.

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 4 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.

Our activities: Annual scientific conferences, annual conventions for engineering deans, ad hoc seminars/workshops organised by our working groups and special committees, scientific publications (incl. the bi-monthly European Journal of Engineering Education), European projects under ERASMUS + and Horizon2020, position papers, European debates, cooperation with other major European and international bodies.

The cooperation with partner and sister engineering organisations in Europe and in the world is also one of our priorities.

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Blended Learning in Engineering Education: challenging, enlightening – and lasting?

The year 2020 has challenged universities worldwide in an unprecedented way. On short notice, universities had to switch from on-site classroom teaching to online teaching formats. We all realize that this extensive online teaching will have a sustainable impact on the way we teach and learn.

The 49th SEFI Annual Conference focuses on the implications of this very special experience on Engineering Education in Europe and worldwide.Many universities used this opportunity for extensive evaluations and supporting research to assess the pros and cons of this transition. How did teachers and learners adapt to the new situation? Which formats and methods have proven so successful that teachers would like to integrate them into their courses in the long term? How can students be integrated into research when they are off campus? How can students socialize with their fellow students if they meet only by video conference? What forms of online assessments are secure and appropriate in engineering?

These and many other aspects of blended and online learning has been discussed during the conference. Via research papers, concept papers, short papers and workshops, participants have contributed on the following topics:

> Methods, formats and essential elements for online/blended learning
> Lab courses and projects in online/blended learning
> Digital tools
> Online assessments
> Social aspects and communication in online/blended learning
> Changes beyond Covid-19
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Hans-Ulrich Heiß

Vice President for Education, Digitalization, and Sustainability
Technische Universität Berlin
SEFI 2021 Chair

WELCOME

Welcome to the SEFI Annual Conference 2021 hosted by Technische Universität Berlin! The pandemic has challenged universities in an unparalleled way. All of a sudden, we had to switch to online teaching and learning and most students were confined to their homes, deprived of the usual social contacts to their fellow students and to their teachers as well. Besides this inconvenience, both teachers and learners made new experiences in online education which changed their attitudes towards E-learning fundamentally. This will lead to lasting changes in the way we teach and learn.

The conference and its proceedings give an overview of how the universities coped with the challenges and what they learned from the online semesters. But also the traditional topics of engineering education, i.e. ethics, sustainability, skills development, internationalisation, industry cooperation, inclusion et al. have been addressed providing a wealth of material to draw on.

We would like to thank all people who contributed to the success of the conference as committee members, as reviewers, authors, presenters, session chairs, organizational and administrative staff. Special thanks to the Online Teaching Team of TU Berlin und the Event Team of TUBS who took the largest load share of preparing and running the conference.

Keynote Speakers

Beverley Gibbs
New Model Institute for Technology and Engineering

Beverley is Chief Academic Officer at NMITE, the first new greenfield higher education provider in the UK for several decades. Welcoming its first students in September 2021, NMITE's flagship programme is an accelerated MEng Integrated Engineering.

Beverley trained as a Production Engineer through an apprenticeship route, and worked in manufacturing, mining and construction sectors before transitioning to an academic career. In 2020 she initiated and co-edited 'Emerging Stronger: Lasting impact from crisis innovation' for the UK Engineering Professors' Council, a May/June 2020 snapshot of immediate responses to the pandemic including case studies and student voices from across UK HE. A second edition will be published in 2021.

Lasting Impact in Turbulent Times

Colleagues who have been reflecting and innovating for years will have been astounded by the speed at which higher education has adapted to the changed circumstances brought on by the pandemic. Yet, even as we pursue transformed learning, teaching and assessment, our historical roots remain influential – in traditional approaches that have simply been moved online, and in exerting a pull to 'go back to normal as soon as possible'.

In this talk, Beverley will highlight some changes that are likely to prove enduring, and those which are a poor substitute given all we know about how engineers learn and the work they do. She will share the structures and approaches NMITE has developed in the absence of a decades-old cultures and traditions, and draw out principles which can inspire refreshed views in any institution.

Rodger Hadgraft
University of Technology Sydney

Prof. Roger Hadgraft is a civil engineer with more than 25 years of experience in improving engineering education, publishing many papers on problem- and project-based learning (PBL), and the use of online technology to support student-centred learning. He is currently Director of Educational Innovation and Research in the Faculty of Engineering and Information Technology, at the University of Technology Sydney, Australia

The Engineer of 2035 – What changes in Engineering Education are required?

Over the last 2-3 years, the Australian Council of Engineering Deans has been working to define the kinds of graduate competencies we need to be developing by 2035.

The 2035 project has identified several key shifts that are required in engineering education:

> a **re-balancing of the theory-practice** components of professional engineering education,
> the inclusion of more **“real-world”** problems with a focus on **addressing societal needs;**
> young engineers need more exposure to **digital engineering**, which is, increasingly, the focus of engineering practice,
> it is assumed that all engineering programs will also make more use of **e-learning** and work integrated learning, and
> it is likely that greater **sharing of good practice** will also be required.

These recommendations are hardly surprising, as they echo other reviews of the last 25 years, such as the UK Henley report and the US National Academy of Engineering reviews around the Engineer of 2020. The big challenge is how do we change to meet these new requirements before 2035?

This keynote will summarise these international reviews and point the way forward to greater collaboration between our universities and societies, including SEFI, to effect the changes required in engineering education and in our educational institutions.

Keynote Speakers

Naomi Winstone
University of Surrey

Naomi is a cognitive psychologist specialising in the processing and impact of instructional feedback and the influence of dominant discourses of assessment and feedback in policy and practice on the positioning of educators and students in feedback processes.

Naomi is a Reader in Higher Education and Director of the Surrey Institute of Education at the University of Surrey, UK. She is also an Honorary Associate Professor in the Centre for Research in Assessment and Digital Learning (CRADLE) at Deakin University, Australia. Naomi is a Principal Fellow of the Higher Education Academy and a UK National Teaching Fellow.

Feedback in digital learning environments: Distant or Dialogic?

Whilst technology can streamline the feedback process, students often report that digitally-mediated feedback can feel impersonal. In this talk, I will explore the benefits and challenges of feedback processes in digital learning environments and consider how we can design opportunities for dialogue in such environments, minimising the sense of distance between educator and student.

Research Papers

ordered alphabetically
by first author

CURRENT STATE OF KNOWLEDGE OF ESD IN ENVIRONMENTAL ENGINEERING PROFESSORS IN COLOMBIA.

PM, Acosta Castellanos[1]
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Conference Key Areas: *Sustainability, Academic teachers needs and support for online teaching*
Keywords: *environmental engineering, education for sustainable development, environmental education, engineering teaching*

ABSTRACT

With this paper, we want to demonstrate the current state of knowledge of Education for Sustainable Development (ESD) in the case of environmental engineering teachers in Colombia (South America). To determine the state of knowledge, a structured survey with 21 multiple-choice questions with the Likert scale scheme was used. The survey was applied to 39 university teachers who teach in environmental engineering programs, from 13 different universities. The survey also verified whether the Environmental Education (EE) trend is still being used by teachers and therefore transmitted to students. It was possible to identify a general lack of knowledge of ESD by teachers and, on the contrary, a strong preference for EE. This is largely due to the fact that, since 2003, Colombia has a policy that promotes EE, which has not had updates or derogations that give way to the ESD. It was found that teachers consider that ESD is important in the field of action of environmental engineers and that this educational trend must be part of the curriculum. Therefore, although the country has strong roots and promotes EE, environmental engineering professors see ESD as an alternative that would strengthen the skills of future engineers.

1. INTRODUCTION

Environmental engineering is one of the areas of engineering, in some countries it is postgraduate degree and in others, such as Colombia, it is an undergraduate degree. The Sustainable Development Goals (SDG) are a field of reference and they mark a

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milestone in the discussion on Sustainable Development (SD) [1]. It is expected that with this strategy, companies, communities and especially governments will advance in achieving SD [2]. With this, it is intended in an integrative way to reconcile the globalized economic and consumption model that prevails today, in a responsible model with the environment [3]. Education plays an important role in the promotion and training on the understanding of SD and especially the SDG, in this sense it has been highlighted that Education for Sustainable Development (ESD) is the model to achieve it [4]. ESD holistically addresses the three fundamental pillars of sustainable development: society, environment and economy [5]. From this, the ESD seeks the transformation of the person, their environment and society, and this change must be reflected in their way of thinking and acting, which will end up impacting all levels of society, in the end, promoting the scope of the SDG [6].

In universities, ESD responds to the need of the labor market where companies are increasingly interested in hiring SD literate graduates [7]. Therefore, higher education institutions have a duty to drive and promote the process of transition to sustainability through teaching, research and dissemination [8, 9]. ESD has increased more strength since the United Nations declared the decade for ESD between the years 2005 and 2014. Thanks to this, ESD is well knowledge in regions such as Europe and some parts of Asia. But it seems slight known in places like Latin America [11].

We find Environmental Education (EE), which has a much greater historical trajectory than ESD, but differ in their objective, ESD seeks to promote the relationship of SD with economy, society and environment, which is supported by economic growth [5]. On the other hand, the EE is characterized by being protectionist, by seeking the generation or awareness, for this reason it distances from consumerist economic models and economic growth [12, 13]. Environmental engineering in Colombia is characterized by being an undergraduate program, whose areas of application are mainly focused on solving problems associated with the quality and coverage of basic sanitation (drinking water, sewers, solid waste, etc.), still persistent problems in Latin America. This branch of engineering in Colombia is relatively recent, the first undergraduate programs appeared in the decade from 1990 to 2000 [14].

Within universities and therefore in undergraduate programs, teachers represent a key factor in promoting education and achieving environmental sustainability. There are different studies that show the support and research that teachers give in higher education around ESD [15]. Apart from the knowledge of ESD, teachers seek to impact students with the goal of achieve a social transformation from their professions [16]. This approach ensures that ESD has teachers as essential actors to achieve the SDG [17]. The challenge of transforming teaching is broad, since it represents making changes in disciplinary approaches so that they integrate social, economic, environmental and cultural aspects in each discipline. This challenge implies new study plans and curricula adapted for this purpose, and that in turn the teachers are trained and prepared within the universities [15, 18]. Engineering studies are a fundamental part of the range of the academic offer of universities; in turn they are engines of development through science and technology, finding the answer to contemporary problems of society, especially in terms of infrastructure [16]. In this sense, due to its broad capacity to impact on urban and natural ecosystems, engineering companies are called to adopt ESD in their teaching and therefore, promote development in terms, not only technical and technological, but in a transversal way involving the environmental sustainability [19]. With this research, from a survey applied to 43 professors of environmental engineering programs from 13 Colombian universities, it was sought to establish the degree of knowledge of ESD and, therefore, infer the degree of transmission and impulse of this current towards students of this discipline. At the same time, we verified that EE is so deeply rooted in relation to ESD in teachers, that is, the preference that teachers have in relation to these two options or models of education.

2. METHODOLOGY

2.1. Type and structure of the survey.

The survey was applied to 39 teachers from 13 Colombian universities that are part of environmental engineering programs. The questions were asked in a positive formulation. For the answer option, the horizontal Likert scale model was used. Questions of this style are structured in a request for an answer, followed by a statement and a rating scale to answer the question posed [20]. The choice of horizontality is given in order to avoid extreme response style (ERS), which tends to occur more frequently in vertical type options [21]. The scale used varies from 1 to 4, where 1 is equivalent to “not at all” and 4 is equivalent to “completely”, corresponding to a unipolar scale [22]. The survey includes 21 questions related to the subject of study, the survey is shown in Table 1.

Table 1. Survey conducted between university teachers.

Q1	Are you or have you taught an undergraduate program in environmental engineering?	Q8	Have you carried out environmental education activities in your role as an environmental engineering teacher?	Q15	Have you ever applied ESD in your classes or subjects?
Q2	Of the objectives of environmental education, please indicate which one you consider would be the most important for an environmental engineer.	Q9	Have you ever been trained or guided in environmental education strategies outside of academic training activities?	Q16	Do you know the differences between Environmental Education (EA) and Education for Sustainable Development (ESD)?
Q3	How important do you think environmental education is for an	Q10	Do you think that within the field of action of the environmental engineer it is	Q17	In your opinion, you think that ESD focuses on actions for the environment.

	environmental engineer?		important to obtain tools to develop environmental education actions?		
Q4	How important is environmental education to you as a person?	Q11	Would you like to be part of the formulation and implementation of environmental education projects?	Q18	In your opinion; Do you think ESD focuses on cultural, social, economic and biological diversity?
Q5	As a teacher of the environmental engineering program, do you think you train your students in the concepts or principles of environmental education?	Q12	Do you think it is important that environmental education be involved within the Environmental Engineering program curriculum?	Q19	Do you think ESD is important within the field of action of the environmental engineer?
Q6	Do you consider that there are sufficient academic spaces (subjects) in the study plan where the environmental engineering student is trained in environmental education?	Q13	In your opinion, in which of the following academic contexts of the structure of the training of an engineer should environmental education be oriented?	Q20	Do you think it is important that ESD be involved within the Environmental Engineering program curriculum?
Q7	Do you consider that within the contents of the subject (s) that you teach, the student is trained in environmental education skills?	Q14	How well do you know the concept or current of Education for sustainable development?	Q21	As an engineering teacher, do you think you train your students in EDS principles?

2.1. Survey reliability

For the validation of the survey conducted between university teachers, the Cronbach's Alpha coefficient was used, which determines the measure of internal consistency of a measurement instrument where several elements are included [23]. The value of the coefficient varies from 0 to 1, and it is divided into ranges that qualitatively interpret the instrument [24, 25]. As a result, an Alpha coefficient of 0.77 was obtained for the applied instrument, therefore, qualitatively it can be said that the consistency and reliability are good.

2.2. Sample and limitations

The total number of universities that offer EE undergraduate degrees are 46, of which 12 are accredited of high quality. High quality accreditation refers to the conditions of maximum educational quality in research, teaching and social responsibility, it is a voluntary process, different from the minimum quality conditions called qualified registration which is mandatory for operation, in both cases the government is in charge of giving the certifications [26]. The collaboration of 13 universities was achieved, which corresponds to 28%, of these, 6 are accredited, which corresponds to 50% of the total of accredited universities. In any case, there is a limitation in the application of the surveys, since many of these are not completed by the entire teaching staff of the program. Another limitation was to achieve certain universities that refuse to apply these instruments due to confidentiality or for other reasons not explained by their directives. It is important to mention that personal or institutional information was not requested in the applications and in the survey in order to protect the data and to guarantee a confidential response. The demographic characteristics of the teachers surveyed can be seen in the table 2.

Table 2. Characteristics of the teachers surveyed.

Ages		Undurgraduete degree	
Age groups (years old)	%	Engineers by training	%
20 - 25	2,3%	Biologist	20,9%
25 - 30	18,6%	Environmental engineer	25,6%
30 - 35	30,2%	Chemical engineer	7,0%
35 - 40	20,9%	Civil engineer	4,7%
40 - 45	11,6%	Agricultural engineer	11,6%
45 - 50	11,6%	Industrial engineer	2,3%
50 - 55	4,7%	Degrees in social sciences	27,9%

3. RESULTS

3.1. Qualitative questions

As shown above, three questions that do not include the Likert scale were asked, these were asked as multiple-choice, questions (Q1, Q2 and Q13). Regarding Q1, of the total of respondents (n = 43), 90% belonged to an environmental engineering undergraduate program (n = 39), in order to determine only the results of the people who are from this program. The responses of the 39 teachers were used for establishing some results and conclusions. In Q2, it is intended to establish which approach (practical, theoretical or practical-theoretical) they give when teaching, in this sense the following options were presented:

(a) hold people accountable and make people aware of the knowledge of the environment and its problems; (b) Involve people in the realities, practices and experiences of environmental problems that are perceived in their territories; (c) develop attitudes that help communities to strengthen their feelings of conservation and respect for nature and the environment, as well as their own culture; (d) develop skills that promote the search for solutions to current environmental problems and

prevent those that may appear in the future; (e) encourage individual or collective actions that solve or avoid environmental problems.

Option (b) was selected by 39.5% of the respondents, 27.9% selected option (d), 20.9 option (c), 7% option (a), and 4.75% option (e). Question Q13 refers to the opinion of teachers about the possible location of EE or ESD competencies in the curriculum, the possible options were (a) human sciences; (b) basic sciences; (c) basic engineering; (d) applied engineering. In this case, 39.5% answered option (d), 30.2% option (a), 16.3% option (c) and 14% option (b).

3.2. Quantitative questions

Table 3 shows the results and statistical values of the applied instrument, where *f* is the frequency. The value per item was determined, which is the sum of the values assigned to each response by the respondents. In other words, for this instrument the maximum value per item is 156, which would mean if all the people (*n* = 39), assigned a value of 4 (completely) to their answer in a question.

Table 3. Statistical values of the instrument.

Question	Value per item	*f* (4)	*f* (3)	*f* (2)	*f* (1)	(%) 4	(%) 3	(%) 2	(%) 1
Q3	151	35	3	1	0	90%	8%	3%	0%
Q4	151	34	5	0	0	87%	13%	0%	0%
Q5	135	22	14	2	1	56%	36%	5%	3%
Q6	113	11	15	11	2	28%	38%	28%	5%
Q7	121	12	21	4	2	31%	54%	10%	5%
Q8	128	18	15	5	1	46%	38%	13%	3%
Q9	115	18	8	6	7	46%	21%	15%	18%
Q10	147	33	4	1	1	85%	10%	3%	3%
Q11	148	33	5	0	1	85%	13%	0%	3%
Q12	148	32	6	1	0	82%	15%	3%	0%
Q14	120	15	13	10	1	38%	33%	26%	3%
Q15	107	12	11	10	6	31%	28%	26%	15%
Q16	115	14	12	10	3	36%	31%	26%	8%
Q17	112	10	17	9	3	26%	44%	23%	8%
Q18	134	20	16	3	0	51%	41%	8%	0%
Q19	150	33	6	0	0	85%	15%	0%	0%
Q20	148	32	6	1	0	82%	15%	3%	0%
Q21	121	12	19	8	0	31%	49%	21%	0%

It is important to mention that the mean value was not used as recent studies suggest not using this value for Likert scales, because the results come from different sources, that is, questions with different contexts [27]. The highest frequency is given in the value of 4 "completely" and the lowest in 1 "not at all" in most of the questions, except for some cases such as Q6, Q7, Q17 and Q21.

4. CONCLUSIONS

In general, for the survey conducted between university teachers from environmental education in Colombia, the individual analysis of the items or questions was avoided, therefore, this discussion, except in some relevant cases, will discriminate the answers to some questions. This study is based on the recommendations of Harpe (2015) for Likert scale instruments. We found a notorious attachment of teachers to EE, which indicates a clear and generalized ignorance of ESD. The answers to the questionnaire show a greater knowledge and clarity in concepts of the EE.

It can be seen from the results that teachers have no clear idea about the concept and usefulness of ESD. The question Q14 shows that only 38% of the teachers know it completely, 59% denote a certain degree of ignorance and 3% do not know this concept at all. In Q16 it is observed that the teachers are not completely sure about the differences between the EE and ESD currents. This could mean, among other things, a mixture of concepts, currents, and methodologies, gaps that will be transmitted to students. In turn, this can generate a clash between the model of sustainable development and conservationism. In this sense, students are not fully informed of the differences, advantages or disadvantages of each model. Knowing that ESD is the model to achieve the SDG [4], the results of this study help to affirm the low levels of progress that Colombia has compared to the SDG. This country recently ranked 9/12 in the Latin America region in the "2019 SDG index for Latin America and the Caribbean" [29].

The generation of conceptual gaps due to the incomplete transmission of information may be due to the fact that this country does not have an updated environmental education policy or a policy that promotes ESD. For the first case the document "Environmental Education Policy" dates from the year 1994 [14], this has a clear protectionist trait and urges all educational entities, from primary school to universities, to enact environmental education. On the other hand, there is no government document that promotes ESD in this country. All this makes to clearly promote the SD difficult for the universities and for these in turn to become an engine to achieve the SDGs. The foregoing evidences in the same way that contrary to what would be expected, universities in this country are not responding to professional needs, where graduates must be literate in SD [7].

It can be concluded that there is a consensus that EE and ESD are important in the teaching of environmental engineering. There is also an agreement that there should be a modification in the study plans. This option opens up the need to reform the curriculum and incorporate either of the two EDS or EE streams. In addition, it promotes the preparation and training of teachers, since the preparation of the subject pushes teachers to know and position themselves on one of the two streams.

It is important that in addition to what is presented, new research is sought that involves other academic actors, including students, managers, employers, and graduates. To know their perception and expand the results.

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COLLECTIVE EXPERIENCE OF APPLICATION OF AN INVERTED CLASSROOM IN THE COMPUTER SCIENCE DEGREE PROGRAM

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ABSTRACT

In the last years, higher education is immersed in the transformation of the teaching experience with the aim of involving students more, as well as motivating them. Nowadays, students are very familiarized with new technologies and media while lecturers have been forced to transform their traditional notes to digital ones. This transformation pace has been accelerated in the last year due to the COVID19 pandemic. One of the main exponents of the said transformation is the adoption of the inverted classroom, a substantially studied teaching methodology where students work on some key concepts before a lecture takes place and face-to-face lecture time is reserved for added value activities. This work presents the results of a case study involving the implementation of the inverted classroom in a computer engineering bachelor's degree. This experiment involves six different subjects in three courses during the 2020/21 academic year. The paper presents the principal motivation for the study, as well as the preparation process and methodology of the out-of-classroom multimedia materials and training of the faculty. It also covers the methodology used for multimedia content creation. Finally, the evaluation results are presented, gathered from questionnaires directed to students and lecturers.

1 INTRODUCTION

In recent decades, the university environment is undergoing through deep changes derived mainly from technological and pedagogical innovations in the field. New technologies provide mechanisms to multiply opportunities for communication and collaboration during the learning process, extending the traditional classroom context to a digital space. However, these technological advances are experienced unevenly between the teaching and student communities. On the one hand, newly enrolled students demand greater use of technology in the learning process, as the information consumption in newer student generations is marked by the continuous use of technology (e.g., they are able to use their smartphones, tablets or computers for hours on end). This ability to be continuously connected through digital devices, however, rivals the ability to concentrate and learn. On the other hand, the teaching community, aware of the opportunities and challenges, is engaged in a progressive transformation to incorporate technology into education in a rational way.

Advances in neuroscience point to student motivation and involvement as a determining success factor in the learning process. In recent decades, the teaching community has made innovative pedagogical proposals that seek student participation through active methodologies as a framework to increase motivation and involvement. One of the most relevant methodologies is the inverted classroom. This methodology consists of students studying and preparing lecture contents outside the classroom, before the actual lecture starts by accessing said contents at home through the use of technology (e.g. videos or required readings). Subsequently, with the lecturer as a guide, classroom time is allotted to additional added-value activities where students deepen and complement the content previously acquired. Such activities can be guided to develop the practical side of the lecture or engaging in more interactive and participatory activities such as idea analysis, debates or teamwork.

With the outbreak of the COVID-19 pandemic, lecturers worldwide have been forced into emergency remote education during the second semester of the 2019/2020 academic year. However, after the height of the pandemic, some universities returned to on-site lecturing for 2020/2021 albeit in a partial manner due to classroom space constraints and social distancing, forcefully adopting the technique known as blended learning, by combining face-to-face and remote lectures. This reduction of onsite lectures has outlined the necessity of optimizing onsite lecturing time. In this context, the pandemic has intensified the use of technologies, as well as the adoption of innovative teaching methodologies by higher education centres in an attempt to counteract the (at least partial) lack of traditional face-to-face lecturing: inverted classroom being one of the main exponents.

In this context, this paper presents the experience of adopting the inverted classroom at our university, across the complete computer engineering bachelor's degree. The rest of the document presents the work methodology carried out, as well as the preliminary results of the implementation and the main conclusions.

2 RELATED WORK

In the last decade, flipped classroom has been considered an outstanding methodology to motivate students in their daily routine. New technologies are fundamental in this methodology and students are very familiarized with them. This methodology is not uniquely designed or carried out in the primary or secondary school, it is also accomplished in the university and engineering faculties.

Gannod et al. [1] implemented the flipped methodology for software engineering students. It was carried out with 40 students and they had video materials to watch between 3 and 6 hours every week at home before the laboratories. These laboratories were associated with the videos and results show that the students were better adapted and advanced faster without professor's support.

Mason et al. [2] experimented the flipped methodology in a mechanical degree with 20 students with the aim of producing graduates who have excellent problem-solving skills. Before the lectures, students had some videos to watch. Then, in class, they were asked to solve a problem in groups or individually, supported by the teacher to solve their doubts. At the beginning, students were frustrated due to the methodology. Nonetheless, final results were equal or better comparing with previous results the students' satisfaction was superior.

Kim et al. [3] presented an experience in three different classes with 115 students involved. Before the lectures, they had some videos to watch and, in class, they had to solve problems related to the videos, group presentations and role plays. At the end of the experiment, they develop a set of 9 design principles for a face to face flipped course.

Parejo et al. [4] implemented the flipped classroom experience in the second year of software engineering degree in the software architecture and integration subject. They compared the results of two different years involving 434 students and 6 lecturers. Before the laboratory sessions, students must watch some videos and a questionnaire was used at the beginning of the class to be sure that videos were completely understood. If one questions was not correctly answered by the crowd, the lecturer explains the concept in class. Results show that students had 24 minutes more to complete the laboratories which provoke that more than 70% of students considered the time to complete the laboratories adequate.

Chiquito et al. [5] completed the experience in the second year of a course called Technology of Materials. They divided students in two groups, 98 followed the traditional approach and 97 used the flipped classroom methodology. The flipped students had to watch some videos before the class and complete and activity to check students' knowledge before the activity. Results show that students which used flipped methodology obtained better results and they detected that female students obtained better results than males in this group.

Gren [6] studied the flipped classroom experience in software engineering subject with 50 students involved. Before the lectures, students had to watch videos around 10-20 minutes. In class, a questionnaire was used to have some feedback about students' knowledge before the class activity. Comparing their results with the previous 5 years, they conclude that flipped classroom methodology improved the academic results.

Hussain et al [7] involved 18 students in a flipped classroom methodology in an engineering degree in a mechatronics course. Before the lectures, students were delivered some online videos with the main concepts to use in the next class session. In class, different techniques were utilized for teaching such as teacher-student interaction, student-student interaction, engaging students by using audio and visuals aids, hand-on activities, and problem-solving exercises. After the lectures Bloom's taxonomy was used for students' summative assessments which helps the lecturers to develop a rubric for grading and discriminating students' performances at various levels. Results show that flipped methodology and improved engagements with their lecturer and their peers although results were not enhanced significantly.

3 CASE STUDY

The starting point of the project is given during the deployment of the strategic plan of the university in the degree of computer engineering carried out in May 2020.

Among the established objectives, a project proposal is defined for the implementation of the inverted classroom methodology as a mechanism to (1) increase the involvement and motivation of students in class and (2) train faculty in the digitization of content.

The project is presented to the academic coordination and receives approval and resources for its implementation in the 2020-2021 academic year. The project involves the implementation at scale of the inverted classroom methodology in two subjects per course with the involvement of 10 lecturers and 253 students.

Before carrying out the experience, in the early half of July 2020, we gathered information from other works to see how we could adapt it to our own case. The related work shows some of the experiences we evaluated.

The lecturers at our university are experienced in the use of active methodologies. Evidence of this is that for more than a decade they have been applying the Project Based Learning (PBL) methodology in all their engineering degrees. In this context, although the university had been providing training pills to the teaching team in active methodologies (including training in the inverted classroom methodology) for several years, a specific training was designed for the project, which took place in July 2020.

During the training, the project's teaching team was trained in the basic concepts of the inverted classroom methodology and the training was completed with three workshops: a first workshop to establish the rules of the methodology that all subjects had to follow, a second workshop to design the implementation of the methodology in each of the subjects involved and a final practical workshop to get started in the autonomous management of the recording studio. It should be noted that prior to the training period, the design and arrangements for setting up the recording studio were made.

All subjects have adopted 4 rules established in the common methodology:

- (1) Outside of class hours, students watch a video(s) with the contents of the subject.
- (2) In the following classroom session, they take a brief questionnaire related to the video they have seen. In this way, students are encouraged to come to class with the basic concepts already reviewed and with the possibility of clarifying any doubts they may have about the audio-visual material. Once the cycle of the more theoretical and conceptual part is closed.
- (3) All subjects have also been supported by exercises and practices. This activity has been carried out in class (being able to finish out of class) and in this way the classroom time has been used to really solve doubts in the application of theoretical concepts. The objective has been to make the most of the classroom time to reinforce the learning process. After each topic or learning module,
- (4) The teaching staff provided feedback to the students on the questionnaires completed.

However, the evaluation applied in each subject has not been affected with respect to previous courses with the incorporation of the methodology. In all the degrees, continuous assessment is applied throughout the degree course, which each subject implements with different types of tests: questionnaires, practices (individual or group) and individual exams on the subject.

Following the guidelines described above, during the first semester of the current academic year (from September 2020 to February 2021), the subjects selected in

July 2020 have already carried out the experience. The following section will show the results obtained following the inverted classroom methodology described above.

4 RESULTS

The results presented in this section correspond to the first semester of the 2020-2021 academic year. During this period, 6 subjects, 10 lecturers and 253 students have been involved. In spite of this being a broad study in which several subjects have been analysed, it should be noted that the validity of the current work is limited the results of a single semester.

In this section, the reception of the experience is analysed. For this purpose, two separate surveys were carried out with students and lecturers.

Table 1. Results of the Student Survey (Strongly disagree, SD; Disagree, D; Neither agree nor disagree, N; Agree, A; Strongly agree, SA)

	Frequencies					Median	Mode
	SD	D	N	A	SA		
Q1: I usually watched the videos before class.	5	19	45	82	102	A	SA
Q2: The videos were easy to understand/follow.	10	34	72	90	47	A	A
Q3: The video material was well designed, well-structured and clearly defined.	14	20	69	101	49	A	A
Q4: The videos have helped me to learn.	10	33	71	86	53	A	A
Q5: The activities developed in class after the quiz have helped me to learn.	22	22	62	94	53	A	A
Q6: The ability to rewatch and rewind the videos has helped me to learn.	6	21	35	79	112	A	SA
Q7: A short video format presenting the main study topics helped me learn more than the very detailed and extensive videos.	10	25	71	95	52	A	A
Q8: Taking multiple-choice quizzes after watching the videos has allowed me to delve deeper into the more complex content before class and therefore helped me understand it better.	29	39	77	78	30	N	A
Q9: Having watched the videos and reviewed the materials provided prior to the class sessions has helped me complete the class activities with more confidence as I was not at a loss.	14	33	76	99	31	A	A
Q10: Having watched the videos and reviewed the materials provided prior to the class sessions has helped me to complete the class activities more easily because the activities were familiar to me.	11	28	76	102	36	A	A

Following the work carried out by [8], we surveyed the student body to find out their opinion on this new initiative in ten different aspects (see Table 1). The questions used in [8] have been slightly modified, and the responses have been collected based on the Likert scale [9] as in the original paper. A summary of the responses (253 questionnaires in total) by the student body is shown in Figure 1.

In general, the students agreed with the statements made in the survey and the reception of the experience was positive. It is worth highlighting statements Q1 and Q6, where the responses have been more favourable. In these statements, it is affirmed that the videos are viewed prior to the classes, and that one valuable aspect of having the audio-visual content is the possibility of revision. On the other hand, the

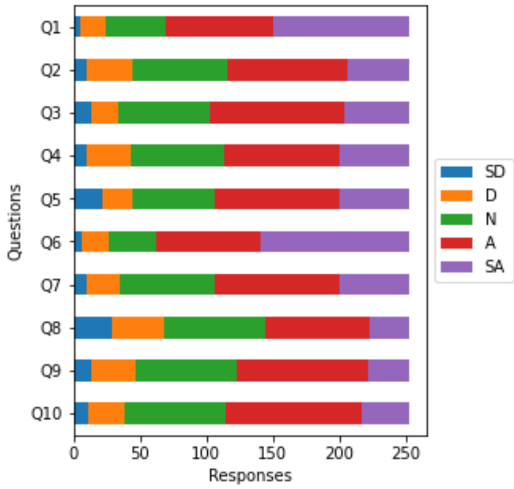

Fig. 1. Results of the Student's Survey (Strongly disagree, SD; Disagree, D; Neither agree nor disagree, N; Agree, A; Strongly agree, SA)

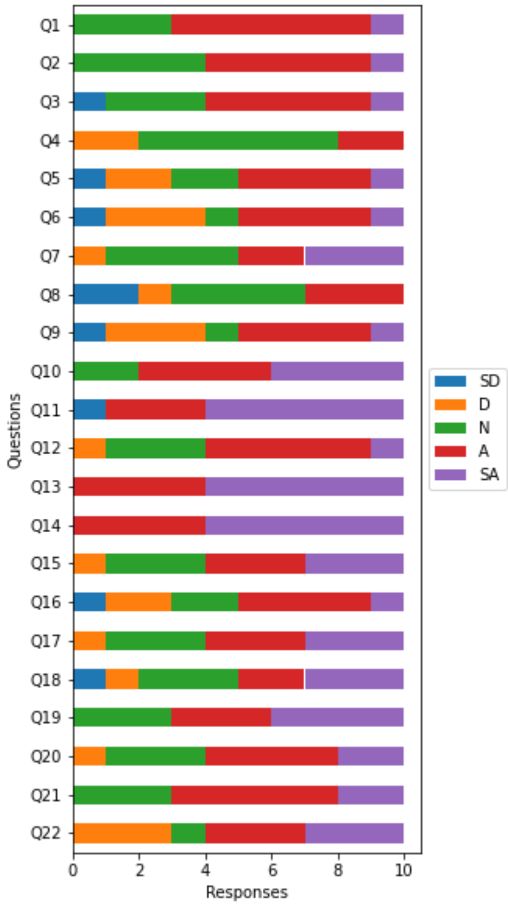

Fig. 2. Results of the Lecturer's Survey (Strongly disagree, SD; Disagree, D; Neither

agree nor disagree, N; Agree, A; Strongly agree, SA)

use of questionnaires did not receive the same consensus in statements Q8, regarding the usefulness of the questionnaires.

Table 2. Results of the Lecturer Survey (Strongly disagree, SD; Disagree, D; Neither agree nor disagree, N; Agree, A; Strongly agree, SA)

	Frequencies					Median	Mode
	SD	D	N	A	SA		
Q1: I enjoy trying to use flipped teaching.	0	0	3	6	1	A	A
Q2: I enjoy the flipped teaching method that is completely new to me.	0	0	4	5	1	A	A
Q3: Curiosity is the driving force behind much of what I do in flipped teaching.	1	0	3	5	1	A	A
Q4: The more difficult the flipped teaching task, the more I enjoy trying to solve it.	0	2	6	2	0	N	N
Q5: I am strongly motivated by the recognition I can obtain from doing flipped teaching.	1	2	2	4	1	N	A
Q6: As long as I can do flipped teaching, I'm not that concerned about exactly what recognition I can obtain.	1	3	1	4	1	N	A
Q7: I seldom think about the recognition I can obtain for flipped teaching from students.	0	1	4	2	3	N	N
Q8: I care about what recognition mechanism exists from flipped teaching community.	2	1	4	3	0	N	N
Q9: I could complete the flipped teaching task if there was no one around to tell me what to do as I go.	1	3	1	4	1	N	A
Q10: I could complete the flipped teaching task if I could call someone for help if I got stuck.	0	0	2	4	4	A	A
Q11: I could complete the flipped teaching task if I had a lot of time to execute flipped teaching.	1	0	0	3	6	SA	SA
Q12: I have sufficient ability to prepare teaching materials for the flipped teaching tasks in advance (such as recording videos and collecting educational resources on the Internet).	0	1	3	5	1	A	A
Q13: The university provides facilities and resources for flipped teaching.	0	0	0	4	6	SA	SA
Q14: The university provides technology and software resources for flipped teaching.	0	0	0	4	6	SA	SA
Q15: The university provides facilities and resources to help me improve students' flipped learning.	0	1	3	3	3	A	A
Q16: The university provides tutoring or coaching resources for students' flipped learning.	1	2	2	4	1	N	A
Q17: I intend to continue to use flipped teaching.	0	1	3	3	3	A	A
Q18: My intentions are to continue using flipped teaching rather than using only traditional teaching.	1	1	3	2	3	N	N
Q19: If I could, I would like to continue my use of flipped teaching.	0	0	3	3	4	A	SA
Q20: I think my students would be in favour of utilizing flipped teaching in their class.	0	1	3	4	2	A	A
Q21: I think my students would believe that flipped teaching could be a useful educational method in their class.	0	0	3	5	2	A	A
Q22: I think my students possess adequate technical skills to use flipped learning.	0	3	1	3	3	A	A

In order to evaluate the reception of the experience by the faculty, a methodology similar to that followed by the students, focused on the completion of a questionnaire, was used. The questions have been defined following the work done by [10]. The responses (10 in total) have been summarized in Table 2. In general, the reception to the experience has been good and pleasant (Q1 and Q2), although the lecturers are unsure about the recognition that they will receive (Q7 and Q8) and they strongly agree that completing the flipped teaching task is time-consuming (Q11). On the other hand, the resources provided by the university have been identified as adequate to carry out the experience (Q13 and Q14) (see Figure 2). Overall, lecturers are favourable to continue using this methodology (Q19).

5 CONCLUSIONS AND FUTURE WORK

In this paper we present the results of an inverted classroom experience carried out in the computer engineering degree. The motivation for this experience is based on the one hand on the change of information consumption habits of the new generations as well as the opportunity identified by the faculty to evolve methodologically as a result of what was experienced during the emergency teaching of the course 2019-2020 derived by the pandemic.

It is a scaled experience that has involved in the first semester of the academic year 2020-2021 six subjects of the first three years of the computer science degree, that is to say, 10 teachers and 253 students. During this experience, 164 videos were created and 38 questionnaires were designed.

For the evaluation, two surveys have been carried out to students and teachers. From the student survey we can conclude that in line with other similar works, student motivation is increased with the use of this inverted classroom methodology. On the part of the teaching staff, it is noted that the effort made by the teachers is high although it is considered necessary (probably after what was experienced in the previous course). Based on these preliminary results, we encourage the teaching community in the field of computer engineering to adopt the methodology.

In the future, we are interested in repeating the experience in the second semester. The aim would be including in the initiative another six subjects and a survey data corresponding to the second semester will be collected and an assessment of the impact of the activity on the academic performance of the students can be made. Once the entire course is completed and after analyzing the results, a workshop will be held to retrospectively analyze the experience and propose improvements for the 21-22 academic year for the subjects involved and recommendations for new subjects that wish to participate in the program.

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SUSTAINABLE DEVELOPMENT AND THE SDGS: REVEALING ENGINEERING ACADEMICS, STUDENTS AND EMPLOYER VIEWPOINTS

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ABSTRACT

As the world's focus turns to the future and not the present, the engineering profession must respond to the ever increasing need to bring about a sustainable future. The objective of this paper is to support the reform of engineering education by acknowledging and building upon the current awareness and understanding of sustainable development held by key stakeholders in the process.

This paper presents the outcomes of a study involving twelve focus groups with Academics, Employers and Students in four European countries (Denmark, Finland, France and Ireland) as part of the A-STEP 2030 European Project. Based on the findings, it is clear that the key stakeholders closely associate the theme of the environment with Sustainable Development. There is also mention of the pillar of economy, but less so, that of society. The findings also reveal differences in the awareness of specific Sustainable Development Goals (SDGs), with SDG 13 (Climate Action) being most widely noted. The findings allow educators to engage in discussion with students to build a more complete understanding of aspects of sustainable development and to act in redesigning curricula to ensure engineers can contribute to a sustainable future.

1 INTRODUCTION

During the last decade, there has been an increasing interest in research on the importance of sustainability in engineering education [1]. The literature highlights the central role of the engineering profession in the achievement of the SDGs: future generations of engineers will not only be catalysts of technical innovation but will also play a leading role in addressing various social issues [2].

It has been argued that sustainability and sustainable development are concepts that are difficult to define, even that they “mean all things to all people” [3]. As other observers have noted [4] the nature and meaning of the concept of sustainability and sustainable development have been hotly debated. A definition that is frequently quoted and held as affirmative (eg. [5]) comes from the World Commission on Environment and Development, which defines sustainable development as development that: “meets the needs of the present without compromising the ability of future generations to meet their own needs” [6, p.39]. Regardless of these differences in conception and discourse, sustainable development is usefully analysed via the “three pillars model” of sustainable development (also called the three circles model [7] or the Triple Bottom Line [8]). The three pillars of sustainability are: environmental, social, and economic.

Further recognition of the importance of sustainability was accorded when the UN chose to include the “preservation of the environment” in its 2000 Millenium Development Goals. In 2015, the MDGs became the SDGs or Sustainable Development Goals, a shift in language that affirms that all real development must be sustainable. Hence as engineering educators we can support educational reform by preparing our students to achieve the SDGs and to do so we must appreciate and expose our students to the three pillars of Sustainable Development.

Reform of engineering education to address these sustainability challenges will only be successful when educators have an opportunity to reflect on their conceptions in order to find potential pathways to change. The purpose of this study was to gain an insight into the viewpoints of engineering students, academics and employers in relation to their understanding of Sustainable Development and in particular to their awareness of the SDGs.

Specifically, the study sought to answer two questions:

1. To what extent are employers/academics/students aware of the concepts of Sustainable Development (SD)?

2. To what extent are employers/academics/students aware of the Sustainable Development Goals?

2 METHODOLOGY

2.1 Context

It is important at this point to provide overall context for the study, before focussing on the specific research questions presented in this paper. The focus groups which are described in more detail in the next section were split into three parts. The first part focussed on the concept of Sustainable Development and participants were invited to brainstorm the themes associated with Sustainable Development. The purpose of this part was to give context to the differing conceptions of Sustainable Development by the participants, as this may affect how they answered follow on questions. The second part of the focus group aimed to investigate the awareness of the SDGs in general and of specific SDGs in particular and finally, participants were invited to discuss the skills required of engineers of the future in order to achieve the SDGs. The outcomes from the first two parts are the focus of this paper.

For the final part, we wished to generate conversation, including brainstorming sessions and discussion and debate on the topic which revealed the differing understandings from each stakeholder group. Hence, a qualitative research approach was employed [9] and focus groups were selected as the most appropriate method of inquiry to investigate complex questions through direct interaction with participants.

As the intention was to compare the results of each participant group across countries it was important that the outline for how the focus group was to be carried out was agreed between all academic partners. To this end, a Focus Group Instructions document was created and was reviewed and agreed by all parties. It is important to note that focus groups in each country were facilitated within their native language, digitally recorded and partially transcribed and only selected citations were translated into English by each partner organisation. It is important to highlight this as a limitation of the work, as the frequency word lists were then formed from translated concepts and terminology. Each partner created a report summarising the findings of the focus groups in each country, using an agreed report template. This was forwarded to the lead partner in this activity and the results were collated.

Twelve focus groups were organised with participants from key stakeholder groups (academics, students and employers) in each of the four participating countries. Invitational emails were sent to academic staff and students in each partner institution and employer groups were recruited through invitation emails sent from either professional organisations in each country or through alumni contacts. There was no sampling criteria applied as all respondents were selected to take part. In total, there were 86 participants who engaged in 2 hour focus groups as part of this study (between March and July 2019) and demographic information is included in Table 1. As the research work involved human participants, ethical approval was granted by TU Dublin and researchers in each country also gained ethical approval for focus groups within their respective universities.

Table 1: No of focus group participants and level of expertise

	No of Students and no of years of study	No of Academics and academic experience	No of Employers and length of experience
Ireland	7 1-5 years	9 1-20 years experience	6 1-41 years experience
France	9 3-5 years	7 2-20 years experience	8 2-49 years experience
Denmark	7 1-5 years	8 2-40 years experience	6 20-35 years experience
Finland	4 2-3 years	8 8-24 years experience	7 15-37 years experience

2.2 Data collection and analysis

In specific relation to the first research question addressed in this paper, participants were asked individually to brainstorm the words or themes they associated with Sustainable Development and these terms were collected and collated for each stakeholder group in each country. The words/themes associated with Sustainable Development (SD) were analysed using word frequency analysis. It is important to note here that phrases were separated into individual words in order to cut down the number of variations available. So for example a phase such as “Renewable Energy”, would be counted as both “renewable” and “energy”. Whilst this gives a representative response to this term, it is also important to note that the context of the word should also be considered, for example “Circular” was normally used within the phrase “Circular Economy”.

Participants were then also asked individually, if they could name any of the SDGs, without the researcher giving any introduction as to what the SDG goals were. This was also an individual exercise. Responses were collected, analysed and tagged to the relevant SDG where appropriate. Some participants gave specific responses which were easy to identify such as “Clean Water” (tagged as SDG 6) or “To make cities safe, inclusive and sustainable places” (tagged as SDG 11). Others gave responses which were interpreted and tagged to two different SDGs such as “To provide education to people in the 3rd world” which was tagged as SDG 4 (Quality Education) and SDG 10 (Reduced Inequalities). Finally, seven responses were not deemed to be related to a specific SDG (although they reflected the concept of SD) and were therefore not tagged. These were; “Sustainability and long term vision”, “Environmental Poverty”, “Security”, “Synergy of human being and nature”, “Sustainable awareness building”, “Technical” and “Social”.

3 RESULTS

Table 2 shows the frequency of the most highly ranked individual words to identify the themes associated with Sustainable Development, which also corresponds to Figure 1. Only those words with a frequency of 10 or more are included here.

Table 2. Frequency of most highly mentioned words by stakeholder group

Term used	Overall Frequency	Academics (Frequency)	Employers (Frequency)	Students (Frequency)
Energy	65	29	23	13
Environment	30	10	8	12
Renewable	30	12	9	9
Recycle	28	10	9	9
Economy	26	12	8	6
Reduction	22	11	6	5
Waste	20	7	5	8
Clean	20	13	5	2
Consumption	17	7	6	4
Resources	17	11	4	2
Education	14	6	3	5
Water	14	10	3	1
Efficiency	13	5	6	2
Green	12	7	3	2
CO2	12	6	5	1
Sustainable	11	6	3	2
Materials	10	7	1	2
Circular	10	4	5	1
Climate	10	3	5	2

Figure 1: Word cloud showing all words and themes associated with Sustainable Development [All countries, All groups]

The results for each participant group were also analysed to contrast and compare different groups. Figures 2-4 shows the individual word clouds associated with Sustainable Development with each participating stakeholder group.

Fig. 2. Academics – themes associated with SD

Fig. 3. Employers– themes associated with SD

Fig 4. Students– themes associated with SD

The overall results of the word frequency exercise presented here suggest that “Energy”(65) is the key theme associated with Sustainable Development, clearly out in front and followed by “Environment”(30), “Renewable”(30) and “Recycle”(28). These key words align very clearly to the pillar of Environment. “Economy”(26), “Resources”(17) and “Circular”(10) are the most mentioned words associated with the pillar of Economy. Words associated with the third pillar, Society, are sparse, with only “Education”(14) and to a lesser extent “Diversity”(5) and “Equality”(5) being included within this pillar, but with only five mentions each.

The picture when we look at key stakeholders tells a similar story, with Energy, Renewable and Environment standing out clearly in all groups. With regard to comparison of student groups across countries, in France, the use of words “Education” and “Management” in relation to SD stands out. Management in this context was mainly used in phrases such as “Waste Management”, “Forest Management” and “Energy Management”.

The academic groups brought the concept of “Clean” to the fore compared to employer and student groups. Comparing between countries showed differing foci with Irish academics concentrating on “Renewable” “Energy” and “Water” and offering words associated with specific technical solutions to SD, such as “Heat Source pumps” “Ground Source pumps” and “Rainwater harvesting.” French academics brought out the idea of “Consumption” and “Resources” as a key theme.

Employers placed more emphasis on “Efficiency” compared with academics or students. In particular, Irish employers associate SD with the “Future” along with themes such as “Carbon” and “Efficiency. French employers highlighted the word “Consumption” but also reflected the words “Global” and “Respect (of nature)” which was not typical of other employer groups. The words “Transport” and “Infrastructure“ and “Urbanisation” also appeared with Danish employers and there was a focus on “Circular”, “Economy”, “Technology” and the “Future” with Finnish employers.

In regard to the second research question, we sought to investigate the awareness of the SDGs in general and of particular specific SDGs. Figure 5 shows the differentiation in which particular goals were most often identified, indicating the level of general awareness of each individual SDG. This figure also shows the number of goals identified by each participant group.

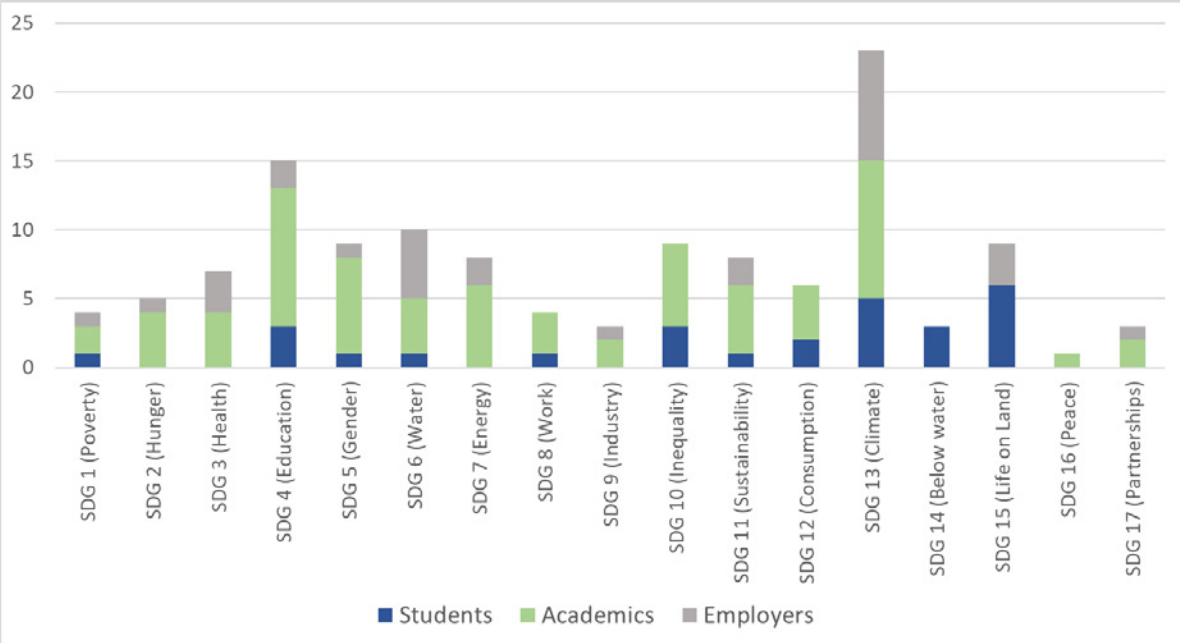

Figure 5: No of mentions for each SDG by participant group.

SDG 13 (Climate Action) tops the list with the greatest number of mentions (23), and far exceeds other goals. With 15 mentions, SDG 4 (Quality Education) comes in second place, followed by SDG 6 (Clean Water and Sanitation) with 10 mentions. Perhaps surprisingly, SDG 5 (Gender Equality) comes in fourth place, along with SDG 10 (Reduced Inequalities) and SDG 15 (Life on Land). These particular SDGs (5 and 10) relate to the wider concepts of the SDGs, or align to the societal pillar of SD. Students did not identify SDG 2 (Zero hunger) nor SDG 3 (Good Health and Well Being), whilst both were identified by Academics and Employers, perhaps reflective of the older age profile within these groups.

4 DISCUSSION AND IMPLICATIONS

Due to space considerations, this paper presents only a snapshot of the findings within the focus groups. More detailed results including detailed differentiation between each stakeholder group and each country (including the influence of governmental policies) can be found in the full project report [10].

The findings concur with previous studies on the lack of awareness of the pillar of society in conceptions of SD [11] and the lack of mention of terms associated with the social pillar in a study on the understanding of “global responsibility” from engineers working in industry [12]. This highlights the need for educators to enhance the engineering curriculum to bring forth the social aspect of SD, as a combination of all three pillars are needed to really achieve a sustainable future.

More specifically, the findings highlight three implications for learning and teaching in engineering education. The first is by acknowledging the differences in each stakeholder group in relation to what we mean by Sustainable Development. Students are focusing on terms such as “recycle” and “waste” more so than academics. This is perhaps due to the updated curriculum being taught at primary level in recent years in relation to the environment and climate action. This should encourage engineering educators to generate discussion amongst students in relation to the three pillars of Environment, Economy and Society so that a more complete understanding is reached by all.

The second is by looking at the gaps or differences between stakeholder groups in relation to awareness of specific SDGs. For example, academics approach the classroom with an awareness of SDG 2 (Zero Hunger) and SDG 3 (Good Health and Wellbeing), yet students are unaware of these SDGs. Finally, the overall awareness of specific SDGs may indicate that engineering educators should turn their focus to goals such as SDG 16 (Peace, Justice and Strong Institutions) as one SDG that needs more attention in the classroom, whereas SDG 13 (Climate Action) may need less initial focus as it appears that academics, students and employers have a clear focus on the aspect of climate action and environmental change.

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LEARNING FROM UNIVERSITIES' RESPONSES TO THE COVID-19 PANDEMIC: LESSONS FOR THE NEW NORMAL

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Conference Key Areas: *On-line student counseling; essential elements for the online learning success*
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ABSTRACT

The pandemic has negatively impacted many students' ability to continue schooling, or to do so with the same level of success. What is not well understood is how universities' responses to pandemic-induced changes helped or hindered students' success during the spring 2020 transitions to online learning. To better understand campus closures and transitions to online and blended learning, this paper explores students' perceptions of their universities' handling of and responses to the pandemic and which actions and resources would better support their success in the new normal. It is important to understand the impacts of universities' responses on students not only because some changes are likely here to stay, but also because pivots caused by pandemics may be required with increasing frequency in the future. The data came from an online survey conducted in the United States in spring and summer of 2020. The survey respondents were 669 undergraduate engineering students from 140 institutions. Student responses addressed several distinct groups of stakeholders with most related to individual instructors, followed by academic administrators, and counselling and disability service centres. Less prominent but still important themes related to other groups were also identified. Responses for each of these groups are presented in turn, and the paper concludes with recommendations for each group.

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1 INTRODUCTION

The COVID-19 pandemic has negatively impacted many students' ability to continue higher education in the United States [1]–[3]. Even for those students who are able to continue, changes caused by the pandemic have made many aspects of attending college more difficult. What is not yet well understood is how universities' responses to pandemic-induced changes either helped or hindered students' success during the spring 2020 transitions. It is important to understand the impacts of universities' responses on students not only because some changes are likely here to stay, but also because rapid pivots will likely be required with increasing frequency. Shifts to blended and online learning, for instance, may continue permanently in some cases, and pandemics and epidemics are happening at increasing frequency [4], [5]. Therefore, we must understand the impacts of shifts to blended and online learning and to be better prepared to make rapid pivots in the future. To that end, this paper explores students' perceptions of their universities' handling of and responses to the pandemic and which actions and resources would better support their success in the new normal.

2 METHODS

The data for this paper came from a nationwide online survey of 669 undergraduate engineering students from 140 universities in the United States. Further details about data collection, the survey instrument, and respondent demographics can be found in [6]–[8]. This paper focuses on responses to three open-ended questions related to universities' responses to the pandemic: 1) What did your university do that was not helpful in supporting mental wellness during the pandemic? 2) What strategies do you wish your university had taken during the pandemic to support mental wellness? 3) What resources do you wish had been provided by the university during the pandemic to support mental wellness? While the survey questions focused on mental health, we found that the open-ended responses spoke to broader instructional issues and held more generalisable lessons for shifts to online learning and universities' responses to emergencies of any kind. Similar responses were found across all three questions, such that it made sense to organise findings by stakeholder group rather than by individual question. Therefore, responses were first categorised by stakeholder group and subsequently by inductive themes within each of those groups. Findings were then narrowed down to prioritise themes that were actionable and that we deemed reasonable. Several quotations were edited for anonymity, to correct typos, or to increase clarity.

3 RESULTS

3.1 Instructors

The majority of comments concerned individual instructor's actions. These comments addressed three categories: 1) amount of work assigned, 2) lack of empathy for student difficulties, and 3) course organisational and instructional problems. As readers will see, there was some overlap between the categories.

The first category of comments related to instructors indicated that students believed instructors assigned an unreasonable amount of work following the pandemic outbreak. While some comments suggested that even a regular workload would be excessive due to pandemic considerations, many noted that instructors assigned significantly more work than they would have during a normal, in-person semester. Phrases such as “drowning in homework”, “flooded with work”, and “an absolute immense amount of work” captured these experiences. Other representative quotations included: “The amount of school work is excessively more than what would be done during the regular school year”, “Some teachers increased workload while students were still trying to get used to different platforms of online learning”, and “classes [are] far more difficult, causing mental wellness to be compromised due to stress/anxiety”.

The second category of comments indicated that students believed instructors had acted without empathy. The general perception was that instructors acted as if their courses could and should carry on as normal and did not recognise, care about, or adjust to the myriad ways in which some students’ lives were upended by the pandemic. Phrases such as “unsympathetic”, “not at all compassionate”, and “cruel” captured this sentiment. Representative quotations included: “Professors need to understand that not all students are local and have access to being on the computer all the time especially with Wi-Fi issues and housing insecurity by not being able to pay rent due to loss of job”, “They just kept going with the course material like if we were still in class”, “[…]”when I missed an assignment due to technical difficulty (hardware failure after dealing with two family members getting sick (grandmother is fine, cousin has COVID)), they ignored my emails asking them to understand my situation, then responded two weeks later saying that I had waited too long to ask”, “The grading policy, it’s much more difficult to get stuff done when you have an insecure internet connection. You get dropped out of class in the middle of lecture. I’ve missed points because my internet sucks. Or just flat out couldn’t do homework because of my internet was out for a couple of hours”, “Professors were being horrible and not at all compassionate. They didn’t care about what we felt”, “[they should have] Kinda relaxed more and not have students stress about grades. So that we could focus on surviving”, “Kept pushing ‘maintaining academic integrity’ and constantly making us feel like the only thing that mattered was our grades”, and “Completing my regular coursework was unreasonable and cruel to expect of me in my mental condition. It almost cost me my life. When I reached out for support, I was not believed and I was reluctantly given *some* accommodation”.

The third category of comments indicated that students experienced organisational or instructional problems with their courses. These problems ranged from instructors not adhering to specified exam times, a move to asynchronous learning, and an overreliance on YouTube and letter grading policies (not switching to pass/fail). Representative quotations included: “My professors made the exams longer because we were at home and they overlapped the time which made it incredibly stressful and difficult to get done within the timeframe given”, “I wish lectures still remained at designated times instead of YouTube videos", "Half of the professors quit teaching and just sent out YouTube videos as their lectures (videos were often not made by them)", "Some classes became completely asynchronous (lectures posted for students to go over on their own) which is good to help with time zones, but a lot harder to engage in the material and makes asking questions a lot harder (primarily due to required effort)", "Teachers assigning us projects without proper instruction or support", and "[they should have] Taken it slower. Not to expect students to have every single engineering software on laptops when it was not required. Not to expect students to be able to get help from professors, because it takes a lot longer through email rather than in person".

3.2 Academic Administrators

Academic administrators (e.g., deans and chairs) were the second group of stakeholders referenced in students' responses. The majority of these comments reinforced the salience of the themes identified above for individual instructors. For example, many students commented that administrators should have prevented instructors from increasing student workload during the pandemic. Representative comments included that administrators "Did not regulate or coordinate the workload between classes", that "professors didn't communicate on when or how much work they were going to assign so it made the workload 10x worse", and that administrators should "Instruct professors on not to give more just because it is all online".

The theme of instructors acting without empathy was reflected in comments that administrators should have required and enforced more empathetic actions by instructors. One specific means of doing so that was repeatedly mentioned was implementing a college-wide switch to pass/fail grading policy: "It is completely unfair to expect all students to complete school work at the same level when there are HUGE disparities between ability and privilege". Other specific actions mentioned were "mandating assignment extensions or forgiveness for certain situations", and "taking mental wellness into consideration when discussing online learning". Another student said: "I also wish the college had been more helpful instead of making me fight for my incompletes while I waited for access to my chronic pain treatments (which were shut down because of COVID)". More generally, comments indicated that administrators should: "More closely supervise the professors because some of my professors have been very difficult and not understanding during this period", "Enforce that all teachers go a little bit easier on us rather than just encourage it", "Tell professors to take it easy and realise students are now just trying to survive and school now has to come 2nd to that", and encourage "professors to lay back a bit on the harshness".

The theme of organisational or instructional problems was reflected in comments that administrators should have done more to prevent these problems. Specifically, students voiced a need for: 1) more coordination at a college and department-wide level (i.e., not leaving organisational and grading decisions up to each individual instructor); 2) more communication with professors on how long and frequently exams should be given, 3) better substitutions for labs; 4) better and more communication with students and staff overall, and 5) helping instructors transition to online learning. For example, one student said the university should:

> Help the teachers be better prepared for the transition to online. Each teacher is trying to figure everything out just like the students. Some professors don't have adequate audio setup which has wasted valuable time in class and makes it harder to understand lecture material.

Additionally, students needed access to computers and software programs that they previously were able to access on campus. As one said: "I wish they would help those who have limit [sic] access to school equipment, such as a laptop, the ability to check one out. I wish they would have better prepared the professors for it, too". A similar comment said: "As an engineering student, we use many computer programs to do schoolwork. I personally never really had the money to pay for these so therefore I would do these assignments at the school computers…Now working from home, I found myself forced to buy them because the department did not offer any help paying for them".

3.3 Counseling and Disability Service Centres

The third group of stakeholders referenced in comments was counseling and disability service centres. Comments indicated that there was a need for 1) more services, 2) different services to respond to pandemic conditions specifically, and 3) continuity of services. These comments indicated that many students' mental health needs were not being met during this time. For example, they indicated that it was difficult to access the counselling during this time. There were many suggestions for different services and resources that were needed in response to the pandemic. Desired services and resources included: emails regarding available health, wellness, and online therapy options; continuation of free counseling that was previously available on campus; more accessible and free online counseling; better availability for counseling; a counseling helpline; online seminars or courses on aspects of mental health including anxiety management and coping with loneliness; psychological testing; and group support meetings or group therapy "where we can all talk or do some kind of activity together". Additionally, responses indicated the need for continuity in counselors, (i.e., not having to meet with a different counselor each time).

Continuity of services was needed in other ways as well. Respondents indicated that services and accommodations normally offered on campus had been disrupted during this time, to the detriment of their mental health and coursework. For example, one respondent shared a story of having their accommodation request ignored: "I had a request for disability accommodation for ADHD ignored. It wouldn't have happened if classes were on campus. I'm really embarrassed about needing accommodations so I didn't follow up on it". Similarly, another shared difficulties not normally experienced:

> Due to chronic migraines, I could not easily access any of my class material because it was all on a screen, nor could I access my usual medical treatments due to COVID shutdowns. My university made it extremely difficult for me to get accommodations and eventually incompletes for my classes. For much of the semester in shutdown I was under significant stress and thought I would not be able to graduate at this college due to my inability to complete essential courses without my usual accommodations.

Another respondent shared: “I was denied a psychiatry appointment I had scheduled before we left campus with student health. Because I had not yet had an appointment, I therefore could not receive medication for my anxiety which was heightened due to the extreme life change”. And still another lamented that, “It was difficult to accommodate tests for people with disabilities that allow them to receive accommodations”. These comments indicated that counselling and disability centres need to work on adapting their services to meet conditions of the new normal.

3.4 Other Stakeholders

The final category of comments concerned other groups of stakeholders not referenced in the above groups. These groups included financial aid, health centres and gyms, on-campus housing, student employment offices, and others. First, a large number of students were unhappy with how quickly their universities shut down. Students reported being forced to leave campus housing with only two days’ notice and never being allowed to return to collect their belongings after that. Second, many comments indicated need for direct monetary support or grants to support students financially. Students found themselves unable to pay for food, rent, relocation costs, or access to therapists once free access on campus was no longer available. Relatedly, there is a need for changes to financial aid polices in light of the pandemic. Primarily this is due to changes to expected family contribution, which is used to determine need. One student explained: “Because of the pandemic my family will require aid next year but the financial aid office said that they would only look at the 2018 financial year which means we will not qualify for aid.” Also related to those financial challenges, the fourth theme in this category was an expectation that tuition and fees should have been lowered and/or refunded. This included fees for services that were no longer accessible, such as gyms, student union buildings, room and board, and parking passes, as well as lowered tuition for “lower facilities and learning”. Fifth, many students needed access to healthy food to help address food insecurity. Less common, but mentioned, needs included gyms offering virtual exercise programs, creating more remote jobs for students who previously worked on campus, domestic abuse support, providing PPE to keep students safe, better access to tutoring/support services, and offering ways to keep people connected or engaged with online social activities. As one student summed up: “It would have been useful to have resources that could have made up for what we are missing since not being on campus (food security, gym access, internet access). Some people’s lives were flipped upside down due to this, and the university made minimal effort to help the affected people”.

4 DISCUSSION

We recognise that students were not the only group negatively impacted by the pandemic. Changes to home and work lives were stressful, disruptive and traumatic for many university staff as well. Most employees did the best they could under the circumstances, and challenges were to be expected because no one was prepared for this. Nonetheless, the data revealed that there are many actions within university control that can and should be improved going forward. Improved responses are needed not only for academic success, but also for engineering students' mental health, which is a persistent challenge, and which the pandemic made worse in some regards [6], [9], [10]. Perhaps most notably, findings revealed that decisions need to made with greater empathy toward students' changed and differing situations. Additionally, findings revealed that some actions, perhaps taken in order to be empathetic, did not actually benefit some students in the ways intended. For instance, although instructors may have decided to switch regularly scheduled live class meeting times to asynchronous videos in order to accommodate differing time zones or changed student obligations, some of our respondents wished that normal class schedules had been maintained. Looking to countries, such as Australia, with longer histories of extensive online engineering education programs could prove useful for understanding how to better conduct remote labs or accommodate testing requirements for those with disabilities.

While some of the resources and actions students wanted may initially seem unrealistic, rather than dismissing them out of hand, it would be worthwhile to invest in creative solutions to the problems—if the goal is to retain and support a larger number students. For example, while still honouring contracts and payroll commitments, are there ways in which fees for services that are no longer operating could be redirected to better support students in new ways? Finding ways to best support students through these realities could mitigate the negative cyclical impacts of attrition. Loss of students has had detrimental impacts on universities' budgets; programs, staff positions, and even entire departments have been eliminated and furloughed. During such times, finding new and creative ways to support students financially may seem out of the question. However, if they *are* supported fewer may leave and budget impacts ultimately lessened. This is a cyclical problem whereby if those supports are not provided, students will be lost, which will further decrease revenue.

It is also important that instructors and administrators rethink and counter the myth of the "ideal" student when making pandemic-related decisions. Prior to this pandemic, engineering education was structured for the "ideal" engineering student who was tacitly assumed to be "White, male, between the ages of 18–22, on campus and without major obligations such as full-time employment or family care" [11, p. 24]. Such assumptions about students disadvantage those whose lives are outside the idealised model of what an engineering student should be. Given the changes caused by the pandemic, some aspects of this idealisation need to be highlighted. It is important that university staff not operate on the assumption that their students have safe and stable home lives, reliable housing, food, reliable internet and technology access, no children or family obligations, and the same income, resources, and healthcare they had on campus. Our findings showed that many students do not fit this “ideal” student myth.

5 CONCLUSION

In response to questions about their universities’ handling of the COVID-19 pandemic, engineering students identified a wide range of stakeholder groups whose actions could have been more helpful. Responses indicated that instructors and academic administrators had the biggest role to play, but also that various student services could be improved. By way of conclusion, we offer the following recommendations for US institutions. Applicability to other countries will necessarily vary. **Instructors should:** not make students do more work than usual, and consider assigning less; adhere to scheduled timeslots for classes and exams; ask “Am I making this decision based on the myth of the ideal student?” If so, make a more inclusive and empathetic decision; find ways to respect disability accommodations students are entitled to; and not overly-rely on YouTube videos to teach class. **Academic Administrators should:** enforce the above recommendations for instructors; develop a plan for future transitions to online learning that ensure staff and students have the technology they need, including for remote labs; during times of crisis, consider requiring empathetic changes to grading policies (e.g., universal pass/fail); coordinate instructional decisions at a departmental or college level rather than leaving up to individual instructors; and learn from other countries and institutions with more experience with distance learning. **Counseling Centres should:** maximise continuity of services and providers; create new online group therapy/support groups offerings; offer all existing appointments remotely where allowed by law, or develop strategic partnerships with counselling centres in different regulatory regimes to ensure wide availability of service to students; and create courses/programs for supporting mental health. **Disability Service Centres should** work directly with instructors to help them find ways to accommodate disabilities for online learning and testing, and create new ways of testing for and documenting disabilities that can be done remotely. **Financial Aid Offices should** change any policies that are based on income from before the pandemic to be based on current income. (We recognise this may require changes at the national policy level first). **Other stakeholders should:** redirect or refund fees for services that are no longer being offered; create ways for providing food that was previously available on campus; identify new opportunities for remote student employment to replace on-campus jobs; and identify ways to transition on-campus services to remote options.

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DISTANCE AND HOME LABS – WHAT DO THE SCIENTIFIC LITERATURE SAY?

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ABSTRACT

Labwork is usually seen as an essential element in engineering and science education. One, of the many purposes, with labwork is to strengthen, develop and deepen students' understanding of real phenomena (i.e., objects and events) and the connection between real phenomena and theoretical models and theories. Another main purpose of lab work is to develop students' abilities to collaborate in experiments and empirically investigate and describe technical systems, natural and technical objects, and natural and artificial phenomena.

In connection with distance learning, it is in general a challenge to design labwork in a good way so that the intended learning outcomes mentioned previously are achieved. This does not only apply specifically to the situation with “forced distance teaching” that has arisen in connection with the COVID-19 pandemic, but generally applies to all kinds of “off campus” teaching and learning.

I have carried out a comprehensive exploratory review of what is reported in the science and engineering education research literature regarding laboratory work conducted as distance labs or as home labs. In my paper I will present initial results from my literature review. I have found that there is, indeed, a quite substantial literature describing remote labs and online labs. However, with few exceptions, the literature is mainly focused on the technical aspects of remote labwork and less on the pedagogical aspects. In addition to various forms of "online" labs and remotely controlled labs, I will highlight different forms of home labs and labs with low-cost equipment as an interesting option.

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1 INTRODUCTION

1.1 Labs in engineering education

Almost 80 years ago, Müller [1] argued that “there is little evidence to show that the mind of modern man is superior to that of the ancients. His *tools* are incomparably better” (my italics). He reminds us “that the history of physical science is largely the history of instruments and their intelligent use” (ibid.). Indeed, the laboratory is seen as having a “central and distinctive role” in science education [e.g. 2, 3] and as a learning environment that “sets science apart from most … subjects” [4].

As a result labwork is usually seen as an essential element in engineering and science education. 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 [5]. The aim is that 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].

The use of laboratory learning activities in formal instruction in science and engineering is intimately related to technology-enhanced learning. In recent decades there has been increasing interest in “technology-enhanced learning”: i.e. the use of new technologies to support the learning in science and engineering. Kyza, et al. [8] have suggested that learning technologies that support meaningful learning in science can be categorized as: a) *scientific visualization tools*, b) *databases*, c) *data collection and analysis tools*, d) *computer-based simulations*, and e) *modelling*.

A common question in the context of technology-enhanced learning and lab instruction is if “computer simulations can replace real experiments”? However, the results from earlier research contrasting similar labs using real versus virtual environments have been contradictory. Some studies have reported better learning results with simulations [9, 10], while other studies have reported that there is a risk that simulations become a world in itself and that students’ do not develop links between theories and models to objects and events in physical reality [11, 12]. However, recent findings indicate that combinations of real labs and virtual labs or real labs and computer-based modelling provide better learning outcomes than either option alone [13-17]. Moreover, engineers need to work with real, complex, systems, non-linear effects, and non-idealized components [18, 19]. Such systems might not easily be modelled using basic laws from science and thus an engineer need to have competence to empirically investigate the behaviour of real systems.

1.2 Labs in distance learning

In connection with distance learning, it is in general a challenge to design labwork in a good way so that the intended learning outcomes mentioned previously are achieved [20-24]. This does not only apply specifically to the situation with “forced distance teaching” that has arisen at many universites world-wide and in connection with the COVID-19 pandemic, but generally applies to all kinds of "off campus" teaching and learning.

As I am writing this paper we do not yet know how fast and effective the present COVID-19 pandemic can be controlled and stopped world-wide or if some mutations will reduce the effects of (mass-)vaccinations. What we can anticipate is that in some future mankind will experience the outbreak of some, yet unknown, pandemic. Moreover, it is worth noting that not only outbreaks of pandemics and diseases, but also natural catastrophies, fires, and other disturbances can result in a need for rapid change to distance teaching (see, for example, Potgieter et al. [25]). Thus universities need to be prepared. There is also a general interest in society to increase access to higher education through distance education and in this context it is a challenging task to design learning environments that also includes the learning students usually get through labwork and similar practical experiences. In this context the term MOOL (Massive Open Online Lab) have been coined [e.g. 26]).

The demands and challenges mentioned above have lead to the following research question: What is reported in the science and engineering education research literature regarding laboratory work conducted as distance labs or as home labs?

2 METHODOLOGY

2.1 Literature search and review

To answer the research question I searched for articles and book chapters using the Scopus database using search terms such as, for example, "remote lab", "distance education" AND "lab", "home experiment", "'take home' lab". Different synonyms were used and, for example, "experiment" and "practical work" were used as alternatives to the search term "lab". The title, abstract and keywords of papers were searched and aone limitation was that papers needed to be written in English or German. Another limitation was that the subject area was restricted to subjects typically taught at schools of engineering, i.e. papers related to engineering sciences including material science, physical sciences (physics and chemistry), and environmental and earth sciences. As I were interested in (practical) labwork mathematics were not included and to get a more manageable number of hits pharmacy, medicine, and health and life sciences were not included in the search although I know that there exist interesting publications in these fields. Although online labs can be adapted to learning in a distance mode I deliberately did not include online labs in my search string. One reason for this is that currently the publication of a special issue of European Journal of Engineering Education targeting online labs is in progress and another reason is that I wanted to focus on distance labs, i.e. labs not conducted by students' while on campus, and thus my search terms would probably catch those papers that describe online labs for the purpose of distance learning. I deliberately did not put any restrictions on year of publication in effect as I wanted to able to find older papers describing at home labs using simple materials as these could still be relevant.

The main body of the search was performed in May to mid July in 2020 with a supplementary search to find recently published papers performed May 2nd, 2021. Hitherto, the search in Scopus has yielded 513 documents (of this total 73 papers were found in the additional search in early May, 2021, i.e. they were indexed in Scopus in the period July 19, 2020, to May 1, 2021).

In the first stage the titles and the abstracts of papers that were found in the search were read. Papers that apparently did not match the research question were excluded at this stage. For example the search term "home lab" also found papers that included the phrase "*smart home* lab" (or similar) in their title or abstract, i.e. (research) labs that were investigating the design and properties of "smart homes" and not labs for education. Although outside the research question, papers focused on school level education (and not higher education) were included in this stage as it could not be a priori be ruled out that such a paper could contain useful ideas.

The papers that remained after this initial screening and could be accessed in full through Linköping University Library were downloaded for a first skim reading of the full texts of the papers to get a first, exploratory, overview of the material. In this (skim) reading it was noted (to the extent information was available in the paper) the topic of the lab, the type of lab, the equipment and technology used, the target audience, the pedagogical design, experiences, and resulting student learning were noted. As this conference paper report a work-in-progress I will in the following not report any quatitative analysis of the material as the analysis is not yet completed. Instead I will as a result of my initial exploratory review in the following section report my general findings and observations from reading the papers. I will also, as examples mention some papers from my literature search.

3 RESULTS

3.1 Types av labs and categorisation

Somewhat simplified, laboratory work can be seen as divided into those that are carried out in the form of a simulation and/or modeling "virtually" and those that are carried out by observing some "real" phenomenon in reality. For the sake of simplicity, I disregard here that it can be successful for the sake of students' learning in laboratories to combine computer simulations with real measurements (cf. [13-17]). Moreover, students' access to the resources or equipment essential to carry out a lab can either be local or remote leading to the typical categorisation and types of labs displayed in Table 1 [27, 28].

By equipment and resources is meant the equipment or resources that is critical to carry out a *particular* lab. For example, in a *distributed virtual lab* students typically access a specific, dedicated, webpage through a webbrowser to run a simulation of some specific phenomena. They still need to have local access to a computer, a tablet, or a smartphone to run the simulation (not all simulations will run on any hardware) and they might need a computer or a tablet to write a report. In a *local virtual lab* the simulation or the modelling is can run locally, "off-line", on students' (or the lab rooms') computers (or tablets/smartphones) and access to internet is not necessary. As more and more resources are placed in the "cloud" I would argue that the distinction between local and distributed virtual labs are becoming more and more blurred. Indeed, both local and distributed virtual labs are commonly referred to as online labs.

Table 1. Types av laboratory experiments (Adapted from [27, 28])

Nature of lab equipment and resources	***Students' access to essential equipment or resources***	
	Local access	*Remote access*
Physical (real)	*"Hands-on" Lab*	*Remote Lab*
Virtual (simulated / modelled)	*(Local) Virtual Lab*	*(Distributed) Virtual Lab*

In a remote lab students control and collect data from an experiment carried out with real, physical, equipment on some remote location (i.e. not in the same room as from where the experiment is controlled). This remote location can be everything from nearby on the same campus to be very far away and even in another country. Typically, but not always, the experiment can also be observed through some camera while running. As with distributed virtual labs students still need a (local) computer to control the experiment, to receive data from the experimental results, and to analyze data. In a "hands-on" lab the experiment is carried out by the students in immediate vicinity and control. It is important to note that nowadays the experiments in "hands-on" labs often are controlled by a local computer and measurements are carried out digitally by sensors or equipment connected to a computer.

One observation from reading the literature is that terms quite often are conflated. I have already mentioned that the term "online" often is used for both local and distributed virtual labs. Another conflation is the use of "virtual" for both virtual labs and remote (real) labs. "Digital" is sometimes used to distinguish virtual labs and remote labs from hands-on labs. However, heavy use of digital tools are common in hands-on labs and the term "digital" is used when one mean distance education or distance meetings.

To avoid confusion when discussing labs in distance education (in the following I also include "distance mode" in this category) I will use the categorisation I have proposed in Table 2. The types of labs in the right column ("remote access") in Table 1 can easily be interpreted as the types of labs appropriate for distance education. However, as will become evident in the following, I (and the literature) claim that all types of labs in the grey area of Table 2 should be considered for labs in distance education (Traditionally, in distance education, students have also travelled to a university campus for a concentrated, hands-on, lab-course. However, this has for many reasons been cumbersome [20] and in the time of Covid-19 not appropriate).

In the following, I will briefly describe (preliminary) observations from my exploratory literature review.

Table 2. Proposed categorisation of labs for a discussion related to distance education. The labs relevant for distance education is marked by a grey background.

	Students' location			
	On Campus		*At home*	
Nature of lab equipment and resources	***Students' access to essential equipment or resources***		***Students' access to essential equipment or resources***	
	Local access	*Remote access*	*Local access*	*Remote access*
Physical (real)	*"Hands-on" Lab*	*Remote Lab*	*At home lab*	*Remote Lab*
Virtual (simulated / modelled)	*(Local) Virtual Lab*	*(Distributed) Virtual Lab*	*At home Virtual Lab*	*(Distributed) Virtual Lab*

A general challenge in distance education, regardless of type of lab, is that students are much on their own in labs and that fruitful collaboration is much more difficult to achieve. Much of the learning gains in successful, on campus, laboratory learning environments have been attributed to students' shared experiences, discussions and collaborative work [5, 29].

3.2 Virtual labs

Virtual simulation and modeling labs can be relatively easily (technically) performed remotely and there is a fairly extensive literature [e.g. 30]. However, there may be requirements for what computer equipment the students have and there may be problems with licenses that do not allow programs to be installed on students' computers or to be run outside the network of the university. This can be circumvented by using students' computers as a remote terminal, but is somewhat cumbersome. A further complication is that all students do not have access to a fast internet connection. In physics in particular, there are ready-made programs and modules that have been developed especially for teaching purposes [31], but even "professional" programs such as Matlab, Simulink or Circuitlab can be used to advantage. As mentioned earlier the literature presents conflicting results regarding students' learning when participating in virtual labs. Above all, it is pointed out that there is a risk that the simulations will become a "world in itself" with little or no connection to reality.

3.3 Remote labs

There is also fairly extensive literature for remote labs [e.g. 32-38]. In addition to descriptions of projects where several universities have merged around remote-controlled multi-user and multi-experiments laboratory work, there is rich literature that describes how remote control can be created with relatively simple equipment such as Arduino cards. With a few exceptions, however, the focus in the literature is on technical aspects and not on pedagogical issues. The resources (material and personnel) required to build and maintain systems are often not clear. In addition to the pedagogical issues and maintenance of systems mentioned challenges to solve in connection to remotely-controlled labwork are scaling, communication protocols and the lack of standardization.

3.4 At home labs

As a curiosa it can be mentioned that the oldest paper I found in my literature search was one from 1938 in which it was described how a chemistry lab could be built in ones home [39]. However, at home labs are less well described in the literature. At home labs can roughly be divided in three categories: Labs that can be performed with simple materials, labs that utilize the inherent capabilities of modern digital tools such as smartphones and tablets, and labs that utilize low cost digital equipment.

There is a lot of older literature that describes labs that can be performed with simple equipment and with simple materials that are available at home, in everyday life or in the environment [e.g. 40]. There are publications that are aimed at higher education, but mainly the literature is aimed at children and young people of school age or younger. In my opinion, however, this literature is worth studying to get inspiration for suitable experiments that can be adapted to courses at university level through requirements for a different and more advanced analysis of studied phenomena. In addition to the older literature it seems that the forced distance mode have led to the revival of at home labs using, for example, using commonly available materials and resources for physics [41] or turning the kitchen into a chemistry lab [42, 43] or into an electromagnetics lab [44].

The development of increasingly advanced digital tools that at the same time have fallen in price enables home laboratories of a different type than before with more advanced measurements and data processing. Various smartphones such as the iPhone and surfboards such as the iPad contain a built-in camera and built-in sensors that can be used for laboratory work. In my literature study, I have seen that there are constantly examples of new ways to use smartphones and surfboards [45, 46]. In addition to the built-in sensors in smartphones and surfboards, there are sensors and measuring equipment that can be connected to these via Bluetooth. In this way, laboratory work can be carried out that previously required a computer.

The digital evolution has also led to the development of specific measurement equipment that is now available at an affordable price – some technical universities have developed boxes with affordable equipment they allow students to borrow for their own use or buy it [47]. I have already mentioned that Arduino cards have been used to control remote labs. Such cards can also be used for home labs and there is some literature describing this [48]. Other examples are Digilent Analog Discovery which is a small interface (dimensions approximately 8 x 8 x 2 cm) that is connected to a computer's USB input and has the ability to function as an advanced signal generator and a multi-channel oscilloscope with spectrum analyzer among other features and is therefore suitable for laboratory work in electrical engineering [49]. Another example is iOLab which is a small trolley (3 x 7.5 x 13 cm) that not only has built-in sensors (position, speed, acceleration, force, rotation) that make it suitable for mechanical experiments [50], but it also has sensors for magnetic field, light, sound, temperature, pressure and voltage. Communication with the host computer takes place wirelessly. The literature for Digilent Analog Discovery and iOLab is more limited, but there are already examples of iOLab being used with good learning outcomes (according to concept tests) in distance physics courses [50].

4 SUMMARY AND DISCUSSION

In summary, there is fairly extensive literature on remote labs and "virtual" labs that can be used for inspiration. However, the focus is more on technical aspects than on the learning and pedagogical aspects. There is an uneven distribution of subjects with most publications related to teaching in electronics, control theory, mechatronics and physics. For distance labs, I would suggest that it is even more important to think through what purpose and intended learning outcomes you have with a lab and focus the design of the lab on that. Moreover, the literature indicates that the pedagogical design of laboratory work is more important than the technology itself and that the costs of developing good laboratory work and maintaining equipment for remote-controlled laboratory work should not be underestimated.

Personally, I think that labs utilizing low-cost equipment (such as Digilent, iOLab and similar that students can borrow or own is something we will be of increasing importance and something we will see more of in the future. Such equipment is also of value for campus teaching as it gives students the opportunity to work outside scheduled labs. Such equipment also provides flexibility to meet different developments of the current pandemic and (possible) future pandemics. Finally I note that labs using such type of equioment will enable students to work “by hand and by computer” [cf. 51]. Indeed, it corresponds to the “*postdigital* perspective [in education], in which the digital makes up part of an *integrated totality*” argued by Fawns [52]. I.e. a totality in which digital as well as analogue technologies and tools have its place as well as human senses and embodiment.

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ACTIVITY-BASED COURSE DESIGN AND THE ROLE OF LEARNING ASSISTANTS

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ABSTRACT

The context for this study is the course *Introduction to Analog and Digital Electronics* piloted during the autumn semester 2020 with 120 first year students. Through the use of observations and interviews, we explore how the use of learning assistants can help in the design and co-creation of learning environments that explicitly support students in their individual development of reflective skills in large first year engineering courses. Grounded in the qualitative analysis of the empirical material and the literature, we argue that activity-based course design in combination with the use of learning assistants can be an important element in engineering curriculum development.

1 INTRODUCTION

For engineering students to be able to solve problems in their future profession, it is essential for them to be able to actively participate in and experience engineering practices during their education and connect these experiences to theory [1]. In this process of learning from experience and integrating it with theory, it is essential that students engage in reflective practices [2]. Building on Dewey's work [3], we argue that learning is a continuous reorganization, reconstruction and transformation of experience, and that reflection is a meaning-making process that helps students to move from one experience to the next with a deeper understanding of the experiences.

It is, however, important to notice that not all students will automatically engage in reflection, and it has therefore been proposed to frame and integrate reflective activities explicitly within courses [4]. Engaging in reflective activities right from the beginning, when entering higher education, emerges therefore as an important goal in the re-design of engineering curricula. A major hindrance for these efforts is the large number of students in typical first year engineering courses. This leads to the question of how to design and create learning environments that explicitly support students in their individual development of reflective skills [5] in large first year engineering courses.

In this study, we will approach this question and explore how the use of learning assistants (more experienced students) can help to overcome some of the limitations regularly experienced when integrating reflective activities in large courses. In our analysis and discussion, we draw mainly upon the qualitative analysis of interviews with both students and learning assistants, as well as the research literature on learning environments and course design.

2 RESEARCH CONTEXT AND DESIGN

The context for this study is the course *Introduction to Analog and Digital Electronics* (ADE) planned for approximately 700 first year students in electrical engineering, computer science and communications. A pilot for 120 students was given during the autumn semester 2020. Through activity-based course design, the course aims at combining the planned and predictable from lecture-based teaching with the exploratory and participatory from problem-based learning [6].

At the heart of this approach are recurring 3-hour long *Experience – Reflect – Practice* (ERP) sessions. Over the period of a semester, the students have 20 ERP-sessions and each session contains a mix of different activities like practical experiments, theoretical reasoning and calculations. Students are encouraged to work in groups in a large designated open work area suited for collaboration, but those who like to work on their own are allowed to do so.

Instead of traditional lectures, each ERP sessions is preceded by a classroom assembly. During this maximum 45 minutes long assembly, teachers will take up themes that have been identified as difficult during the previous ERP session, as well as provide some framing and information for the coming ERP session. The topics for the assembly are generated during weekly meetings between learning assistants and teachers and are based on recurring questions and challenges they have encountered when interacting with the students. All activites were mainly done physically at campus, but with the possibility of following digitally if necessary.

When it comes to hand-ins, the students deliver individual reflections focused on the activities they participate in once a week rather than solutions to an assignment or lab report. To allow for facilitation and support of all students, learning assistants take an active role in the course [7]. They support the students during the ERP-session and have individual meetings with each student every other week to discuss the students' reflections and progress from the two preceding weeks. There were 8 learning assistants involved in the course, which comparable to similar courses at NTNU and as such resources will not pose a limitation in the implementation process.

To explore the role that ERP-session play in the course design and how the individual meetings are experienced, we used a qualitative research approach. Data was collected through observations of individual meetings towards the end of the course and individual interviews with students (n=4) and learning assistants (n=4). Students were recruited from the entire student population in a self-selected manner. Learning assistants were recruited based on the already recruited students to ensure a match in the student-learning assistant pairs. The interviews lasted between 20 and 50 minutes and were recorded and transcribed. They were conducted and transcribed by Carvajal, who is not part of the teaching team in the course. The interviews were held in the participants mother tongue, Norwegian, and only the sections used here have been translated to English.

For the analysis, the interviews were pooled together and a general inductive analysis approach [8] was used to identify, analyse and describe patterns and themes within the data. The material was read and re-read to explore what role ERP-sessions play and how they are experienced. Through this iterative process, we identified different themes that emerged from the interviews. These themes were further explored by considering relevant literature and using it as an additional perspective to develop and deepen the analysis. In this study, we will focus on two themes from the analysis: course design and individual meetings. In addition to the interview data, we draw upon some quantitative results from an end-of-year survey given to the students in the course (n=45).

3 RESULTS

From the survey, we observe that most students appreciate the design of the course, 96% of the respondents answer that they are overall satisfied or very satisfied with the course. The students were also asked to assess the degree various activities contributed to their understanding of electronic systems. Here, 87% reported that the *ERP sessions* to a large or very large degree increased their understanding; 84% reported this for *interactions with peers*; and 87% for *interactions with learning assistants during the ERP-sessions*. With regard to *interactions with learning assistants during the individual meetings*, 56% said it had to large or very large degree influenced their understanding, and 23% reported little or very little increase in understanding.

Based on the interviews, we will in the following section focus on the students' and the learning assistants' experiences with the activity-based course design and the individual meetings between student and learning assistant.

3.1 Course design

From the interviews, it becomes clear that the students and learning assistants are aware of the course design and its connection to their learning. Furthermore, the students state clearly that they prefer the structure of this course compared to their other course which have a more traditional design. From their point of view, their involvement in the discovery and exploration through the ERP-sessions contributes greatly to their learning:

> «I think it is absolutely brilliant really! I wish that all my courses were like this, because I felt that I was left with new learning after every single session, and it may sound quite strange that you do not do that in all the courses, but there are many courses I in fact feel that you are not left with leaning after each session. But, here it was like something new and you were part of the whole process itself. So for me at least it has been a really good way to work» (S4).

The students point out that it is important for them to take ownership of their own learning and to participate in discussions:

> «I have not had any courses that are organized in the same way, so much self-learning or like you have to experience and learn from. I really think that a lot of people have been content with it because you have room for discussions and can experience things yourself as well» (S2).

By situating active experiences of electronic phenomena at the center of the course, the students' curiosity is stimulated giving them the opportunity to think about their own questions, resulting in reflections where experiences are related to theory:

> «[...] in ADE I feel that it has been sort of like « why does the current go there? » *and then we get an explanation for it and then «ok, but that make sense » and then I remember it. So, I really think that the course has suited my curiosity very well*» (S3).

While many courses aim to foster independence and reflective approaches with respect to content, the learning assistants report that this course motivates students to reflect regularly on their own learning processes in addition to the content:

> «Because it is not something you just say, *«We will teach you to reflect, and that it is important that you become independent, and that you think about what you can and what you cannot», all the course coordinators says that regardless, if you ask them. But here it actually becomes a task for the student to do it, be set to reflect, and you have to do it once a week*» (LA4).

Through further comparisons with courses with similar content but different designs, it becomes apparent that the students believe that learning through experiences facilitates the entire learning process and leads to more understanding. To some degree on the expense of rote theory memorization:

> «I really think it is interesting. And I like the way it is organized, because the difference in relation to other courses that are quite the same is that we learn more, it makes it easier, one

> understands it in a more practical manner. While others may learn even more theory and knowledge about the things, but they do not understand the why» (S1).

This is echoed by the learnings assistants, who also highlight that the students have learned a large amount of theory without realizing the extent due to the design of the learning experiences:

> «And then they have learned quite a lot the first year, in fact they have learned a lot of theory, but they have not felt it themselves that they have had a lot of theory, so the course has been altered... it has been done in such a way that they feel that things are going well and that they understand things, even though there is a lot» (LA3)

As the course is organized around activities with an extensive support system through collaboration with peers and the learning assistants, students who cannot or do not want to participate in the course at campus can find the course more difficult than their peers. Participation is a key factor of the learning process in this course and the students recognize this clearly:

> «[...]If you are not sitting in [the working area] when you are working with it, where one kind of has access to all the learning assistants and resources, then it was quite difficult to work with the subject. [...] » (S4)

Overall, the students and learning assistants emphasize that the course design facilitates the students' learning and development of knowledge and understanding through a focus on discovery, exploration and a support system of peers and learning assistants.

3.2 Individual meetings

An important part of the support system mentioned above is the obligatory individual meetings between student and learning assistant. While collaborating in small groups with their peers can be beneficial with regard to both motivation and understanding, the students can choose to not ask their peers questions due to concerns that they will slow down the progress or reveal a lack of knowledge, thereby losing some of the benefits of the collaboration. The individual meetings with the learning assistants, on the other hand, provide a dedicated arena for students' individual needs and based on the interviews and our experiences it appears that they are comfortable asking questions without considering the needs of their peers in those meetings:

> «The greatest learning outcome is probably getting things explained until you understand them. Because when you are working, it is quite normal to just understand things halfway and then one wants to move on, you do not want to be the one that linger or halter the work. While here you have a quarter of an hour of conversation that is only devoted to your competence, so you can ask until you receive the answer you want or you understand it. So, that is perhaps one of the best things about those conversations in relation to groupwork» (S1).

This is supported by the learning assistants who experience the individual meetings as a safe space for the students, where the student can ask questions freely as only the learning assistant and student are present:

> «They can talk to someone in private because some might feel that is a bit embarrassing to say that «*I did not understand this*» in front of the other students and then they have... I think

> that a big benefit of them being able to come and ask us questions in a confined manner is that there is only one person that are listening» (LA3).

To succeed as learning assistants, they must have the skills to create a safe environment and at the same time be knowledgeable enough to meet the students' expectations on the course curriculum. This is noticed by the students who report, when comparing experiences, varying levels of competence among the learning assistants:

> «I find it very nice to be able to ask someone who knows it a little better, but unfortunately there has been a big difference between the learning assistants, because some know both the inside and outside of the course, while others are a little like that they do not completely understand all of the principles» (S1).

Similarly, from the learning assistants' perspective, the usefulness of the individual meetings was greatly influenced by the student's preparation and motivation, which differed from student to student:

> «Some students were very engaged and prepared, had a lot of questions and got a lot out of the conversations. And others, they did not have anything with them, they did not have anything they were wondering about, something that made it very difficult for me to try to figure out what they were thinking about» (LA2).

As a result of these differences between the students, the learning assistants explained that they developed different strategies to handle the diversity in the student population; asking questions to lead the students into discussions or reducing the time dedicated to the meeting:

> «But then I started asking different kind of questions to try to get them started. And now it is not like I must force them to have a conversation, if there is nothing to talk about then there is no point anyway»(LA1).

The ability to guide the students through these conversations is an additional skill required by the learning assistants in their role in this course. This along with the ability to create a safe environment and a mastery of the course content results in high requirements placed on the learning assistants. This is also reflected upon by the learning assistants themselves, who identify the importance professional self confidence in this role:

> «You have to have professional self-confidence, or at least confidence, to keep doing it this way, because having to ask questions...to ask the correct questions, be curious and such, requires that you also have belief in your own skills and certitude that you actually know this, otherwise it will be very difficult» (LA4).

To summarize, the individual meetings fill an important role in the course design. These meetings give the students an arena where they can fill the gaps in their understanding. By using learning assistants as facilitators, it is possible to use activity-based course design in courses with many students. However, the effect of the individual meetings is highly dependent on the mindset of the student and the competence of the learning assistant, which is reflected in both the interviews and survey.

4 DISCUSSION

From the survey and the interviews, we see that the activity-based course design appears to support students in their learning process. The survey shows that a large majority of the respondents were satisfied with the course and that the organization supports their learning. While the students interviewed were recruited through self selection, and therefore might have a bias, we believe the results of the survey support the findings from the interviews and allow us to use them to explore the effects of this course organization further.

By situating the ERP-sessions at the center of the course, instead of lectures or written material, the students become curiosity driven and are required to continuously reflect on their own mastery. Collaborative work and learning assistants are important elements to address gaps in students learning through discussions with peers or through the individual meetings.

One success factor of the course design, identified by both students and learning assistants, is active participation of the students in the organized learning activities and conscious use of the support structures in the course. Discussions with peers and with learnings assistants are highlighted as important to learning both in the interviews and the survey. Students that do not actively participate will therefore have less opportunities for reflection and potentially learning compared to their peers.

A safe and inclusive learning environment is therefore paramount to allow a diverse group of students to participate in the learning activities and benefit from the activity-based course design. To co-create this type of learning environment requires a particular focus on the social dynamics between students, between students and learnings assistants, as well as the physical learning space. The social environment needs to be based on and embrace values of support, trust, and collaboration, rather than competition [9]. Furthermore, learning assistants and teachers need to act as role models and live these values and emphasize the importance of exploration, discovery and reflection rather than finding the “right answer”. In addition, the physical space needs to be designed in a way that is conducive to collaboration and discussions [10].

As underscored in the interviews, mastering the role as learning assistant in this course requires a professional self-confidence. The learning assistants need to master the course content while simultaneously being able to reflect on their own position as role models who foster a certain type of social learning environment. As this course is planned to be given to approximately 700 per year, the learning assistants must be aware of that they both need to work together to create a supportive learning environment and as a group be independent facilitators as the course faculty cannot follow every assistant closely. Based on the initial empirical findings in this pilot, we are, however, positive that an activity-based course design where learning assistants play a central role is possible and a suitable approach for large first-year engineering courses. By involving learning assistants in new ways, we can overcome challenges and limitations with teaching resources that traditionally constrain first-year course activities.

5 SUMMARY AND ACKNOWLEDGMENTS

Grounded in the qualitative analysis of the empirical material and the literature, we argue that activity-based course design in combination with the use of learning assistants can be an important element in engineering curriculum development. In order to be able to upscale the ideas outlined here and to apply the concepts to other courses, it will be important in the future to gain even more insights into how learning environments can be co-created with students, learning assistants, and faculty, as well as how this affects the learning process, and how the learning assistants understand and develop their role within the course. Finally, we would like to thank all students and learning assistants that have been part of this pilot.

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Towards Stakeholder Specific Visualization of Learning Paths in Software Engineering Teaching

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ABSTRACT

In software engineering and other technology related teaching educators increasingly integrate de-facto online tools into coursework. However, the impact of using these tools is not clearly understood. To this end, this research project will provide a visual dashboard with extensive and stakeholder-specific visualizations to serve the diverse needs of different stakeholders, e.g., teachers, teaching assistants, administrative personnel and students.

This paper reports the results of our initial analysis of what kind of views teachers want to take to their courses and what kind of information teachers see as valuable visualizations on learners' progress. We conducted 17 semi-structured interviews in two universities. The interviews were thematically analysed, giving as results three key themes. The results give a good starting point to create a visual course dashboard. Our study takes a step towards supporting various stakeholders in learning environments through visual means. While the input data, metrics and visualizations are based on the tools used in software engineering courses, we see that several results can be applied to other contexts.

Conference Key areas: Essential elements for the online learning success.

Keywords: visualization, software engineering, software engineering education, online learning

1 INTRODUCTION

Online teaching tools have been utilized in teaching for decades and their potential is widely recognized [1]. Massive Open Online Courses (MOOC) have risen as a method to provide non-formal and informal learning to many [2]. At the same time, the importance of software engineering education has increased because of the constant growth in the need for software engineering professionals. In addition, professionals in many other fields today need basic programming skills. When the COVID-19 pandemic hit, formal teaching was also forced to take a major leap toward online teaching and learning.

The number of courses and the number of participants per course in software engineering higher education today are big. This leads to the teaching staff needing more tools to 1) support a growing number of students and 2) deal with students with heterogeneous backgrounds and motivation. Learning management systems (LMS) such as Moodle, TIM [3] and A+ LMS [4] are used to reduce the teachers' workload by the means of online course material and automation in grading [4, 5] and the students' learning is student-driven and independent of time and place. In addition, the content is categorized so that students who specialize in Information Technology can take more difficult exercises than students from other fields [6].

Already, LMSs combined with professional software engineering tools such as Continuous Integration (CI)[1] and version management tools give the teacher information of the outcome of the students work, but little about the progression of work before final submissions or the students' general feeling and motivation towards learning. Hence, there is a need for more information and several tools - teaching and programming - that can provide that information.

The goal of *VISDOM* project's teaching use case is to provide a visual dashboard that can meet the diverse needs of different stakeholders, e.g. teachers, teaching assistants, admin personnel and students - mainly in the context of online and hybrid learning since there the students are assumed to work more independently. To study educator needs to monitor learners' course progress and learning, we interviewed 17 programming and software engineering teachers in two universities. Our research question (RQ): What kind of visualizations software engineering teachers would like to have? is answered with thematic analysis of the interviews giving three key themes.

The rest of the paper is structures as follows: Section 2 gives the background of the work. Section 3 describes the planning and execution of the interviews and Section 4 gives the results of the initial analysis. Section 5 gives the discussion of the results and Section 6 concludes the paper.

2 Software Engineering Education

The general guidelines for software engineering undergraduate [7] and graduate [8] curriculum are published by Assosiation of Computing Machinery (ACM). These curriculum guidelines specify software engineering education content in terms of elements of skill and knowledge the students should learn, including the software development process. Similarly, the software engineering Body of Knowledge [9] is used when building university level software engineering curricula. While these plan out the thematic content, the teaching methods should support the students' learning as well.

In their systematic literature review Santos et al. [10] identified four approaches to set up innovative approaches in teaching programming, one being project-based teaching practices. They found that students are better motivated when collaborative learning and continuous monitoring are used. However, the study does not indicate any particular use of software development tools to support learning or how information about the learning process and student progress should be shown to teachers or students.

[1]a practice commonplace in software development where members in a software team integrate their work frequently. `https://www.martinfowler.com/articles/continuousIntegration.html`

A gap between industry and teaching [11] has been identified to exist, mainly because of the nature of the software engineering profession; software industry expands to new areas faster than the academia. This leads to problems in teaching, as student projects tend to lack realism, and courses on different topics may be isolated and the connections between courses are not visible enough to students. Software engineering education is also not considered to teach enough soft skills (collaboration and teamwork). Further gaps related to the required skills in industry have been identified in [12]. A large number of students makes it difficult for a teacher to focus on individual issues and provide needed tutoring. To improve learning results and increase the real-world competencies of the students, more comprehensive education setups have been created and used at universities around the world [12]. Such setups pursue to offer the students an opportunity to practice their software development skills in environments and tasks that are as close to typical industrial contexts as possible [13].

A survey on program visualizations in education has been conducted by Sorva et al. [14]. There is a variety of approaches and tools to visualize programming structures and the behavior of software, such as Jeliot [15], Javavis [16] and AnyviewC [17], that are used in programming courses. Visualizations have also been used in teaching project management. There the most common visualizations used are Gantt charts showing the project activities such as those presented by Vanhoucke et al. [18]. Other works have used Gantt charts alongside other visualizations. Deblaere et al. [19] have create RESCON – an educational tool for illustrating scheduling and project management concepts, where they have included project duration curves and resource profiles in addition to Gantt charts. Salas-Morera et al. [20], who have created PpcProject to teach project management, also include visualizations on resource allocations in addition to Gantt charts. Scheduling and resource allocation are also key elements in a simulator developed by Collofello [21], where schedule pressure is visualized with a speedometer.

Matthies et al. [22] used ScrumLint, which enables comparing teams and there progress, to check for process violations on a software project course using Scrum. They only used the tool post-hoc as a way to supplement their survey and tutor-based evaluations of students' performance, but discuss how the tool could be helpful already during the course in showing teams how they are performing. Mäkiaho et al. [23] have developed the MMT tool for teachers to monitor progress in students' capstone projects through a visual dashboard based on manually entered data.

To the best of our knowledge, there are no studies where visualizations would have been used in the context of teaching software engineering processes or project management using real life data from various tools and combining that data with informative visualizations. Furthermore, existing studies have mainly used visualizations to illustrate one particular aspect, such as the duration of the projects or the overall progress. In this research we aim at visualizations that are created from real software development work of students, using multiple data sources and providing useful information to several stakeholders.

3 RESEARCH METHODOLOGY

This work aims to identify, what kind of visualizations teachers would like to have from online and hybrid course work. The study was conducted as a single case study [24] to gain insight on educator needs in higher education. The method was selected as case study research [24, 25] is suitable to study a topic tied to and not clearly separable from its practical context. This is true for higher education learning where teachers have practical experience on the everyday learning in online and hybrid learning.

The case study was executed by interviewing teachers from two universities. The interview questions were iteratively designed by the authors in late May, early June 2019. The authors have extensive experience in software engineering higher education. The goals of the research project as well as knowledge on the state of the art of software development tools was used in designing the interview protocol (interview protocol is online[2]). It's worth to note that the protocol was designed before

[2]The interview protocol:
https://docs.google.com/document/d/1LtRR4GBa_12ZfMDjcv0JotYQrnRSaYM30jfHaYyJXp0/edit?usp=sharing

the COVID-19 pandemic. The interviewees were identified from the universities based on availability, experience and the topic of the courses taught. The courses ranged both undergraduate and graduate level teaching.

3.1 Data Collection

Data was collected through 17 semi-structured interviews of teachers in two universities. The interviews followed the interview protocol and lasted approximately one hour. Two researchers, one conducting the interview and the other taking notes, were present in each of the interviews. Open ended questions were used to ask further questions based on interviewee's answers. The interviews were recorded with consent and the tapes transcribed with professional transcription services. However, one interview is included in the analysis only based on the notes as the interviewee states not wishing the interview to be recorded. From a total of 17 face-to-face interviews, 11 were conducted in October 2019, whereas 5 interviews were conducted between June 2019 and March 2020. The last interview was conducted over Zoom[3] in March 2021 as a complementary interview due to the changed needs for the global pandemic. The interviewee demographics can be found online[4].

3.2 Data Analysis

Thematic analysis [26, 27] was used to analyze the collected data. Data-driven coding [28] was utilized instead of any predefined codes to ensure the interviewee's experiences were represented accurately. The initial thematic analysis was developed by one researcher who went through each interview and coded meaningful segments. A second researcher participated in discussions regarding the codebook's structure to achieve consensus on coding practices. The codebook's validity was evaluated in three rounds by having two other researchers fit a selection of citations to the correct codes. In the first iteration the codebook and 26 citations, two randomly selected for each theme, were assigned to evaluators. The initial codebook was restructured after the first evaluation round based on evalutors performance and feedback. The second evaluation round was conducted with the same logic by providing the restructured codebook with two randomly selected quotes for each theme, overall 18 citations. The second evaluation round resulted in an interrater reliability (IRR) of 0.43, signifying a moderate agreement [29], which was calculated using Fleiss' Kappa [30, 31] as it allows IRR to be calculated for three or more raters. After the second round, the coder and evaluators had a session where coding related disagreements were discussed and resolved. A third round of evaluation was performed with 12 citations, again two randomly selected citations per theme, once the themes were agreed upon by the three researchers. In the third round, the coder and two evaluators discussed their disagreements and the round resulted in an IRR of 0.66, signifying a substantial agreement. The final themes are described in the following section.

4 RESULTS

Six themes were identified with thematic analysis (Figure 1). Each theme had two to six subthemes, denoting different aspects of each theme. However, several themes were not directly related to teacher needs or visualization. Our aim is to work towards extracting a number of metrics for visualizing student progress within software engineering teaching. Thus, we take a data-oriented approach on our results by focusing on three main themes as they best address teacher needs from a visualization viewpoint. The remaining three themes (social aspects and communication in teaching, teaching resourcing, and tooling and the use of data) left out of the scope of this study relate to teaching experiences with communication, resourcing, and the use of tools. The rest of this section describes the selected themes and the visualization opportunities and metrics discussed by the interviewees.

[3] `https://zoom.us/`

[4] The interviewee demographics:
`https://docs.google.com/spreadsheets/d/1Y43zwlLPSSjzoS9S3TZByh6q0pVZWFpEDekgVTgQET8/edit?usp=sharing`

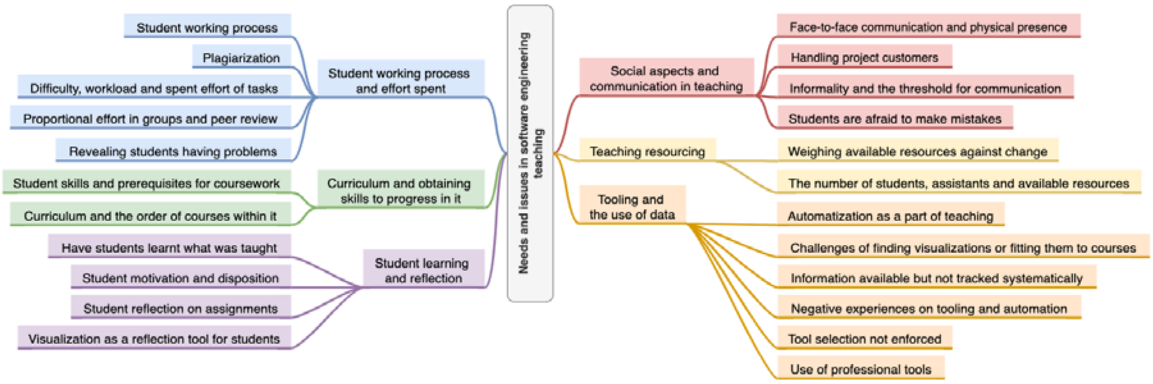

Figure 1: The codebook resulting from the thematic analysis of software engineering teacher interviews. The six boxes originating from the center represent the identified themes, whereas the outermost items originating from themes represent individual codes.

4.1 Theme one: Student Working Process and Effort Spent

The results suggest that software engineering teachers lacked a higher-level view of student or group progress and placed significant interest in tracking the students' working process – what is happening and what is not happening. Several interviewees had come up with different strategies to try to have students work in a continuous manner. In the first stages of a course, teachers were also interested whether work had even begun for groups or individual students. Later on, the interviewees sought statistics and trend-related information about participation and assignment-related points collected by students. Programming related courses often utilized the number and timing of commits in version control system (VCS) as an easy indicator whether actual work was being done. Project-based courses also tracked the ratio of not started, currently working on and done tasks. Several interviewees described they would like to know how points were distributed between students, how student's points accumulated overall during the course, how the points were distributed per week, and how many students were projected to pass the course at given time. Tracking presence in lectures and exercises and the number of assignment submissions also served the interviewees in judging how many students were actively participating in the course.

The findings show that one of the main reasons for tracking student working process and activity was to identify the students, groups or projects having problems or whether some students had stopped working and disappeared from the course. Several interviewees mentioned that they would like to have a tool that allowed them to proactively contact students having problems or those otherwise falling behind. It was also considered important to discover what were the problems students were having. The interviewees felt that such a tool could help them focus their resources in helping those who need it by resolving student issues before they silently dropped out of the course.

The results indicate a clear need to understand how much time students used for each task and that the effort was reasonable. Concrete work-related metrics such as how many students completed specific tasks overall and how much time they used for each task were often used to determine how much effort assignments required from students. Additionally, the time spent on tasks was considered as an indicator of how difficult the tasks were for students. However, it was noted that students tend to report hours in a sporadic manner.

> "I cannot see their working hours. Sometimes they share the Google document, but no. We see them, they deliver it every week, when they collected all the things. Because not every student is recording the hours every day. Before the actual presentation they try to fill up those things. And for me as a teacher, it will be a nightmare to follow all the working hours every day for them."

The results further suggest that the interviewees wished to prevent freeloading in group assignments by evaluating the distribution of work within groups. While programming courses could use commit information from VCS, courses without programming assignments often featured peer review as a method of ensuring fair evaluation for all students. When students were assigned to communicate with each other, the interviewees described that they would like to see statistics about communication activity. These statistics included whether students post their answers on time, the number of comments to peers, how fast comments were made in response and the imbalance of communication between groups. Finally, several interviewees hoped for a way of automatically detecting plagiarization, as currently providing proof of plagiarization was difficult and often a manual process.

4.2 Theme two: Curriculum and obtaining skills to progress in it

The results suggest a need for a higher view of teaching on a degree program level. Teachers felt that collective yearly reports did not provide early or accurate enough information to intervene before students get into problems. Higher level visualizations would allow teachers to be able to gain continuous information, see how students are progressing, and even contact students pre-emptively in case of problems. One interviewee proposed an idea of visualizing degree programs as stories, where students would understand what a software professional would do in different roles, and how courses related to each others as a story towards being a professional developer. Another interviewee proposed a similar solution where the whole degree program would be visualized.

> "But we should get that kind of graph, that here is the, let's say study module, take its course, and show what needs to be in front of it, form just like this chain, that we don't have. But all of the information is there. This could be a great tool for students so that they, we'd show a kind of tree, that here are your courses, and as you complete them the color changes. Here's how you progress. And in this spot comes the bachelor's thesis and like that."

Furthermore, the results suggest that visualizing thesis work as a part of higher-level visualizations would benefit various stakeholders such as teachers, students and university staff. A few interviewees suggested a similar tooling solution that would allow students to report their individual thesis progress on a template, allowing teachers to structure thesis work for students, track their individual progress, see whether students actually worked on their thesis, and increase transparency on estimating realistic graduation dates. Besides reporting progress, students would use said tool to reflect the bigger picture of thesis work and how much work is done and still needs to be done.

The results further suggest that students may lack the necessary skills or knowledge when enrolling to more advanced courses. Interviewees often expected students to have an understanding of topics introduced in prior courses as they were necessary for performing well in their courses. Lacking the required prerequisites is challenging for students as well, as interviewees noted that students without necessary skills tend to silently drop out of their courses without telling anyone.

4.3 Theme three: Student learning and reflection

The results indicate a need to see whether students had learnt what was taught. Correct execution of tasks was seen as one of the simplest indicators, such as whether students were able to complete weekly assignments. For project based courses, a few interviewees discussed that correctly performing the process itself was an indication of learning.

> "That we have different step of the different processes, and then they are able to implement the different step of the different processes. So if we go to requirement elicitation, I just check if we are able to write the user stories correctly, (...) to write them in the correct format, and then if they are able to split them and not to make (-) too big user stories."

Other interviewees discussed essays and learning diaries as good ways to gauge learning. However, some remarks were made that not everyone is capable of expressing themselves in written assignments, making discussions and face-to-face sessions a good way to find out how well students had understood what was taught. Overall, interviewees considered automatic analysis of often free-form qualitative assignments challenging. Both concrete and abstract metrics such as number of sections, length of text and indication of a reflective thought process were proposed to aid in analysis of text-based assignments.

The results further indicate that visualization from a student viewpoint could serve as a reflection tool for students. Examples of this include providing assignment specific visualizations or a visualization where students could benchmark their own progress against others in the same course. Additionally, some interviewees were interested in learning the general disposition of students towards the course. Concrete examples were provided as collecting feedback, checking whether students completed optional assignments and whether they thought the assignments were useful.

5 DISCUSSION

5.1 Visualization opportunities

Interviewees described possible visualization needs and opportunities in two different fashions: 1) detailed descriptions of what kind of data they had or would want to have available to them, and what kind of information they would like to see based on that data, and 2) visionary visualizations to help understand complex and multi-variate concepts such as progression in degree program. We will primarily take a data-oriented focus, in order to extract a number of metrics and envision visualizations based on them.

Tracking time spent on tasks helps understanding required effort to complete tasks, which in turn may help understanding difficulty level of tasks. Understanding the needed effort and difficulty of tasks could also be used to determine whether the required workload from students was reasonable in practice. Visualizing actualized effort would be beneficial both for the teachers as well as for students. Interviewees mentioned that some students had difficulties in understanding and estimating the effort required to complete courses and were sometimes surprised of the required effort.

Tracking succession rate may also benefit understanding how difficult tasks are. Particularly with programming assignments, students may commit several times before their code passes the tests. If the number of commits for particular tasks is significantly higher than on average, it may indicate a more difficult task or that the teacher should address a certain topic more in depth. Similarly, if significantly fewer students submitted answers to a particular task, it could be considered more difficult than others.

Level of participation may be an indicator of commitment towards finishing the course. Some interviewees already mentioned having explored participation and point related data statistically with varying results. Examples of the relationships explored include steady assignment completion, participation in consecutive exercises and the relationship between points and exercise projects and exam. Overall, possible metrics are distribution of points between students, cumulative points and distribution of points over time, and the completion of optional assignments.

Tracking progress and trends would allow teachers to get an overall view of how many students and groups have difficulties keeping up from early on, and also get a realistic idea of the pace with which students advance during the course. Teachers could also benefit from visualizations of student peak activity periods to determine whether students work systematically or in spurts near the end of deadlines. Some interviewees also mentioned that students could be motivated by providing them visualizations that would allow them to compare their progress with others in the same course. Both teachers and students could also benefit from a projection of passing the course with the current trend.

The presented results set the stage for developing software that visualises student progress in software engineering, forming a base for prototype implementations and further research within the project. Combined, metrics for tracking time, success rate, progress and participation could be presented using visualizations. These visualizations could be implemented with a tool that would allow teachers to investigate the visualizations, learn of students in trouble (clear deviations in the visualizations), and be able to proactively contact such students. Lastly, several different viewpoints for framing and interpreting data were mentioned in the interviews such as student, group, course and between courses. This means that each of the presented metrics might look slightly different when viewed from varying perspectives. The interviewees also mentioned teaching assistants, teachers themselves, and staff such as study advisors as potential users (stakeholders) of such metrics and visualizations.

5.2 Threats to Validity

We will consider threats to validity as described by Wohlin [32] and cover the points which are relevant to our study. Conclusion validity concerns the correctness of conclusions drawn, and internal validity concerns threats that may affect the variables with respect to causality. For both the key issues are elements in data collection and analysis. We selected interviewees based on their expertise, availability, and relevance. We had no prior knowledge as to how they would consider the questions or what their attitude would be towards the topic. The interviewees did not volunteer directly (which might give falsely positive results), but they did all individually agree to partake in the study. The same interview protocol was followed for all interviewees. The only difference was that one interview was conducted via Zoom, with an additional question on distance learning.

We also need to consider the threats posed by having the themes validated by authors only. Here the majority of interviews were performed by other authors than the one creating the codebook. Further, one of the evaluators of the codebook was not part of performing the interviews. The validating authors were given the quotes and themes separately and independently, and no indication was given as to how the first author had done the initial mapping.

Construct validity concerns how well the results are generalizable to the concept or theory behind the experiment, and external validity regards generalizability to industrial practice. Our results are not meant to be generalizable over the whole software engineering teaching related field but indicate starting points for further research in visualizing useful information and data for teachers of software engineering. Finally, there are elements common to software projects within university setting and projects in the industry. Having visualizations applicable for multiple stakeholders and environments is also a goal of the research project. However, for the purpose of this study, we are only aiming at results for teaching.

6 CONCLUSIONS

This paper provides a report of our initial analysis on what kind of views software engineering teachers want for their courses and what kind of information they value in following learners' progress. We found that software engineering teachers lack higher-level views for tracking student progress in both course and degree program level. Additionally, our results indicate that software engineering teachers lack tools for identifying and contacting students that are lagging behind or having problems completing assignments. Thus, it is important to create initial metrics that can help teachers towards understanding the required effort and difficulty of tasks, sensibility of student workload and the pace of work. This creates a starting point for further research. Based on the results presented, we are currently building the first prototype implementations of a system that can visualize student progress.

7 ACKNOWLEDGEMENT

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THE IDENTIFICATION OF FUTURE PROFESSIONAL SKILLS FOR THE GRADUATE STRUCTURAL ENGINEER AND THE CO-CREATION OF THEIR DEFINITIONS.

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ABSTRACT

Employers recognise that the future is changing and as such the structural engineer's role is changing along with the skill set required. The skills gap has been acknowledged yet there is no consensus on which skills are most important for these engineers. This research presents the outcome of a project which proposes future professional skills needs for the structural engineer and the co-creation of their definitions. A review of the most recent relevant literature alongside chartership requirements of the Institution of Structural Engineers (IStructE) and Engineers Ireland (EI), as well as consideration of three seminal consultation and analysis reports on the future skills in the sector, led to the identification of 7 skills. These are the traditional, though evolving skills related to communication, technical ability, management and engineering practice as well as emerging skills related to sustainability, technology and digitisation and society. It is accepted, however, that there may be different conceptions of each term, therefore, the presented research describes the co-creation of definitions for each of these skills with undergraduate structural engineering students. The work describes how focus groups were used to engage students in a conversation around the meaning and importance of each skill resulting in specific action orientated definitions for each skill. These definitions will then be used in the next phases of the project which engage the same students in a reflective e-portfolio exercise and structural engineering educators in a review of the programme outcomes in relation to such skills.

1 INTRODUCTION

Third level institutes are increasingly concerned with ensuring that their students develop attributes which will better equip them for the world of work, but also as members of society [1]. This paper presents the methodology and findings from the first work package of a project which aims to "design our structural engineering programme so that students can develop skills which will enable them to become exemplary structural engineers with a focus on the future of our planet and it's people." This work package aims to firstly identify these skills and then co-create their definitions with undergraduate students.

A narrow field of literature was targeted due to the aims of the project being focused on Ireland specifically and professional structural engineering skills as students move to chartership beyond graduation. The identification of skills needed for the structural engineering graduate began with the two Irish bodies which offer chartership in Ireland; the Institution of Structural Engineers (IStructE) and Engineers Ireland (EI). Chartership is essentially a professional registered title, and the requirements for achieving it are different for each body. Under Irish law certain engineering work is reserved for EI chartered engineers. The application process is based on the submission of evidence of learning and experience particularly related to 5 competencies. The IStructE require graduates to undertake a programme of Initial Professional Development (IPD) which is then followed by an interview and intensive examination. The IStructE IPD programme outlines 'core objectives' that applicants for chartered membership must achieve. These competencies and core objectives for chartership were examined alongside engineering academic literature. This built on the previous work by some of the authors who synthesised two systematic reviews of worldwide literature on the topic, [2] identifying communication, teamwork and interpersonal skills as the top most referenced skills in recent literature, followed closely by core technical skills and business acumen. Aspects of each of these skills also need to be evidenced as competencies when applying for Engineers Ireland chartership [3] or core objectives for IStructE chartership [4]. The terminology varies between the sources, therefore“Core Technical Skills”, “Communication”, “Management” and “Engineering Practice” were chosen as the terms to describe the key skills required.

The second area of focus is on the future of the construction industry and emerging needs of the sector. Primarily, relevant aspects of three sources were used, again due to the specific focus on Ireland; The Expert Group on Future Skills Report on the Built Environment [5], Engineering 2020 [6] and KPMG’s 2020 analysis of the construction sector [7]. These were scrutinised alongside the recent proposed changes in Engineers Ireland Accreditation programme outcomes [3] and the new TU Dublin Strategic Plan [9], the university at which the authors carried out the research. These formed the core focus of our study. Looking to the future allowed us to identify several areas of future change which may not have previously been prioritised in structural engineering programme designs nor included in graduate attribute models. They are summarised as:

- Modular, off-site or prefabricated construction/manufacturing [5, 7, 8]
- Environment and Sustainability and/or related SDGs [5-7, 9]
- Diversity and inclusion [3, 6, 9]
- Technological advancements including collaboration techniques (BIM) and digitisation [6, 7, 9]
- Engineering as a business / Commercial Awareness [3, 5, 6]
- Increasing regulation inc. GDPR and other new or tightened standards [3, 7]
- Ethical and societal responsibilities and/or related SDGs [3, 6, 9]

These emerging skills were clustered into “Technology & Digitisation”,“Sustainability” and “Societal” skills for the purpose of this study.

Having examined the literature surrounding specific requirements for structural engineers in Ireland, a synthesis of the requirements can be described as: Technical Skills (including Core Technical Skills and Technology and Digitisation), Non-technical skills (including Communication, Management and Engineering Practice) and Attitudes (including Sustainability and Society) [10]. The seven clusters are identified in Figure 1 which also shows the key themes emerging from each literature group.

Despite describing how the clusters of skills emerged, the authors recognise that there may be different perceptions of each term and any research work which discusses or tests these skills should provide descriptions to reduce the risk of a misunderstanding [2]. This research study takes this concept one step further by not providing definitions created by the authors, but by co-creating the definitions with third year structural engineering students using small focus groups as detailed below. These same students will use these definitions in a later part of the project.

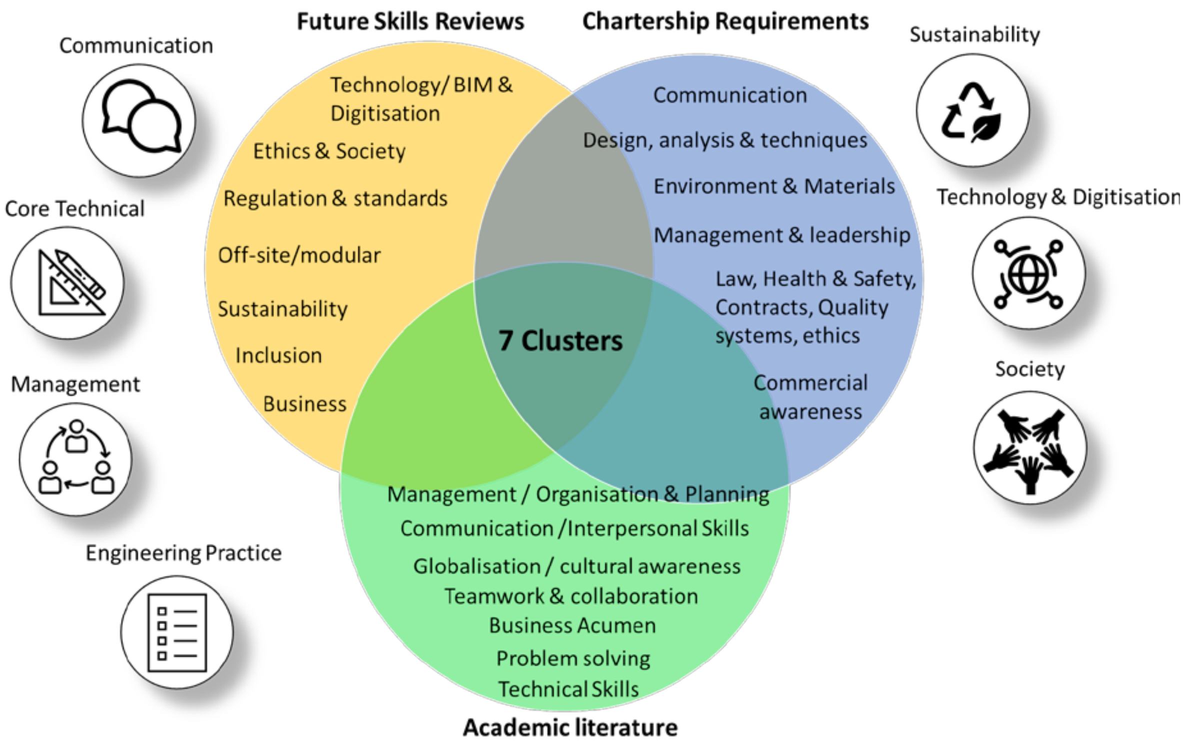

Figure 1: Clustering of Skills emerging from the literature

2 METHODOLOGY

Co-creation has been described by Ryan and Tilbury [11] as a pedagogical idea that emphasises learner empowerment, engaging learners in constructing and questioning knowledge and learning. For this study, the students engaged in co-creation in the curriculum as described by Bovill and Woolmer [12]. In order to attain broad definitions and potential new skills that may have been overlooked by the researchers and for the sake of rigour in the qualitative data collected, the researchers chose to adopt a focus group methodology to generate deep discussion on the skills, their definitions and any missing aspects.

The aim was to co-create definitions for the identified 7 skills clusters, and produce 'action lists' for each cluster. These lists were generated for two reasons. Firstly, because action learning aligns with the overall ethos and long term goals of the project which will include the introduction of new activities within the programme to strengthen skill development. Secondly, 'learning outcomes' within module design and re-design are defined by action terms that are measurable and observable. This format and wording will be familiar and easily interpreted by educational staff during the next phases of the project.

2.1 Sample identification

The sample of students for the study was drawn from current third year structural engineering students at TU Dublin. This is a four year programme which is accredited by Engineers Ireland as meeting the education standard (with further learning) for chartership. The rationale for selecting these students is that they have a better range of educational experiences when compared with first or second year students and so they are best equipped to define the skills that are presented to them. We also hope to assist them in developing their portfolio of skills development in this year and also in final year.

2.2 Ethical Approval

As the research work involved human participants, ethical approval was required for the focus groups. Focus group participants received written information about the objectives of the focus group study, confidentiality of data collected and the possibility of withdrawal. Following the researchers provision of the rationale and outline of the study, students were provided with an ethical consent form seeking their permission to use the data collected for this research. The audio from discussions with students was also recorded to enable checking and clarification at a later date as required. Participants provided written consent before the focus groups began and ethical approval was granted by the TU Dublin Research Ethics and Integrity Committee [Ref: REC-20-77].

2.3 Focus group

A request for research participants was emailed to the third year structural engineering class group and all volunteers who had signed the ethical approval form were accepted. The procedure guidelines used by the researchers was agreed with the research team before the session and the focus groups were carried out remotely using Microsoft Teams. After introducing the researchers, the project and the aims of the focus groups, the students were provided only with the titles of the seven skill clusters; “Communication”, “Core Technical”, “management” and so on.

Taking each skill in turn, students were prompted initially to consider each skill individually and then discuss in the group what that skill meant to them. As this was a co-creation exercise, the co-creation took place in real time by recording, discussing and agreeing the definitions of each skill presented using a Powerpoint slide to work through the process and record the outcome. After the focus group, the two researchers involved in the focus group, met to review and refine the definitions, based on the outcomes of the discussions and the audio recording. This included correcting grammar and syntax. The definitions were also reviewed by the remaining research team to check for clarity. These exercises helped add validity to the outcomes. The definitions were then compiled into a table of skills and definitions.

3 RESULTS

Definitions and action lists for each skills cluster are presented in Table 1.

Table 1: Definitions of Skills co-created with Third Year Structural Engineering Students

Core Technical
Definition: The skilled structural engineer of the future has a strong grounding in mathematics and science within structural engineering. This includes the fundamental principles of structural engineering, material behaviour, engineering equations and problem solving. Action List: • The ability to design and analyse a structure or parts of a structure • The ability to use appropriate equations and methods to solve a problem • The ability to recognise, understand and use structural engineering terminology and definitions
Engineering Practice
Definition: The skilled structural engineer of the future understands and follows the protocols, processes, rules and regulations of practicing within this field. Action List: • The ability to identify and follow the required standards and codes • The ability to describe and recognise the design stages in a project • The ability to perform a cost-benefit analysis in comparing options during initial design • The ability to recognise roles and responsibilities within a team • The ability to follow good practice and protocols in design and on-site engineering including health and safety, Universal Design, and Environmental impact statements
Communication
Definition: The skilled structural engineer of the future can effectively exchange information through a variety of diverse means and with diverse groups in various settings and circumstances. Action List: • The ability to present information in a clear and understandable form • The ability to communicate through a variety of online formats including video conferences, emails, or messaging services • The ability to present to a group • The ability to write in a clear, well-structured and understandable manner, cognisant of spelling, grammar and syntax • The ability to share, understand and record information in a meeting setting including minute-taking
Management
Definition: The skilled structural engineer of the future can manage themselves and others in keeping on track towards an end goal. Action List: • The ability to delegate responsibilities within a project or task • The ability to display leadership • The ability to motivate a team towards a goal • The ability to plan a project, it's tasks and deliverables • The ability to record progress and keep themselves and the team on schedule • The ability to prioritise tasks within a larger project or subject

Table 1(cont.): Definitions of Skills co-created with Third Year Structural Engineering Students

Technology and Digitisation
Definition: The skilled structural engineer of the future is able to learn and use new technologies and digital advancements in analysis, testing, communication and collaboration. Action List: • The ability to translate 2D drawings to 3D models and images • The ability to use online resources for self-directed learning • The ability to use up to date software for structural design • The ability to use hand calculations to check software output • The ability to use automated testing equipment and data recording devices in a laboratory setting • The ability to interpret output from software and data recording devices • The ability to convert between metric and other international systems
Sustainability
Definition: The skilled structural engineer of the future has a working knowledge of the impact of design choices on sustainability and targets the reduction of impact on the planet and its natural resources. Action List: • The ability to compare design choices in terms of sustainability • The ability to reduce material usage through design • The ability to design for longevity • The understanding of the relative green credentials when choosing between materials or structural products • The ability to do examine the environmental impact of a structure • The ability to list locally available structural materials and products
Societal
Definition: The skilled structural engineer of the future has an understanding of how they can impact society directly or indirectly, and makes efforts to give back to the community, understanding the inseparability of structure or structural engineering practices and people and place. Action List: • The ability to engage with a community for the betterment of structural engineering or a structure • The ability to research and reduce the negative impact of a structure on a locality, including the local community, local services, traffic, and local businesses • The ability to be ethical in daily engineering practice

3.1 Discussion and Conclusions

Several disparities were identified between the commonly understood definitions of terms in academic and professional writings and the interpretation by the students. One example of this is the complete omission of any discussion on Building information Modelling (BIM) within “Technology and Digitisation” when compared to its almost exclusive presentation under this heading in the Future Skills report [5]. The students are taught BIM in several modules throughout the programme and are therefore very familiar with it. This brought to light the importance of using terminology which relates concepts to specific skills and module titles.

The skill that students struggled most to define and produce action lists for was “Societal”. They needed to be encouraged to think about their future role within the engineering profession and larger society many years into the future. It is interesting to note that this reflects initial findings of other aspects of the project, whereby societal skills were identified as being the most poorly represented within individual modules.

The co-create approach was found to produce results which could not have been identified through literature examination alone. The findings were very specific to the cohort and within the context of the programme being examined. This serves the purpose of this project well as the intention is to consider the existing programme design and introduce changes where needed. The approach would need to be adopted across several institutions in order to gain results that could be combined and generalised across all structural engineering programmes. As an exercise in itself, the co-creation process facilitated students to reflect on their own experiences and abilities, which is a requirement within the chartership process for both the IStructE and EI. Students were engaged and lively throughout and all requested a copy of the results and to be kept informed.

The next stage of this research involves a full programme review in order to examine areas where the skills presented here can be integrated. During this step, the staff at the school will reflect on their own modules and rank the extent to which each skill is represented. Staff are also provided with the opportunity to detail how they would define each skill cluster. Our aim is to engage our students in a programme which sets a sound foundation not only for their academic training, but orientating their views towards the skills they will need in the immediate future as a graduate and their long term career as an **exemplary structural engineer** with a focus on the **future of our planet and it’s people.**

4 ACKNOWLEDGMENTS

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Challenge Based Learning Approaches for Education 4.0 in Engineering

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ABSTRACT

Higher Education Institutions in the field of engineering are currently in the process of designing teaching-learning approaches within the framework of the Fourth Industrial Revolution, Education 4.0. This process implies the need to improve the cognitive abilities of Generation Z students with regard to active, collaborative learning and personalized and self-paced teaching. Our institution had implemented in August 2019 a new educational model, based on four fundamental pillars: Challenge Based Learning (CBL), flexibility, inspiring trained teachers and, a comprehensive educational and memorable experience. The present work is a study on the effectiveness of the CBL approach in engineering; the didactic use of technological tools and the design of innovative strategies to enhance the development of the skills declared in the Education 4.0 Framework: global citizenship, innovation and creativity, technological mastery and interpersonal awareness. The methodology used was quantitative-experimental, involved more than 250 students and was developed over three years. The use of several assessment instruments allowed to obtain conclusive results: (i) the impact of the design and implementation of adequate cognitive tools on the quality of learning outcomes; and (ii) the relevance of the use of cutting-edge technological tools in each stage of a 2D learning taxonomy (cognitive process dimension / knowledge dimension).

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1 INTRODUCTION

Education 4.0 is an educational approach designed to align with the emerging fourth industrial revolution. The pillars of this new industrial revolution are intelligent technology, artificial intelligence and robotics, Biotechnology and Sustainability. It must contain a more real approach, more of the current environment, real issues, real answers [1]. Universities have had to change their teaching-learning models to focus on these areas of study. However, this would not be enough, but the students must learn about the areas by doing, that is, under a practical, dynamic scheme, changing the knowledge transfer approach in a way that is closer to the environment in which we live today [2].

This makes engineering education go through significant changes. Therefore, it requires academics to modify traditional engineering education. Taking into account the principles of Industry 4.0, the teaching staff should allow their students to face Industry 4.0 and to continue researching on the subject in conditions of lifelong learning. In other words, it requires establishing tangible engineering competencies in both processing and thinking that can be applied to emerging technologies [3].

In addition, education needs new adaptable education systems that are developed and realized through the use of technology and the Internet, more in events such as the COVID-19 pandemic [4]. Technology-enhanced learning offers such possibilities by supporting the teaching and learning process through the integration of e-learning and technology. Provides access to socio-technical innovations. Learning with technology can maximize students' academic experience in fast-growing areas of interest to Industry 4.0 at all levels of global education. This requires strategies such as challenge-based learning or active learning. There is a gap that is created between the need for employers to certify that students possess the skills required for the work environment and the current circumstances of the pandemic that prevent educators from fully developing these skills. Therefore, the study and proposal of new strategies of the teaching-learning procedure that decrease this gap are extremely necessary. Education in the Fourth Industrial Revolution can be identified with four skills and four learning characteristics of high-quality learning, the Education 4.0 Framework, as shown in Table 1.

This study addresses the following research question on how to intellectually involve engineering students by promoting soft skills (considering technological tools and digital transformation not as goals in themselves but as means):

How to incorporate in Challenge-based settings those open learning experiences that develop Education 4.0 skills using tools from an Active Learning approach?

2 THEORETICAL BACKGROUND

2.1 Challenge-based Learning Theory

CBL has its roots in Experiential Learning (EL), which has as its fundamental principle that students learn better when they actively participate in open learning experiences than when they passively participate in structured activities. Therefore, EL provides opportunities for students to apply what they learn to real-world situations where they face problems, discover for themselves, test solutions, and interact with other students within a given context [5]. EL is an integrative and holistic learning approach that combines experience, cognition, and behavior [6].

EL approach involves much more than just participating in “doing something,” solving a problem that has been previously solved by the teacher, or getting involved in a project as an assistant. It should be noted that EL can be used in Project-Based Learning, however for the CBL, the level of uncertainty is different, mainly when there are agreements between universities and training partners where students are scholarship holders or interns at the training partner's facilities, because sometimes the experience of interactions is limited to students doing jobs with little demand and almost always challenging.

On the one hand, the first priority of the new educational model was for our university to establish agreements with the training partners in accordance with the objectives of the educational model. This, of course, implies an understanding on the part of the training partner that the main objective is the development of competencies through solving the challenges that the training partner wants to solve. On the other hand, the university undertakes to respect at all times the confidentiality of the process, the intellectual property of the resolution of the challenge, and the guidelines of both the engineering school and the training partner to understand how students can develop. competencies through CBL experience [7][8].

Table 1. Skills and learning characteristics of the Education 4.0 Framework

Skills	Global citizenship Innovation and creativity Technology Interpersonal	Learning Characteristics	Personalized and self-paced Accessible and inclusive Collaborative Student-driven

2.2 ACTIVE LEARNING THEORY

Some of the essential conditions to promote effective Active Learning (AL) experiences are [9]:

- ❖ Learning experiences should include activities of reflection, critical analysis and synthesis.
- ❖ Learning experiences should be structured in a way that promotes decision making and student responsibility for results.
- ❖ The experience must involve all participants not only intellectually but also emotionally and socially.
- ❖ The instructor and students may experience success, failure, uncertainty, and risk taking, because the results of the experience may not be entirely predictable.
- ❖ The experience should promote students' self-awareness, empathy with their peers and a greater knowledge of the environment and other cultures.

AL and CBL are educational process approaches that have been successfully incorporated into engineering curricula because they achieve a real-world perspective and view student learning as a process by "doing" on a subject of study. It is a type of experiential education where students are exposed to situations in their environment, AL is the basis of pedagogical activities and CBL is the didactic technique where the student faces a real problem where their knowledge, experience, multidisciplinary and collaborative work It is necessary to develop a proposal for a solution to the challenge. The result is obviously the development of both transversal and disciplinary competencies. These approaches offer a student-centered learning framework that emulates real work experiences in industry and corporations: they build on student interest in giving practical meaning to education, while developing key competencies observed by organizations international: Leadership and social influence; Emotional intelligence; Reasoning; Problem solving and ideation; and Analysis and evaluation of the system.

3 METHODOLOGY

3.1 Research Design

The design chosen for the project was the Experimental Research, Quantitative, 4-group Solomon type [10]. It was intended to control the possible interaction that could exist between the PreTest and the Treatment. Two groups have received PreTest (EG-T-PreT and CG-PreT) while other two have not. Likewise, two groups have received Treatment (EG-T-PreT and EG-T) while other two have not. The group criteria were the following:

EG-T-PreT: Experimental Group, Treatment with PreTest

EG-T: Experimental Group, only Treatment without PreTest

CG-PreT: Control Group with PreTest

CG: Control Group without PreTest

The study was mainly based on the implementation of both approaches, CBL and AL, and all students participated simultaneously in activities that promote learning and enrichment of disciplinary competences, as well as transversal competences [2]. During these experiences, students were guided by the authors and supported by partners, who contribute not only to the design and implementation of activities, but also to the feedback received by teachers and students at the end of the process. The methodological design is schematically illustrated in Figure 1.

3.2 Participants

A total of different groups were involved over six semesters (S1 to S6), from August 2018 to June 2021, as shown in Table 2. The research was conducted with a sample of 330 students that joined the study voluntarily, 130 of them during 2018-2019 in face-to-face (F2F) learning settings, and other 200 of then, during 2020/2021, in fully online (OL) learning settings. The experimental group -198 students- underwent cognitive and metacognitive instruction (with Treatment), while 132 students remained untrained in the control group (without Treatment). Of the 198 experimental group students, 102 received pre-test and treatment and 96 students received only treatment. Of the 132 students in the control group, 74 received the pre-test and the remaining 58 students did not.

It is important to emphasize that the students of the 14 groups that appear in Table 2 participated in the Post-Test. Participants who contributed to this study had an average age of 22 years by the end of each semester and were distributed in nine different courses (the official ID of each program and courses appears in parentheses) taught by both authors, as follows:

B.S. Sustainable Development Engineering program (IDS):

- Biology and Sustainable Development (BT1009)
- Natural Resources Management and Climate Change (DS3002)
- Capstone Project for Sustainable Development (DS3005)
- Integration of Energy Processes (IQ2001B)
- Technologies for the Efficient use of Electricity (TE2042)

Energy Distribution Systems (TE3053)

B.S. Biotechnology Engineering program (IBT):

- Molecular Biology (BT1003)
- Biomimetics and Sustainability (IB1006)

B.S. Mechatronics Engineering program (IMT):

- Applied Electronics (TE2033)

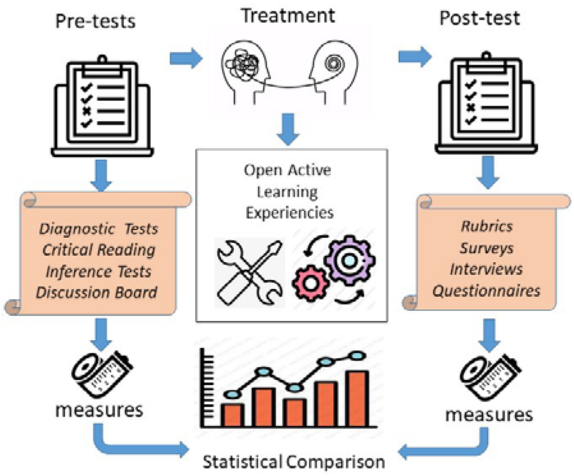

Fig. 1. Procedure Design.

Table 2. Methodological data used in the study.

Group Type		#Group	#Students	Course	Program	Modality	Semester & Year
EG-T-PreT (102 students)	198	1	32	IB1006	IBT	OL	S6-2021
		2	26	IB1006	IBT	OL	S5-2020
		3	26	TE2033	IMT	OL	S6-2021
		4	18	DS3002	IDS	OL	S6-2021
EG-T (96 students)		5	30	IQ2001B	IDS	OL	S6-2021
		6	17	TE2033	IMT	F2F	S3-2019
		7	26	BT1003	IBT	F2F	S2-2019
		8	23	TE3053	IDS	F2F	S3-2019
CG-PreT (74 students)	132	9	29	TE2033	IMT	OL	S4-2020
		10	24	IB1006	IBT	F2F	S3-2019
		11	21	TE2042	IDS	OL	S4-2020
CG (58 students)		12	15	DS3005	IDS	F2F	S1-2018
		13	25	BT1003	IBT	F2F	S1-2018
		14	18	BT1009	IDS	OL	S5-2020
TOTAL students			330				

3.3 Open Active Learning Experiences (Treatment)

The best strategy for the incorporation of the open learning experiences was in the form of didactic interventions and integrated infusion-immersion approach in curricular courses of the engineering programs [11][12]. The activities were designed considering the actual cognitive stages of thinking of the students, and incorporated analysis sessions. The treatment included some of the following experiences (competences/skills to develop appear in parentheses):

•Dialogue Seminars, held after hours and outside the classroom, in spaces with adequate furniture of the Learning Commons, in F2F courses, and in videoconferences rooms, in OL courses (Broad Perspective).

•Supervised Questioning Session with a leader instructor to stimulate the recall of knowledge and sharpen understanding of concepts acquired in previous sessions (Criticality)

•Challenge-based learning with experts in industry facilities, energy utilities facilities and technology companies (Teamwork).

•Training of students in the operation of the cockpit console of the radio station, training in the use and production of audio with portable equipment for recording podcasts in the classroom and outdoors (Transfer).

•Student participation in contests and competitions of cultural nature (Creativity and Taking Risks)

3.4 Instrumentation (Data Collection in Pre-Test and Post-Test)

Diverse types of instruments were used: diagnostic tests, with multiple-choice and true or false questions designed to establish the approximate knowledge of each student; Reading comprehension tests, designed to determine the level of cognitive maturity of students; a modified version of the tests and rubrics presented by Paul & Elder; and finally, to assess how well students performed each outcome and considering that assessing the evidence for competences and soft skills involves subjective judgments concerning products or behaviors, an already-existing rubric was used, the VALUE Rubrics, from AAC&U, developed for the Essential Learning Outcomes of the Association of American Colleges and Universities [13].

PreTests were important to know the level of cognitive maturity of students. In this study, Egan's taxonomy was used to place students on the different five levels. It is important to emphasize that the PreTest does not have a diagnostic function in terms of domain-specific knowledge level. The PreTest were also used to know the level of development that students have in Education 4.0 skills.

4 RESULTS, FINDINGS AND DISCUSSIONS

During the first three semesters of the project (S1, S2, S3), preliminary treatments were conducted on 66 students to determine with greater accuracy the flexibility and design of the assessment tools, while 64 students were included in the control group. In the spring semester of 2020 (S4), the emergence of COVID-19 forced us to abruptly to modify our design to go from face-to-face learning to online learning through the ZOOM platform; we adapt the collaborative sessions to be carried out in videoconference format and the laboratory sessions to be carried out, some in simulation software and others in remote laboratory systems. In that semester 50 students of the control group performed the Post-Tests. Finally, in the last two semesters of the study (S5, S6) a total of 132 students were included in the experimental group, performing the modified and adapted treatment to be carried out 100% online; in that period 68 students participated in the control group.

In order to verify that the students of the experimental group and the control group had similar initial conditions of soft skills development, the results of diagnostic pre-tests in both groups were compared. Initial comparison between 176 students (102 students of the EG-T-PreT and 74 of the CG-PreT), revealed no significant differences in their skills background, as shown in Figure 2a. The finding of relevance that we can report from the pre-tests is the strong impact of social-emotional skills, noted in students in semesters S5 and S6 (from August 2020 to June 2021), presumably due to disappointment and frustration when starting a semester under strict measures of confinement and social distancing caused by the second wave of COVID-19.

The preliminary analysis of the results obtained in the Post-Tests of the years 2018-2019 revealed that the situation attended in the teaching-learning involved the insecurity in effective communication (oral and written) and the difficulty in developing soft skills and transversal competences. The post-tests on digital skills using VALUE rubrics showed that the experimental group attained 37% improvement over the students of the control group in the upper "Capstone" level and a 35% decrease in the number of students at the lowest "Benchmark" level of the rubric, , as shown in Figure 2b. The exercise of activities in small groups was highly beneficial, so that our methodology can be considered a successful, especially in fully online environments.

The results showed that the Open Active Learning Experiences established a positive effect, since it could be verified that the work of heterogeneous active groups also favours different affective results, as self-motivation, personal ethics, enthusiasm, and intellectual responsibility.

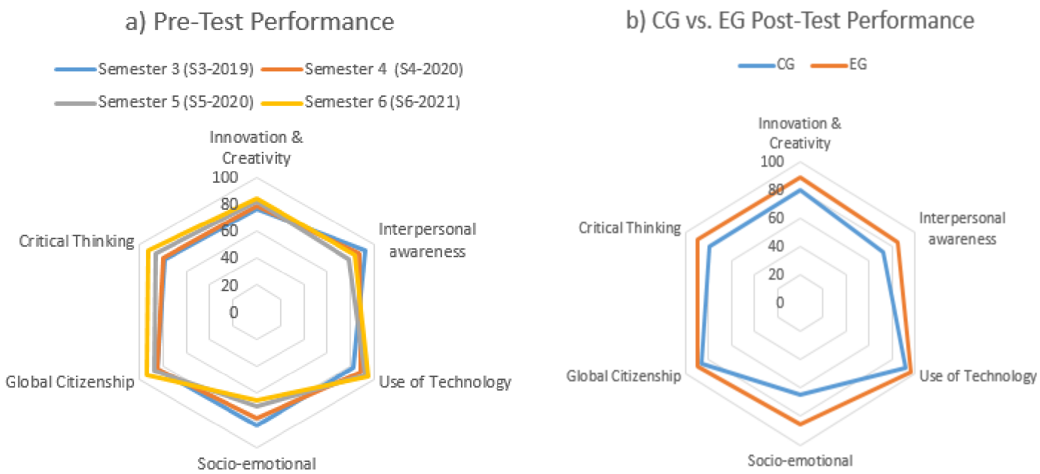

Figure 2.a) Pre-test Performance in semesters S3, S4, S5 and S6. b) CG vs. EG Post-Test Performance.

Faced with the triggering question, regarding how to insert Active Learning experiences in CBL courses, our proposal to use technology-enhanced open experiences was a viable option, since the students themselves recognize -in both

academic course and training exit surveys- a significant increase in the Education 4.0 Framework skills, as well as in socio-emotional empathy.
The adoption of open learning spaces made it difficult to predict how students would respond to the contributions of their peers, how the interthinking process would evolve and to what extent each would develop the Education 4.0 framework skills. Challenge-based learning approach also involved the instructor making decision was a process with the necessary flexibility to change the instructional process in midstream. In addition, those environments demanded a high degree of leadership on the part of the instructor and a strong emerging collaboration between instructor-student and between students with their peers.
Although a broader distribution was intended, only the students who were interested in participating in the study could be included in the sample. Because of this, the groups of students from the engineering program in which we are associated are not completely representative of higher education in our institution.

5 SUMMARY AND CONCLUSIONS

During the last year, due to the emergence of the COVID-19 crisis, all higher education institutions adapted their curricular courses to partially known digital and technological environments, and revisited the syllabi to be taught in completely online courses. The challenge was enormous, and differences of opinion persisted on how to include advanced technological tools virtually in the courses to achieve a good development for the soft skills of the Education 4.0 framework. The present work is a study on the effectiveness of Active and Challenge-based Learning Approaches and the didactic use of some technological tools. The design of innovative strategies made it possible to enhance the development of some of the required skills such as: global citizenship, innovation and creativity, digital literacy and interpersonal awareness. The use of rubrics allowed to obtain conclusive results since it revealed the importance of promoting the formation of metacognitive awareness, and the great impact of the design and implementation of adequate cognitive tools to achieve high quality results in the learning process.

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STEM UNIVERSITIES AND THEIR RESPONSE TO THE COVID-IMPOSED DIGITAL MOVE: A COMPREHENSIVE OVERVIEW

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ABSTRACT

In the last decades, Higher Education has undergone an ever-increasing trend of digitalisation. Universities have already been working for years on adapting to the digital era, with new technologies and increased accessibility driving educators towards adopting new teaching methods. In this context, the sudden outbreak of the COVID-19 pandemic enforced changes that would have taken years to happen in just a few months. Now that digital education is no longer optional, universities have been urged to adapt to an online environment, using a wide variety of approaches. This research aims at centralizing all the scattered knowledge that has been generated in the emergency-focused response to the pandemic, to turn it into a collection of best practices for educators and STEM universities. This study was run on a pool of 50 universities from 28 countries, by conducting interviews with students from each institute between November 2020 and February 2021, analyzed through content analysis and thematic analysis techniques. These interviews covered 5 main areas: Teaching methods adapted to the online environment; Digital tools used for online lectures; Online laboratories; Online assessment methods; Personal interaction between students or students and educators in an online environment. The paper finally recommends techniques that educators can use to create a more effective and digital-enhanced learning experience for their students, with the right balance of digital content and in-person interaction. It also advises actions that universities can take to support educators in achieving this goal, and to digitally enhance interaction between their students and educators.

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1 INTRODUCTION

The latest advances in the field of technology, such as continuous connectivity, increased digitisation, and instant access to information, led to redefining many aspects of both professional and daily life. In this context, digital education has evolved and has become a vital part of this digital revolution, making use of the most modern technologies to create an optimal learning environment focused on students.

In the latest months following the outbreak of the COVID-19 pandemic, the digitisation process has been exponentially accelerated. Universities had to adopt technology and digital tools as part of their standard methodology in no time [1]. Even though the COVID-19 crisis has caused many challenges, new insights and ideas on the topic have arisen which can lay the groundwork to drive the change in education for the next years.

Specifically, higher education had already been in the digitalisation process for a decade[2], but universities adapted at different speed and in different ways to the new needs the pandemic imposed. The knowledge generated on this adaptation process has not yet been organised and shared among institutions rigorously and systematically. Findings are scattered and uniquely used in specific universities, or even just in particular courses. Therefore, centralising and evaluating the information acquired over the last year can provide the tools to create the basis for digitally-enhanced education in a post-pandemic context[3].

With these ideas in mind, this research aims at centralising the scattered knowledge that has been generated in the emergency-focused response to the pandemic and to turn it into a collection of teaching best practices for educators and STEM universities. The paper provides a comprehensive overview, based on the students' perspective, of the actions taken by universities in the fields of (online) teaching methods, digital tools, (online) assessment methods, and university support for (online) interaction. It aims at helping to design new approaches to digital education, by providing concrete examples of other European universities.

Consequently, this research approaches the following questions: How did European STEM Universities tackle the transition from in-person to digital education? How were teaching and assessment methods adapted? Which tools were used to support them? What are the best actions to be taken?

2 METHODOLOGY

The data presented in this paper was gathered through a series of interviews with one student from each university in the sample. We interviewed students in pairs, with 4 different interviewers. We conducted interviews in 50 STEM universities from 28 European countries, in the period between November 2020 and February 2021. Using a pre-designed script, each interviewer was going through a series questions, recording the interview in form of raw texts and checkboxes.

The interview had the goal of gathering factual information about the measures that each university took in facing the pandemic. To extend the information gathered in the interview to the whole university, rather than just the specific experience of each interviewee, we contacted interviewees 1-2 weeks before the interview itself. We provided 5 questions on the topics that the interview would touch upon, asking the interviewee to gather more information about it from his/her peers, to then report to us. This, together with the fact that we were probing for factual information (and not opinions, for which statistics is of essence), was done to mitigate the concern that a sample of one student per university wouldn't be representative.

We designed the interview script[1] to cover 5 areas: the general approach of the university regarding teaching activities, tools used for online teaching, online teaching methods, online assessment methods, and university support for students.

[1] `https://bit.ly/33c8MC2`

We conducted the first 3 interviews with a slightly different script, used for testing and fine-tuning. For this reason, those have not been included in the statistics in the paper, which will only be about the remaining 47 universities. Nevertheless, the ideas gathered in those 3 initial interviews are reported in the text throughout the paper.

After this, we analysed the data analysis by using thematic analysis[4] and content analysis[5] techniques, to bring responses from raw text to a format that allowed statistical analysis.

The analysis process consisted of an iterative process between 3 steps.

1. **Assigning codes to meaning units in the text:** We went through the text of all interviews and assigned a code to any found meaning unit. In this context, a meaning unit refers to each piece of information that has been collected from the students.
2. **Reviewing the code list:** While creating codes, we logged them in a codebook, with the name and description of the meaning unit the code was capturing. This allowed reviewing the codes within the team, and it minimised cognitive bias throughout the codifying process.
3. **Grouping those codes in themes:** After creating and reviewing the codes, we looked for themes[4] within them. In this context, a theme refers to a specific pattern found in the data. Each theme captures some crucial information about the data in relation to the research questions, and features patterned meanings across the data set. Codes were rearranged, merged, and deleted, to find meaningful trends and patterns.

The last step was to format the created codes as boolean values tables, to be able to run statistical analysis effectively.

3 RESULTS

3.1 General situation in the university

This section investigates how universities adapted their traditionally organised activities to the online format. For more clarity, we define below the four main activities, as their meaning may differ depending on the university or on the major:

- **Courses:** theoretical lectures;
- **Practical lectures:** all the activities where students apply their knowledge or do practical experiments;
- **Assessments:** projects, midterms, and final exams;
- **Research activities:** research conducted by any student, as a part of a research team in the university or for his/her diploma project.

3.1.1 Observations

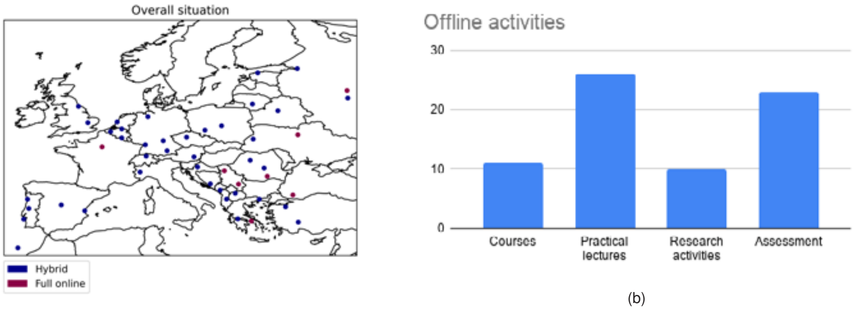
Universities took a wide variety of long-term and short-term measures to quickly adapt to the outbreak of the pandemic. While some universities adapted quickly to online learning, using the already existing infrastructure, others were taken by surprise: 7 out 47 universities (10%) had cancelled classes in order to prepare a plan and update their infrastructure to support digital education.

Figure 1a geographically shows the approaches that universities took in the adaptation, either fully moving online or using hybrid approaches with some activities still live. scenarios adopted by the universities. 39 out of 47 universities (83%) used a hybrid approach, trying to conduct offline activities when possible, while 8 universities had online classes exclusively, starting from March 2020.

Following the trends present in all aspects of society, universities tried to reduce the number of participants in live activities, in order to limit the number of interactions between people. 38% of the universities from this study have tried different approaches that would permit safe offline activities, such as:

- Dividing students into two groups that were alternating in class;
- Organising an on-campus day a week, to group all live activities together;
- Having all classes at reduced capacity and introducing a booking system for students.

To further elaborate on the type of activities that still happened live, Figure 1b presents a histogram of the activities that universities tried to organise offline. We can observe that 23% tried to organise offline courses, and 21% encouraged research activities to happen live. Additionally, 55% of the universities have tried to have practical lectures fully or partially offline, while 49% universities tried to have in-person assessments, rather than online ones, with a total percentage of 30% universities trying to provide offline solutions for both practical lectures and assessments.



(a) (b)

Figure 1: (a) Geographical distribution of the universities trying hybrid approaches. (b) Histogram representing which activities universities tried to organize offline. The codes in the histogram are non-exclusive, so the total counts add up to more than the total of 47 universities in the analysed database

3.1.2 Discussion and Conclusion

Although all the activities mentioned in this section have an online equivalent, 40 out of 47 universities (85%) have tried to organise at least one type of the above-mentioned activities in an offline manner. Based on this, we notice that universities have made considerable efforts to organise as many activities as possible live and to maintain the safety conditions, that could flag that these are considered important to ensure good learning experiences for the students.

Additionally, based on Figure 1b, it is noticeable that most universities focused on having practical lectures and assessment sessions live, rather than remote. Considering that STEM disciplines partially rely on practical, hands-on experience and can require special equipment only present in a designated laboratory, the need for having offline practical lectures is logical, and it is reflected in the data of this section.

3.2 Digital tools

In this section, we give an overview of the tools that have been used in European STEM universities for different activities. We also analyse which resources the universities provided to students and professors, and present the approach that different universities had on practical lectures.

3.2.1 Observations

We probed the interviewed students upon which tools have been used for both theoretical & practical lectures, and for sharing study material. There was no significant difference observed between tools used for theoretical lectures and practical lecture, just using more interactive features like breakout rooms for the second ones.

We can see in Figure 2a that most of the universities used non-integrated video-conferencing tools. Zoom and Microsoft Teams were by far the most used, with 34 (72%) and 28 (60%) cases, but also Google Meet, Skype, and Webex were mentioned. There was also a significant number of universities that used video-conferencing tools fully integrated with their university platform, the most common being Moodle-based platform (32%), including its plugins like BigBlueButton (7 cases, 15%, included in "Moodle-based" in the figure). But we can also see other tools like Google Classroom and Blackboard Collaborate, or unspecific University websites hosting streaming/recordings.

Additionally, other tools were used in parallel to increase online interaction. The main ones reported were Kahoot (8 times, 17%) and Google form (4 times) for quizzes, and even Miro for having a more collaborative environment for the class (2 times).

Figure 2b shows the same analysis on the tools used for sharing study material. A tool integrated into the university platform was used more often that in Figure 2a, with Moodle being the most widespread (51%), and a university website (non-Moodle-based) also being very common (43%). Also here, we notice non-integrated methods for sharing materials like emails (13%), Microsoft Teams (11%), and others. Blackboard Collaborate was only reported once, Google Drive and Google Classroom twice, they are included in the "Other tools" column.

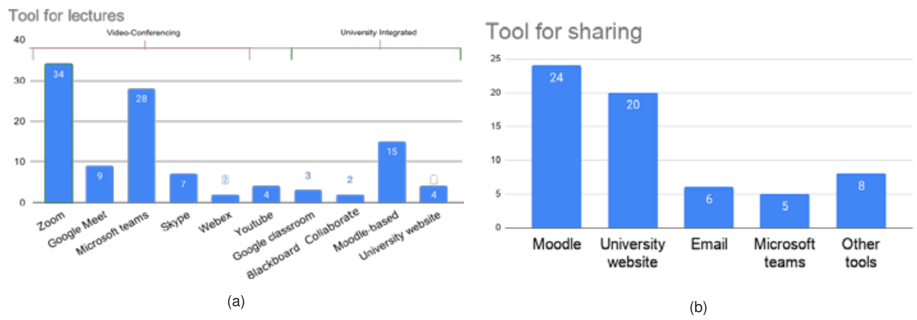


Figure 2: (a) Histogram of the tools used for lectures. (b) Histogram of the tools used for sharing material (slides. assignments,...) between professors and students. The codes in the plots are non-exclusive, so the total counts add up to more than the total of 47 universities in the analysed database

We also analysed the university support in providing tools to educators. In almost all cases, the university did provide educators with some sort of tool. In 15 cases (32%), tools were centrally provided. In 15 other cases, there were tools provided by the university, but some of the professors were not using them and were resorting to custom (eventually free) ones. In 12 cases (26%), the tools were provided and used, but some educators also used additional non-university-provided ones in parallel (e.g. Miro or Kahoot together with Zoom). In 3 cases the interviewee mentioned that tools were provided only in the second semester, and in 2 cases that the educators did not have any provided tool.

3.2.2 Discussion and Conclusion

The move to digital education needs to be empowered by a series of tools that support universities, professors, and students in interacting in an online environment. In the context of the rise of the COVID-19 pandemic, professors and students have worked in integrating these tools into Higher Education, possibly with the support of university bodies.

All universities have used at least one video-conferencing tool that was allowing for live interaction between students and educators, and one tool for sharing material between students and educators. We considered these to be the essential elements needed to be able to run an online class.

We presented in this section a large variety of used digital tools, with professors that tested many of those independently. This was probably an inefficient time-drain, as many different educators had to go through the same process in parallel. It also highly relies on the single educator, which is a weak strategy due to the vastly differing skill sets of different educators. We therefore advise universities to support educators by providing them with an adequate framework of digital tools that they can use for their classes, after an eventual round of needs gathering. This will allow them to focus on what they are experts at: the content of their lectures.

The approaches visible in this part are included in a spectrum within:

- A fully-decentralised approach, where educators were independently figuring out the best tools to use, and aligning with the students. An example would be having lectures via a Skype call set up by the educator, who also shares the links and materials via email to all the students.
- A fully-centralised approach, where the university provides a central tool with the course schedule, links to the video-lectures, space to upload materials and ask questions. To the knowledge of the authors of this paper, Moodle and Blackboard Collaborate support this feature.

In the middle of the spectrum are approaches where there is a university website to share materials, and that the educator can use to share links to lectures and materials, eventually with software licences provided by the university.

A fully-decentralised approach can be more flexible and agile, but it relies more heavily on single educators to handle the logistics of the online class and to work through the myriad of tools available. A fully-centralised approach requires more resources from the university to be effective. The university also needs to set up and maintain the system and gather requirements and give trainings to educators, otherwise there is the risk that they will not make use of the supplied tools, as seen at the end of the previous section (3.2.1). However, this approach supports the educators more, leaving them larger bandwidth to focus on the content of their classes.

3.3 Teaching methods

This section studies how teaching methods were adapted to the online environment, to conduct lecture, maintain engagement, and ask questions. Throughout this paper, we will use the term ”teaching method” to refer to “the general principles, pedagogy and management strategies used for classroom instruction”[6]

3.3.1 Observations

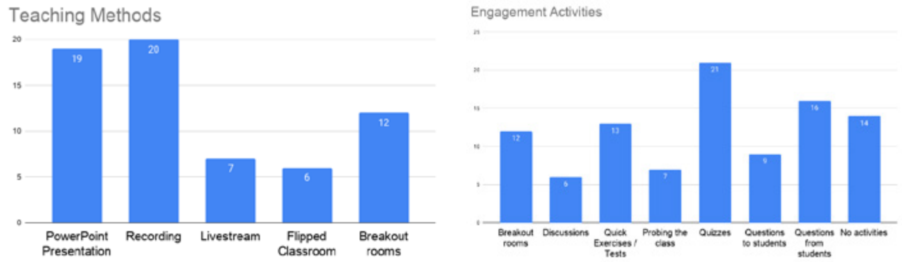
To start, we investigated in the interviews the degree of change that occurred in teaching methods. 72% of the students stated that there was no noticeable change in the teaching methods when moving to online education. Adaptations consisted uniquely on the platform used (not a physical class, but an online class), but not on the way information was delivered. The main reports were that educators were using the same presentations as they would use in an offline classroom. On the other hand, there were 17% who affirmed that changes in the techniques were noticeable with respect to on site education.

In Figure 3a, we report the most popular teaching methods. The most common were having lectures recorded (42%), presentations (40%), or Live-streams (15%). 13% also used a Flipped Classrooms[2]. methodology and 11 (23%) used breakout rooms for group activities. Finally, 4 universities also used videos from external resources to explain concepts. Lastly, and 2 introduced a measure to make lessons shorter for maintaining the focus of students.

As a general trend, we observed that measures and techniques depended mostly on the individual teachers rather than on the whole institution, as reported in 62% of the interviews. In addition, 11% of the universities proclaimed that the adaptation to online learning evolved later

[2]Type of blended learning where students are introduced to content in advance and practice working through it in class

in the pandemic, getting better in the new term in September 2020.



(a) (b)

Figure 3: (a) Histogram showing the teaching methods used during the pandemic. (b) Histogram showing the engagement activities used in online classes. The codes in the plots are non-exclusive, so the total counts add up to more than the total of 47 universities in the analysed database.

We also investigated in the interviews which activities were used to maintain students' engagement during the lectures, summarised in Figure 3b. The most common one was organising short quizzes during the lectures (47%). Other often used methods were about asking questions, either from students to educators (34%), or all the way around (19%). Breakout sessions or quick exercises/tests were also used 28% and 30% of the time. A few students mentioned that the professor was probing the class to sharpen attentiveness, either asking questions or checking attendance (15%).

Asking questions is an important step of understanding a piece of information and, while in a traditional offline environment there is no need for a special framework for this, the digital environment made it more difficult to address spontaneous questions. Various solutions used for question answering are presented in Figure 4, both for questions during the lectures, and outside of the lectures.

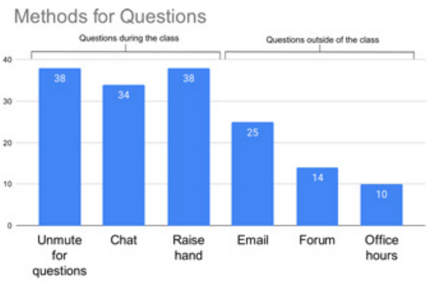


Figure 4: Overview of the methods offered to students for questions. The codes in the plot are non-exclusive, so the total counts add up to more than the total of 47 universities in the analysed database.

As we can see, most universities used spontaneous methods for questions during lectures: raising hands or unmuting in the used video-conference tool (81%) and using the chat to write doubts (72%), where questions were also answered sometimes. Two universities also set up something more elaborate like having a moderator dedicated to collecting and eventually answering questions. On top of that, many universities also provided ways to ask questions outside of lectures. They mostly used emails from students to the educators (53%), and a forum-like environment where both students, educators, and teaching assistants could answer questions (30%). Other options like having office hours that students could book (eventually in groups) or representatives of the class asking for the whole class (for more organizational questions) were used in some universities. In 2 cases, even a mentor professor was assigned to each student.

3.3.2 Discussion and Conclusion

At the beginning of this section we have seen that students do not perceive that changes were made regarding the teaching methods. Most of the teaching methods used were indeed “classical” presentation-like lecturing (both in a video-conference, recorded, or live-stream), even if we can also see more elaborate techniques used for having more discussions within the class (breakout rooms or flipped classroom). On a similar note, for asking questions both during class and outside, most of the approaches were spontaneous ones, much similar to a standard live setting. This could indicate that these approaches works just as well in an online environment as in a live environment.

However, there were also a few methods that made use of the additional opportunities that a digital environment offers. A forum-like environment, much used in online communities for knowledge sharing (Stack Overflow being a famous example), can also enhance the effectiveness of the communication within a course, since all the students can see the answers to questions asked, and they can even answer each other. This also happened in the engagement activities of Figure 3b, where quizzes or breakout rooms do make use of the more digitalised environment.

This all, combined with the fact that the change was usually highly dependent on single educators, could flag that teachers, being under high stress, did not have the time to revise their teaching methods for the new environment. Due to the time pressure, they might have been forced to focus all their energies on keeping everything running while adapting to the new digital infrastructure, with only a limited pool of educators independently finding some space for innovation. However, some of the techniques seen in this section could eventually also be integrated in digitally-enhanced live classes in the future.

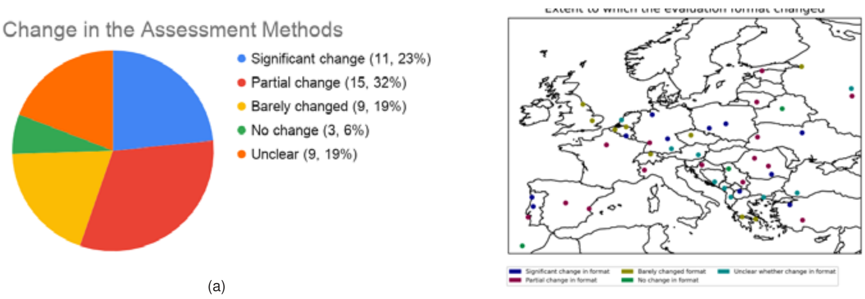
We have seen in this section that many educators tried to stick to classical ways of teaching like presenting, trying to fit it directly to an online environment. This could be because of the high stress given by the COVID-19 context, and because they already had to spend time and resources in figuring out the tools to use. However, a few positive approaches that made use of the strength and flexibility of online lectures were tried, with some of those being desirable also in a normal setting. These should be properly propagated and used among educators, integrating them into the classroom of the future. In this time of emergency, much was left to the educators themselves but, in the coming years, universities could facilitate knowledge sharing in this regard by creating platforms for that, such as conferences, courses, or discussions, to make sure that educators have the necessary knowledge to innovate in their lectures

3.4 Assessment Methods

At the rise of the pandemic, universities had the challenge of finding a reliable way to examine students‘ learning outcome in an online environment. In this section, we report the main techniques and adaptations that were used for this.

3.4.1 Observations

Figure 5a shows that more than 50% of universities had a significant or partial change in assessment methods, 69% of the answers excluding the “Unclear” category. In 11 cases, there was a significant change, with a completely new way of determining the grade (e.g. cancelling the exam and moving the grade to a project). 15 other cases only had a partial change, with the same format but different structure (e.g. changing a closed book exam to an open book exam). In 9 cases it barely changed, meaning that only the necessary things to adapt to an online examination like the platform were changed. Only in 3 cases, the assessment did not change at all.

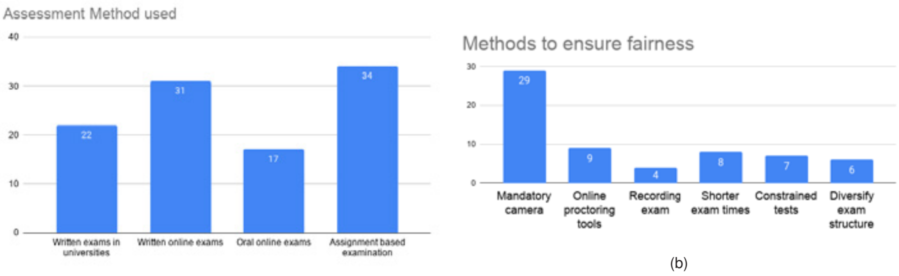


(a)

(b)

Figure 5: (a) Pie chart showing the degree of change in assessment methods. The codes in the pie chart are exclusive, so they add up to the total of 47 universities in the analysed database. (b) Geographical visualization of the same data.

Figure 6a reports the format used for online exams. We can see that the exams were mainly carried out in written (66%) and assignment-based (72%) form. Oral exams were done in 17 cases (36%), with some students mentioning that oral exams were removed.



(b)

(a)

Figure 6: (a) Histogram with an overview of the assessment methods that were used.(b) Geographical visualization of the same data. (b) Histogram with an overview of the used methods to ensure fairness. “Constrained test” means that students were not allowed to go back to previous questions after submitting their answers. “Diversify exam structure” means that the order of questions and/or the parameters for exercises are changed for each student individually. The codes in the plots are non-exclusive, so the total counts add up to more than the total of 47 universities in the analysed database.

Figure 6b presents how universities ensured the fairness of the examination and avoided cheating. There were 2 main categories of methods to ensure fairness: monitoring (e.g. mandatory camera usage, online proctoring tools like a lockdown browser that did not allow using anything else on the PC, recording the exam, or having tests where you cannot go back), reformatting the existing evaluations (e.g. making it shorter, different versions of the exam papers). Making camera usage mandatory was the most popular method to ensure fairness during examination, with 29 cases (62%). All other methods had a similar number of universities that used them. It is worth noting that some of the students reported that Blackboard Collaborate (the tool used for lectures and sharing material) was also used for exams, since it supported a lockdown browser window that only allowed students to use the tab of the exam.

Another approach was restructuring the evaluation to a method where controlling the class was less crucial. Common approaches here were changing to an open book exam or moving to an assignment-based assessment (projects or presentations).

3.4.2 Discussion and Conclusion

It is noticeable that the number of universities which have adapted their evaluation format is a lot larger than the number of universities that changed their educational format (69% vs 17%). This could be because adapting assessment methods were more of a necessity, since the final exam is an integral part of a curriculum, and the professors needed to find solutions to still reliably assess the learning of students.

We can see that the most used method was an assignment-based assessment, with many universities that moved in that direction. This, together with the several different methods adopted in Figure 6b, can indicate that ensuring a fair examination and preventing cheating was one of the pain points, and that an assignment-based assessment by nature works around this.

We have seen in this section the ways the examination was adapted, and several different methods to control and ensure a fair examination, which likely costed a good amount of resources to educators, also seen how common was having a change in assessment methods. For these forced-online circumstances, solutions that worked around this issue by being more assignment-based seem more time-efficient. However, a discussion on whether it would also improves the quality of the course in a post-pandemic would require more thorough evaluations and it is outside of the scope of this paper.

3.5 Training and social support for students

The COVID-19-imposed online move put additional constraints on the digital education framework that universities had to set up, since being remote was suddenly a requirement rather than an option. This forced students and universities to reinvent many of the events that were allowing interaction between students, and it required some new skills for students and educators. This section reports which trainings different universities offered to students and educators, and which actions have been taken to still provide some sort of social interaction among students, which is an essential part of the university experience.

3.5.1 Observations

Another area that the interviews probed upon was the training that educators and students received for online learning and for coping with the online world. For educators, the main ways of training were written guidelines, courses, or video tutorials, that were mentioned about half of the time. However, the students were often unsure about the accuracy of this information.

For students, the results are presented in Figure 7a. The trainings were mainly about using the tools themselves, in the form of video tutorials (32%) or written guidelines (19%). Mental health support was also often mentioned (30%), in the form of seminars or the possibility of having private consultations with psychologists. Often the interviewee reported that these were already there before the pandemic, but they were promoted more after moving online. 8 interviewees (17%) also reported that they had soft skill training on online learning, email communication, coping with stress, and mindfulness. 6 interviewees reported that professors were individually supporting students when needed. Lastly, 11 students (23%) reported that no training was provided.

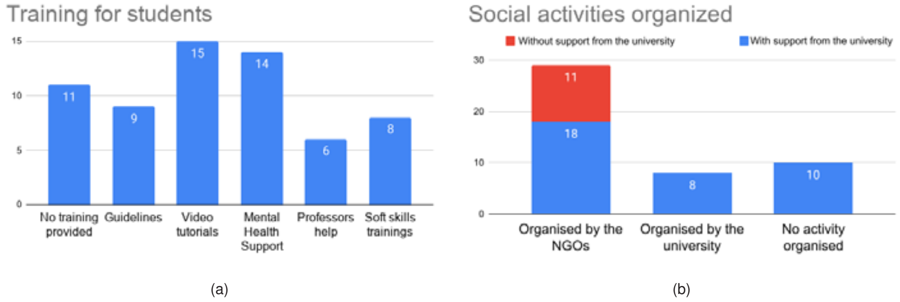


Figure 7: (a) Histogram showing which training was provided to students. (b) Histogram with an overview of the used methods to ensure fairness. “Constrained test” means that students were not allowed to go back to previous questions after submitting their answers. “Diversify exam structure” means that the order of questions and/or the parameters for exercises are changed for each student individually. The codes in the plots are non-exclusive, so the total counts add up to more than the total of 47 universities analysed.

The last area that this section touched upon was which actions have been taken to provide at least partial social interaction among students. As seen in Figure 7b, NGOs had a big role in sustaining the social aspect of students' life in these times. Out of the 47 interviewees, 62% mentioned that their social activities were organised by NGOs, 17% mentioned that their social activities were arranged by universities, and 21% mentioned that no social activities were organised at all. 11 of those 29 (38%) mentioned that the NGOs held these without university support, while the other 18 (62%) mentioned that the university supported the NGOs in organising these, either through already-existing collaborations or by commissioning some of the activities. A wide variety of activities has been arranged, most of which included both an academic-related and a social part: Event with companies (presentations, career fairs, or competitions like hackathons); Recruitment events for clubs and NGOs, with social activities; Soft skill trainings; Game nights; Panel discussions among students and professors; Students speed dating

3.5.2 Discussion and Conclusion

We saw in this section that the universities put high efforts in supporting students in adapting to the new digital environment, providing various training and support. Apart form training purely on tool, we also see a care for the emotional situation of students, with measures like providing mental health support, or simply having professors helping out students in their needs.

Another area where students needed support is social interaction that, even if maybe less obvious at first sight, this is a crucial part of the student experience, contributing to the personal growth that those years bring. The lockdown put a strain on this, limiting the possibilities for students to be in contact with their social circle or enlarging it. We can see that most of the universities put effort in (partially) maintaining this part of the students‘ experience and that NGOs had an important role in helping them achieve this, acting on this area where universities, possibly busy coping with the change, did not have resources or experience to fulfill.

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DOES ENTREPRENEURSHIP EDUCATION AFFECT PHD'S ACADEMIC AND BUSINESS PERFORMANCE?

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Conference Key Areas: *Challenge based education, Maker projects*
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ABSTRACT

This study aims to investigate the impact entrepreneurial education programs can have on academic and business performance of researchers. We analysed the academic and business results of 73 PhDs who attended an entrepreneurial education program codesign by universities and an international research centre in the last five years compared to 73 PhDs who did not. We based our analysis on a mix of quantitative and qualitative data regarding scientific and entrepreneurial achievements and interviews with former participants to the entrepreneurial education program. Evidence from our analysis shows a positive effect of the entrepreneurial education program on academic and business results.

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1 INTRODUCTION

Scholars and practitioners have raised the question concerning what skills are needed for academic researchers to increase their ability to identify areas of research with a higher potential impact. (Gould, 2015). The continued development of the university's Third Mission has led to a revision of the classic academic skills of researchers and has required them to develop skills that allow them to have impacts with their research, to understand and solve problems with a long-term view, to exploit opportunities that arise on the market and apply the results of their research to these opportunities.

According to the literature (Muñoz et al., 2019; Rippa et al., 2020), entrepreneurship education programs are an opportunity for researchers to acquire knowledge and skills related to the business and entrepreneurial field. The literature suggests that these types of programs can provide academic researchers with the skills necessary to recognize and understand complex problems and market opportunities, enhance the value of their research findings and to communicate them (Barr et al., 2009). In this framework, the European Union has pointed out the importance of focusing on entrepreneurship education, for both academics and non-academics, and, consequently, has underlined the need to a more diffused integration of entrepreneurship programs in higher education institutions (European Commission, 2008).

Building on this, a number of programs, designed specifically for researchers, have emerged. However, only a few studies have investigated the impacts of such courses on researchers. Moreover, these studies have mainly focused on changing in entrepreneurial mindset – e.g. entrepreneurial intention and self-efficacy – and on the skills acquired by PhD students during the programs, and have neglected the possible impacts on academic and non-academic performances (Duval-Couetil et al., 2021; Thursby et al.,2009). These studies have shown that one of the key elements allowing PhD students to learn business skills is that of learning together with people from different backgrounds, such as MBAs and JDs (Juris Doctors).

Yet, to the best of our knowledge, there is still no evidence on how these programs can affect the performances of the researchers who have taken part in them. More precisely, there is no evidence on how entrepreneurial education can enhance academic performances, pertaining to, for example, the number and quality of publications, or to business performances concerning, for example, the transfer of knowledge from research to the market through startups.

The goal of this research has been to fill this gap and to take a first step toward understanding the effect of entrepreneurship programs on the career performance of academics. To do this, a mixed methodology has been used to measure the effect of entrepreneurial education programs on PhD's academic performance, such as number and quality of publications, and the transfer of knowledge from research to market, by analysing the number of created startups.

The research questions we aim to answer are:

R1: *Do entrepreneurship education programs have an effect on the academic performance of researchers?*

R2: *Do entrepreneurship education programs affect the decision of researchers to create a startup?*

2 THEORETICAL BACKGROUND

In recent years, entrepreneurship programs targeting academic researchers have been gaining more and more momentum (McNabola & Coughlan, 2014). Scholars and practitioners alike have highlighted the relevance of entrepreneurship education for academics (Duval-Couetil and Wheadon 2014).

The role of academic researchers is increasingly changing as it requires the academic and business competences to be combined in order to exploit the business opportunities which arise from the results of research, ease the technology transfer process and promote the Third Mission at the university level. (Miller et all,2014). Bearing this in mind, one proposed solution has been to encourage the participation of researchers, as doctoral students and postdocs, in entrepreneurial education courses. These programs, if properly structured, allow researchers to acquire different skills from those accumulated in academia or during doctoral studies (Duval-Couetil et al., 2021).

Several programs have been created in response to the call for more commitment to entrepreneurial education, especially in academia. In their 2009 paper, Barr et al. outlined the best practices gained after fourteen years of TEC, an entrepreneurship course designed for researchers and students in the Science, Technology, Engineering and Mathematics (STEM) fields and for MBAs. Barr and colleagues highlighted four points that are essential for the effectiveness of the program:

- Reality: The program should allow students to work on real problems and on technologies that actually exist, or are under development, so that they can develop a real company.
- Intensive: The program should reflect real-world problems by having students tackle several tasks in a short amount of time.
- Interdisciplinary: The teams should be composed of students with different backgrounds, e.g. STEM, Business, etc.
- Iterative: The program should teach students how to perform multiple iterations on the idea they are working on.

An interesting insight into the effects of entrepreneurship education programs on academic researchers is provided by the TI:GER program (Thursby et al.,2009). This program is based on the collaboration of PhD students, MBAs and JDs in order to bring the thesis topics of PhD students to the market. The program aims to train Phd Students, MBAs and JDs and create synergies between their different backgrounds to foster a career in innovation-related fields. From the questionnaires administered pre and post course, it was found that this course had a positive effect on the participants, helping to smooth out the differences in terms of skills related to the exploitation of a new technology. Moreover, in addition to improving researchers' skills, this program also had a positive effect on the entrepreneurial intention and self- efficacy of researchers (Duval-Couetil et al., 2021).

However, the study on TI:GER program only focused on differences in skills and did not explain the mechanisms and synergies that can arise from a possible contamination between the various backgrounds and did not analyse the longer term effect on the attendants career performance.

Building on this, this paper is aimed at understanding whether entrepreneurship education programs could have an impact on the performance of the researchers who attend them. Moreover, the aim is also to understand whether this kind of program could improve the number and the quality of the publications of PhDs and their business performance concerning the creation of startups.

3 METHODOLOGY

3.1 Data and Methodology

The data refer to 146 PhDs from a technical university in Italy. 73 PhDs has attended a challenge-based entrepreneurial education program (treated sample) while the other 73 did not (control sample).

The course attended by the PhDs is called Innovation for Change (I4C), jointly developed by by the Collège des Ingénieurs, CERN Ideasquare and the Politecnico di Torino. I4C is a challenge-based entrepreneurial education program in which teams composed by MBAs and PhDs collaborate to create solutions (based on brand new technologies and with a societal and economic viewpoint) to real high social impact problems according to a long-term view, proposed by large companies and organizations. To solve the problems proposed, teams are invited to work for 20 weeks on a solution that could be implemented in 20 months and which could have an impact on real world on 20 years. The objective of this structure is to help participants link present activities to long term global challenges that are outside the radar of most of for-profit startups.

For each PhDs in the sample, we collected demographic data and information related to academic and business performance. The demographic data were collected from public sources available on Politecnico di Torino website while information on academic performance like the number of publications, the h-index and the number of founded startups were collected from Scopus and LinkedIn.

By using demographic data related to the PhDs who attended I4C, we create a control sample of PhDs who did not attend the program. The control sample was created to avoid significant differences from the treated sample pertaining to the demographic variables. The demographic variables used to build the control sample were gender, doctoral cycle, doctoral field, master's degree earned and nationality (Italian vs Foreigner). Possible differences between the two groups in the demographic variables were tested using the t-test. No significant differences were observed. The descriptive statistics concerning gender, doctoral field and nationality are shown in Tables 1 - 2. Females represent the 28,77% of the sample while Foreigners represent the 21,92%. As expected, most students belong to the Engineering field while only a few belong to the Architecture field.

To answer our research questions, we perform econometric regression analyses. More precisely, we use both linear regressions (OLS) and negative binomial regression, to account for the discrete and non-negative nature of our dependent variables.

Finally, 9 interviews were conducted with former I4C participants to establish any further effects of the program and help us highlighting the mechanisms affecting the PhDs' learning process and to interpret the results of our quantitative analysis. The semi-structured interviews were focused on the following areas:

- Background and current employment of the PhDs
- Their experience in the program and with their team.
- Effects of the program on their career.

Table 1. PhDs according to their gender and nationality

Variable	Treated Sample (n)	Control Sample (n)	Overall Sample (n)	Overall Sample (%)
Men	52	52	104	71,23 %
Female	21	21	42	28,77 %
Italian	56	58	114	78,08%
Non – Italian	17	15	32	21,92%

Table 2. PhDs according to their doctoral field

Variable	Treated Sample (n)	Control Sample (n)	Overall Sample (n)	Overall Sample (%)
Architecture, history and project	4	4	8	5,48%
Architectural and landscape heritage	2	2	4	2,74%
Energy	8	8	16	10,96%
Physics	2	2	4	2,74%
Management, production and design	5	5	10	6,85%
Aerospace engineering	5	5	10	6,85%
Environmental engineering	1	1	2	1,37%
Chemical engineering	10	10	20	13,70%
Civil engineering	1	1	2	1,37%
Eletrical, electronics and communications	14	14	28	19,18%
Computer and control engineering	8	8	16	10,96%
Mechanical engineering	8	8	16	10,96%
Metrology	1	1	2	1,37%
Materials science and techology	3	3	6	4,11%
Urban and regional development	1	1	2	1,37%

3.2 Dependent Variables

We performed regression analysis using three different dependent variables. The descriptive statistics of the dependent variables are shown in Table 3. We used the number of publications and the h-index as dependent variables for the first research questions. Figures 1 and 2 show the distribution of the number of publications and the h-index for the two groups.

Finally, we used the number of startups founded by PhDs as dependent variable for the second research question. Figure 3 shows the number of startups created by groups.

Table 3. Dependent Variables

Variable	Mean	Variance	Min	Max
Number of publications	3,192	15,300	0	27
H-index	2,116	4,12	0	8
Number of startups founded	0,034	0,033	0	1

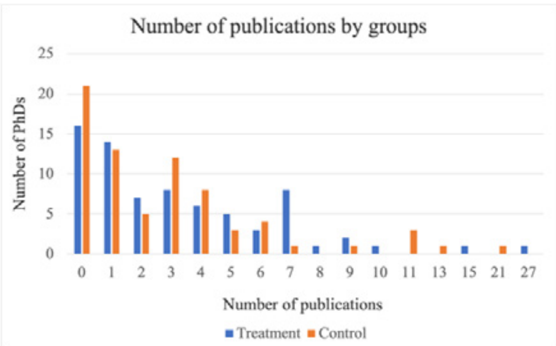

Fig. 1. *Number of publications distribution for the two groups*

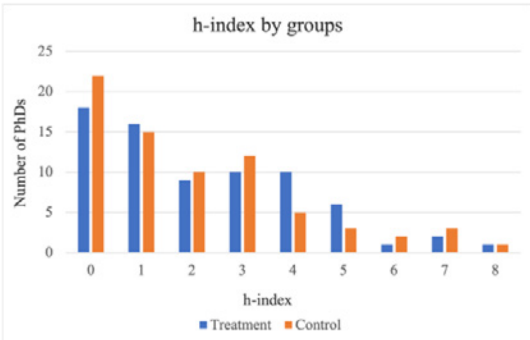

Fig. 2. *H-index distributions for the two groups.*

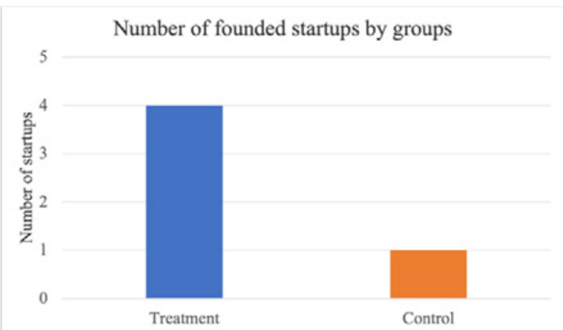

Fig. 3. *Number of startups created in the two groups*

Participation in the I4C course was used as key independent variable in the regression analyses. Moreover, we introduced control variables for doctoral fields and whether a PhD is still working as a university researcher or not.

These control variables were used to avoid confounding effects related to any differences in the number of publications between the field of research and incentives in publications and creating startups between academics or non-academics.

Table 4 shows how the variables were measured and defined.

Table 1.Independent and Control Variables

Variable	Description	Value
I4C	The PhD researcher has taken part in I4C	1 if he/she has taken part in I4C, 0 otherwise
Is still a researcher	The PhD researcher is still a university researcher	1 if he/she is still an academic, 0 otherwise
Doctoral Field i	Field of research i	1 if the PhD works in research field i, 0 otherwise

4 RESULTS

Results of the regression analyses are shown in Table 5. The results show a positive and significant effect of the program on the performance of the PhDs.

Dependent Variable	**Number of Publications**		**h-index**		**Startup Created**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Variable	**OLS**	**Negative Binomial**	**OLS**	**Negative Binomial**	**OLS**	**Negative Binomial**
I4C	*0.709**	*0.231***	*0.237**	*0.110***	*0.047**	*1.550*
	(0.050)	*(0.033)*	*(0.059)*	*(0.041)*	*(0.085)*	*(0.143)*
Is still a researcher	*1.069*	*0.211*	*0.211*	*0.106*	*0.043*	*1.281*
	(0.253)	*(0.388)*	*(0.552)*	*(0.525)*	*(0.289)*	*(0.324)*
Constant	*-1.290*	*-14.682****	*-0.303*	*-15.573****	*-0.021*	*-22.175****
	(0.141)	*(0.000)*	*(0.361)*	*(0.000)*	*(0.291)*	*(0.000)*
Observations	*146*	*146*	*146*	*146*	*146*	*146*
R-squared	*0.272*	*-*	*0.305*	*-*	*0.108*	
Dummies for the Doctoral Field	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Clustered Errors	*I4C Doctoral Field*	*I4C Doctoral Field*	*I4C Doctoral Field*	*I4C Doctoral Field*	*I4C Doctoral Field*	*I4C Doctoral Field*

*Robust pval in parentheses *** p<0.01, ** p<0.05, * p<0.1*

More precisely, as shown from column (1) to (4), participation in I4C has a positive and significant effect (p>10%) on the number of publications and h-index.

This result reveals a positive correlation between entrepreneurship programs and the academic performance of the PhDs who attended the course. The results in columns (5) and (6) show that the participants are more likely to found startups than non-participants, although this result is less robust.

To better understand how the entrepreneurship program affect PhD's performances, we analysed the evidence that emerged from the interviews. The main results are:

1. The PhDs underwent a contamination with the MBA approach to innovation.
2. PhDs achieved a greater ability to frame and solve complex problems.
3. PhDs increased their ability to present their research.

An interesting insight that has arisen from points (1) and (2) is related to the contamination between MBAs and PhDs. During the I4C program emerged the cognitive distance between these two figures, especially in the way they face and solve complex problems. An example of this can be found in an excerpt taken from one of the interviews.

"*You could see a very different approach to problems. I saw them [MBA students] taking a much more practical approach, whereas the other PhDs and I were more anchored in the feasibility of things. Maybe it's a kind of mindset, but I saw them as being much more involved in the idea. Having a good idea and then maybe working on it later on to make it feasible, whereas the other guys and myself had the opposite approach, which was to have a feasible idea and then improve it. … The approach I had at the time was fine, but if we are talking about innovation, not incremental innovation, we need an approach like theirs, which was really ahead.*

Concerning point 3, the course seems to have improved communication skills, as can be seen from an excerpt from the interviews.

"*The communication part gave me a lot, including things I took home for academic research. In the academic world, you usually don't pay much attention on communication: you* usually *do the presentation; the data are available, you present them and that's it, and in the meanwhile everybody has fallen asleep. Instead, the way things are presented acquires a certain important because, even though the information is very technical, you have to transmit it. Now, when I make a presentation it's not like before; students and researchers are too focused on the results and not in the way they are presented. However, now I suffer from a form of paranoia. … It's no longer two slides, but I want to make it clear why the thing I'm publishing* is relevant."

5 CONCLUSION

Our results offer to policymakers and researchers in universities new knowledge helpful to improve and grow this type of programs. The regression analyses showed that the entrepreneurial courses led researchers to perform better than those who did not participate in the course. The impact on academic performance appears to be twofold, an increase in the number of publications and in their quality. The most interesting result is related to the positive impact of these courses on the h-index of the researchers.

Such an increase in the quality of publications could be related to a better understanding of their field of research, the potential of the obtained results, and also to the way in which they are presented. In addition to the academic skills of the researcher, this higher quality of productions could be related to the business skills learned during the course and the cross-pollination with students who have a business background. Furthermore, these are important implications for universities and policymaker, to foster this kind of programs and to enhance engagement through entrepreneurial activities among academics.

On the other hand, regression analysis also shows that the course had a positive impact on the number of startups created by researchers who took part in it. This result should be interpreted with care, given the size of the selected sample and the number of startups founded in the sample, but it is a good signal for the academia and the society as a whole, given the potential of startups founded by researchers (Battaglia et al., 2021).

Moreover, the interviews with former participants revealed several insights into the effects of the program on researchers. Results and interviews reveal that the cross-pollination between PhDs and MBAs shifts the way researchers approach complex problems. This could imply a change in the working approach of researchers, moving from an approach related more to product development to one focused more on understanding the problem that has to be addressed. Such an approach could therefore lead researchers to focus first on the general understanding of the problem, rather than focusing immediately on a solution, thus limiting the possible opportunities of a research area. This is another important implication for universities and policymaker, in order to create and promote more structured and impactful entrepreneurship educational program for researchers.

This work is not without limitations. Indeed, it has not taken into account any possible self-selection effects within the sample. A possible self-selection of researchers toward entrepreneurship issues could contaminate the effects obtained from the regression analyses, especially those related to the number of founded startups.

This work is intended as a starting point for future research on the link between researchers' performance and entrepreneurship courses. The evidence obtained from this study shows that this type of program has a positive effect on the researchers' performance. Future research could extend this work by using a larger database to study the performance of researchers and extending it to other universities. Finally, in order to limit possible self-selection issues, future studies could measure the characteristic traits of entrepreneurs in order to build a sample that would limit such effects.

In spite of its limitations, this work aims to be a point of reflection for policymakers and universities on whether to improve and foster challenge-based programs in entrepreneurship for PhD students.

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FEEDBACK LITERACY AS A PROFESSIONAL COMPETENCE FOR FIRST-YEAR ENGINEERING STUDENTS: STUDENTS' FEEDBACK EXPERIENCES

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ABSTRACT

Feedback has a major influence on learning and achievement, but students are not always aware of opportunities and responsibilities that come with it. To benefit the most from feedback opportunities, it is important for students to perceive feedback as useful, while feeling accountable and self-assured to be able to take action. In this paper a focus group discussion is conducted with first-year engineering students to understand how students experience feedback processes and what their beliefs about feedback are. Students see continuous feedback as an important goal of feedback processes, but underestimate the importance of their own active role in the process. They clearly prefer oral and individual feedback to have an opportunity to start a dialogue, but are reluctant to do so in an online setting or through email. The final goal

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is to introduce feedback literacy as a professional competence, so students become aware of their role as active learners in the feedback process.

1 INTRODUCTION

Feedback is among the most critical influences on learning and achievement [1]. There is a growing acknowledgment that feedback needs to be a learning-centred process where students' ability to actively engage with and utilise feedback processes needs more attention [2], [3]. Since students predominantly hold a teacher-driven view of 'feedback as telling' in which feedback is often limited to an input [2], it is important for learners to develop student feedback literacy as a key mechanism for maximising the potential of feedback processes [2]–[4]. Carless and Boud [5, p. 1316] define feedback literacy as "the understandings, capacities and dispositions needed to make sense of information and use it to enhance work or learning strategies". Activities such as reflecting on a wide range of assessment experiences, have the potential to nurture self-regulatory learning behaviours, making it possible for feedback literate students to improve performance or learning strategies [6], [7]. Since feedback literacy is also a valuable professional asset, it can be seen as a steppingstone towards a lifelong learning mindset [5]. Molloy et al. [2] state that the development of feedback literacy should be an embedded strategy as part of existing activities and should be introduced early in the first year. This way students can benefit the most from the curriculum and are not dependent on the limited opportunities for input from educators [2].

This paper focusses on the results of a focus group discussion with first-year engineering students in order to understand how they experience feedback processes and to gain insight into their beliefs about feedback. The focus group discussion is analysed based on the feedback literacy framework of Carless and Boud [5].

2 METHODOLOGY

2.1 Participants

All 88 first-year engineering students of the Faculty of Engineering Technology (KU Leuven, Campus De Nayer) were asked to voluntarily participate in a focus group discussion. A limited number of only 4 students participated, all male (total cohort 84% male, 16% female).

2.2 Focus Group Discussion

The focus group discussion was organised at the beginning of the second semester of the academic year 2020-2021, and was conducted in an online setting, lasting 1.5 hours. It started with rapport-building through mutual introductions to maximize interaction between participants. The semi-structured format was based on Kitzinger [8]. The facilitator's involvement was minimized to asking introductory questions and keeping the discussion focused. The discussed topics were related to the meaning of feedback, earlier feedback experiences, and expectations and barriers regarding dealing with feedback.

The focus group discussion was transcribed verbatim and thematically analysed. The transcript was first read in depth while writing down initial codes. Themes were then constructed based on the feedback literacy definition of Carless and Boud [5].

Ethical approval was obtained for this study from our university's Ethics Committee (G-2020-2354) and participants have consented to be part of this research. They were informed that their participation was voluntary and that the analysis would be conducted anonymously.

3 RESULTS

The feedback literacy framework of Carless and Boud [5] consists of inter-related features with the goal of maximizing potential for students to take action and engage with feedback, being (1) the appreciation of their own active role in the feedback process, (2) the continuous development of capacities for making judgments about their own work and the work of others, and (3) managing affect in positive ways. The findings of the focus group discussion are grouped according to the relevant themes.

3.1 Appreciating feedback

3.1.1 "Feedback literate students understand and appreciate the role of feedback in improving work and the active learner role in these processes."

All students agree that one of the purposes of feedback is continuous improvement: feedback makes it possible to perform on a higher level for a subsequent task than the level that is possible without getting feedback. They see feedback as an input for adjusting their performance towards the required standards, but also mention this as a barrier since the exact requirements are not always clear.

3.1.2 "Feedback literate students recognise that feedback information comes in different forms and from different sources."

One student states that feedback is very wide and consists of all possible kinds of information, even facial expressions during a conversation. He also mentions scoring on a test: a low grade signals him "to study harder" or to question how a teacher might have wanted it differently.

During the discussion, all students agree that feedback comes in formative and summative form. When they think of feedback examples, they initially refer to formative comments on presentation and writing skills, based on their earlier experiences. One student clearly approaches summative feedback on a test as a linear relationship to "how much he knows" about a specific topic and finds this the best possible feedback. It enables him to reflect if he made up to the expectations or not. Later in the discussion, all students prefer formative feedback because it is more detailed and thus provides a better opportunity to improve.

Most students appreciate group feedback after an exam, but favour individual feedback. Their preference goes towards oral feedback because it offers the opportunity to start a dialogue and ask for specific details in order to fully understand the message. A video call can be a valuable option, but a face to face dialogue is preferred because that way it is easier to go through a document, such as a report or an exam, together. All students agree that a chat session cannot replace an oral discussion as the message can be open to interpretation.

One student explicitly mentions that he mainly seeks feedback from people that can help him best, such as a teacher, but also specific friends or classmates.

3.1.3 "Feedback literate students use technology to access, store and revisit feedback."

One student refers to task submission forms which he used in the past. These forms had a feedback field and made it possible to access collected feedback at a later stage. None of the students took any further initiative to use technology of their own to store collected feedback. They write things down on a piece of paper or in a course textbook itself to find it back automatically when reaching out to the core information. One student explicitly states he remembers feedback and does not write it down, even after another student indicates only remembering such information is dangerous because you might lose the exact message over time.

3.2 Making judgments

3.2.1 "Feedback literate students develop capacities to make sound academic judgments about their own work and the work of others."

One student suggested 'a moment of reflection' as a synonym for feedback, because it improves judging his own work. Another student mentions he "can do feedback on his own" if he has "input data" such as the correct solutions on exam questions or exercises. The group agrees this can be true for an exam, but not for an open exercise because it is too difficult to judge al the individual subtopics. For an open exercise they conclude formative feedback is essential.

3.2.2 "Feedback literate students participate productively in peer feedback processes."

All students agree that having regular meetings during a teamwork is a valuable form of giving feedback to each other. If they do not work together as a team and receive feedback from individual classmates, they clearly state they hardly take it into account because they do not rely on the competence of their peers and see the teacher feedback as the only valid input.

3.2.3 "Feedback literate students refine self-evaluative capacities over time in order to make more robust judgments."

The students did not explicitly mention self-evaluative aspects during the focus group discussion, but one student mentioned dealing with feedback as a permanent weighing of accepting or rejecting the feedback information. He will always listen to feedback, but only if he is convinced it will improve his performance and fits his way of working, he takes the feedback advice into account. A second student confirms, but questions if it is a real choice or something that happens "automatically" without actively questioning the feedback information. A third student simply mentions he only listens to feedback if he is not satisfied with his results. If he's convinced for himself he did a good job, he won't listen to feedback, even if he received a near-pass grade.

3.3 Managing affect

3.3.1 "Feedback literate students maintain emotional equilibrium and avoid defensiveness when receiving critical feedback."

One student argues that criticism or "negative feedback" cannot be seen as valuable feedback if it does not contain opportunities to improve. A second student steps in and confirms the statement that it is not feedback if the message gives no opportunity to improve. He also mentions getting criticism on some parts of his work can create confusion on the full assignment, since it can make him unsure about parts without the explicit feedback. A third student doesn't mind getting criticized and does not associate it with a negative feeling.

3.3.2 "Feedback literate students are proactive in eliciting suggestions from peers or teachers and continuing dialogue with them as needed."

All students see opportunities to actively engage with teachers after an on-campus lecture. The students also mention they can ask for feedback on exams after the grades are published. All students agree that it is also possible to obtain feedback from a teacher during lab sessions, but that it is up to the student to ask for it.

During an online activity, they are reluctant to ask questions because they have the feeling of "disturbing" a teacher. If a teacher is on campus, they assume that he/she is there for lectures and is therefore automatically available to answer questions. Some students do not mind asking feedback to a teacher by e-mail since they see it as the best source of information. Other students hesitate because teachers often mention they are busy, and a reminder needs to be sent if there is no reply.

One student mentions a collaborative system as Google Docs as a useful tool while working on a joined task. It allows team members to quickly share feedback on specific parts of a task. The other 3 students are interested in his idea of using such a tool in a similar setting in the future.

All students also refer to occasions where they expected feedback, but did not receive feedback or too late so that it was not possible to properly use it. They did not indicate taking action in asking for this late or missing feedback.

3.3.3 "Feedback literate students develop habits of striving for continuous improvement on the basis of internal and external feedback."

Only one student referred to generating feedback on his own work, while another student mentioned a reflective moment as an opportunity to improve judgement. The students do not further report a systematic drive for continuous improvement.

3.4 Taking action

3.4.1 "Feedback literate students are aware of the imperative to take action in response to feedback information."

Three students feel a sense of obligation to respond to feedback in some way. One of them mentions the effort it took to generate feedback and the moral obligation to take the feedback into account as a token of respect to the feedback giver. A second student feels obligated to use the feedback, but only if he is scoring low, to prevent the teacher from thinking he is unwilling. If he passed a task and is satisfied with the grade he obtained, he does not feel a necessity to even collect any form of feedback. The third student suggests that he feels obligated to make a decision based on the feedback, but that deciding not to take the feedback into account is also a valid outcome. All students agree on this reasoning.

3.4.2 "Feedback literate students draw inferences from a range of feedback experiences for the purpose of continuous improvement."

The students see feedback as an opportunity for continuous improvement, but are not giving specific examples during the focus group discussion. Only one student refers to small corrections such as missing graph titles that are easy to change, remember and re-apply. If it is not something that is remembered, it is not deliberately reapplied in a subsequent task or it is not mentioned during the focus group discussion.

3.4.3 "Feedback literate students develop a repertoire of strategies for acting on feedback."

None of the students mentioned specific strategies, except for writing things down to make sure information is not lost when studying the same topic again.

4 DISCUSSION

4.1 Appreciating feedback

All students see continuous improvement as an important goal of feedback processes, similar to the findings of Dawson et al. [3]. In their study, 90% of students indicated that feedback is about improvement. All our students agree that feedback makes it possible to perform on a higher level for a subsequent task and mentioned occasions with feedback being too late as barriers to properly use it.

Students prefer oral and individual feedback because it gives them the opportunity to start a dialogue and provides a better opportunity to clearly understand the message. The work of Dawson et al. [3] confirms that face-to-face interactions are students' most favoured medium to facilitate effective feedback. For the same reason, the students do not see a chat session as a valuable alternative, as the message may still be open to interpretation. Winstone et al. [9] reports students' particular frustration about teachers' use of complicated language, but none of our students explicitly mentions this. Their preference for oral and individual feedback may also be related to the lack of clarity of the required standards.

All students state that they only write down their feedback on paper, or just try to remember it. This makes it more difficult to revisit feedback and to transfer what they have learned from earlier feedback experiences. By asking students to reflect on feedback at specific times during the semester and by storing these reports in a student-centred portfolio, students are given the opportunity to easily revisit previous feedback experiences and conclusions at any point in their study. Since feedback literate students seem to welcome technology-enabled approaches to store, access and revisit feedback [5], such digital reflective reports can also be an opportunity to nurture self-regulatory learning behaviours and make students more aware of their current feedback opportunities [7].

4.2 Making judgments

When they are not cooperating as a team, students indicate that they do not rely on the competence of their peers to give feedback and see teacher feedback as the only valid input. The work of McConlogue [10] also shows a distrust of peers' ability to judge and argues that becoming a peer assessor is a long-term process where initial peer feedback should be withheld until students develop expertise in composing feedback. Contributing to peer feedback will help students to better self-evaluate their work by making comparisons with the work of others [10]. Since teachers' resources are limited, it is also important for feedback literature students to see peer feedback as a process that augments teacher feedback [2], [11]. Therefore, when introducing a peer feedback system, it will be essential to use a clear framework and to explain students how they should be assessing work and composing comments.

Students also indicate the difficulty of judging open exercises. They indicate their preference towards formative oral feedback to get confirmation that they are on the right track or to receive hints how to get on the right track. Having the opportunity to start a dialogue with a teacher makes it is easier to find out what the exact expectations are and how they can be met.

One student mentioned 'a moment of reflection' as a synonym for feedback. He indicated it improves the judgement of his own work, which is an important aspect of feedback literate students [5]. As stated earlier, the introduction of reflection reports can help students in developing these self-evaluating capacities over time.

4.3 Managing affect

During the discussion, students indicate that they are proactive by asking questions during on-campus activities and know that this is their own responsibility. During online activities they are reluctant to take this active role and to ask questions. However, when they are expecting feedback but do not receive it, they do not contact the teacher. According to Dawson et al. [3] timeliness to use feedback in subsequent work is a fundamental requirement for feedback to occur at all. Since our students explicitly mention timeliness and improvement of subsequent work as important, but not mention their own role in it, it appears they consider the timely provision of feedback and the opportunity to use it in their later work as a sole responsibility of the teaching staff. Therefore, they might miss an opportunity to use it in a different course or setting. While it is understandable to first-year students to be hesitant to contact a teacher, it can also be an opportunity to start a dialogue. Teachers must make students aware that they are always free to ask for feedback, especially if they are expecting it.

During the discussion, students did not express emotional discomfort towards receiving critical feedback. One student explicitly mentioned he does not mind getting criticized and does not even associate it with a negative feeling. However, they did state that critical feedback should always be accompanied by an opportunity to improve.

4.4 Taking action

When students receive feedback, most of them initially claim to feel a sense of obligation to respond to it in some way. When one student claims that deciding not to take feedback into account is also an action and a valid outcome, the other students agree on this reasoning. This conclusion may indicate that students in general now the purpose of feedback, but that they are not always sure how to use it if the feedback message does not clearly formulate an instruction on how to improve. Bearman et al. confirms that feedback might simply be ignored if students do not understand what to do differently [12]. Since Winstone et al. [9] indicates it is the responsibility of educators to challenge the students expectations on feedback by encouraging practices that promote self-regulation rather than dependence on explicit instruction, it is important for educators to give students the possibility to see how their feedback can be used in subsequent work.

5 CONCLUSIONS AND FURTHER DEVELOPMENTS

All students show their appreciation towards feedback and see continuous improvement as an important goal of feedback processes. They prefer a dialogue to avoid misinterpretation of the feedback message, so it is important that they have opportunities for these face-to-face discussions. Teachers also have to make students aware that they can ask for feedback when they expect it but do not receive it. Additionally, teachers should give students the possibility to take action by showing how feedback can be used in other work to prevent students from ignoring it.

To promote student feedback literacy in the future, it is important that students see peer feedback as an additional source of information, as they currently see teacher feedback as the only valid input. To build thrust in their peers' ability to judge, guiding students in assessing work and composing comments to peers will be essential. Additionally, contributing to peer feedback will help students to better self-evaluate their own work.

With the continuing focus to promote student feedback literacy, we will also introduce digital reflective reports at specific times during the semester. By capturing these reports in a student-centred portfolio, students will learn to work with feedback in a structured way and will have the opportunity to revisit previous experiences and conclusions at any point in their study.

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AN APPROACH TO MAPPING THE DEVELOPMENT OF PROFESSIONAL SKILLS IN A STRUCTURAL ENGINEERING PROGRAMME

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ABSTRACT

Engineers of the future will be presented with complicated, complex problems and their role in the development of sustainable solutions to global problems will become even more critical. Recent literature highlights the need for the development of a set of professional skills in order to address these challenges. These skills include technical, non-technical and attitudinal skills. This paper describes a case study of a whole-of-programme review of teaching and assessment of professional skills in a structural engineering programme. In a systematic process, lecturing staff mapped the modules they teach against a set of professional skills, which were distilled from literature review. The programme map was then analysed to provide insight into the depth to which professional skills are being taught and assessed. This analysis underpinned a review of the teaching of professional skills and led to the identification of both gaps and opportunities to introduce new learning outcomes, teaching activities and assessment techniques.

1 INTRODUCTION

This paper presents the methodology and findings from the second work package of a project which aims to “design our structural engineering programme so that students can develop skills which will enable them to become exemplary structural engineers with a focus on the future of our planet and it’s people.” This work package involves a whole-of-programme review of the teaching and assessment of these skills in a structural engineering programme at TU Dublin.

The aims of this study are to provide insights into the depth to which these skills are currently being taught and assessed in our programme and to identify gaps and opportunities in the programme.

1.1 Skills Development Need

It is clear from the literature that there is little consensus on which skills are most important in an engineering degree programme [1], [2], [3]. This debate has been ongoing since the 1800’s [4]. The role of the engineer is changing and becoming more complex. The societal view of the engineer is broadening from merely being seen as a technical expert. Engineers are dealing with “wicked” problems, and need a range of professional skills in order to solve these wicked problems [5], [6], [7], [8].

Third level institutes are increasingly concerned with ensuring that their students develop skills and attributes which not only prepare them for the world of work, but also better equip them as members of society. Given the climate crisis we are living through, education focus has shifted towards sustainability and the complex problems faced by society. Engineering education has a major role to play here, as it is important that students develop the tools to tackle complex problems, gain awareness of how engineers can affect climate change and attain the skills needed to develop sustainable engineering solutions [9]. It is recognised that graduates need to actively experience, construct and practice in this area in order to build competence [6]. This challenge can be considered an opportunity for those graduates with the correct balance of strong social, professional and technical skills [10].

The design of the engineering programme at TUDublin is influenced by the accreditation requirements of Engineers Ireland [11] and a new University Strategic Plan [12]. Engineers Ireland is the accrediting body for engineering degree programmes in Ireland and launched a new set of accreditation criteria in January 2021 [11]. The programme outcomes have been broadened with a focus on sustainability, engineering management and teamwork and communication and now include specific aspects of ethical use of technology and data and equality, diversity and inclusion in professional practice.

The University Strategic Plan [12] is based on the concept of three pillars: People, Planet and Partnerships with some parallels to the three pillar model of sustainable development (environmental impact, social impact and economic impact) [13]. The plan commits us to developing responsible global citizens in our students, by facilitating learning and knowledge creation and instilling a sustainability mindset in our students and staff.

Work package 1 that preceded this study involved a review of recent literature alongside chartership requirements of the Institution of Structural Engineers (IStructE) and Engineers Ireland (EI) as well as three seminal consultation and analysis reports on the future skills in the sector. This led to the identification of seven traditional and emerging professional skills presented later in the paper [14].

2 METHODOLOGY

2.1 Programme Structure

The programme assessed in this study is a four year Honours Degree in Structural Engineering. The degree programme has a common entry first year where students learn the fundamentals of a wide range of subjects including civil, mechanical and electrical engineering. In second year, students may choose the civil and structural engineering stream. In third year students specialise further into the civil or structural engineering stream. The analysis of the programme began at Year 2 where the students have selected to follow a career in civil or structural engineering and from the structural engineering stream from Year 3 onward.

A high level overview of the current curriculum is provided in Figure 1. All modules are 5ECTS credit modules unless noted otherwise. Year 1 is shown greyed out as it has not been included in the analysis described in this paper.

2.2 Future Skills

Work package 1 identified a list of 7 professional skills required by future structural engineers. These skills were categorised as follows: **Technical**, which includes Core Technical Skills and Technology and Digitisation, **Non-Technical**, which includes

	Engineering Common Entry	Civil and Structural Engineering Stream	Structural Engineering Stream	
Subject Stream	Year 1	Year 2	Year 3	Year 4
Maths	Mathematics 1	Mathematics 21	Mathematics 31	Mathematics 41
		Mathematics 22	Mathematics 32	
Analysis	Physics	Engineering Analysis 21	Structural Analysis 31	Structural Analysis 41
		Structural Analysis 22	Structural Analysis 32	
Mechanics	Mechanics	Fluid Mechanics	Mechanics of Materials 31	Mechanics of Materials 41
		Mechanics of Materials 21	Mechanics of Materials 32	
		Mechanics of Materials 22		
Professional Development	Professional Practice	Professional Development 2	Professional Development 3	Const. Management and Economics 42
Design Studio	Design Projects	Construction Technology	Design Project 3	Scheme Design 4* 10ECTS CREDITS
Other Subjects	Tech Graphics	Concrete Technology	Design of Steel & Conc 3	Design of Steel & Conc 4
	Chemistry	Surveying	Geotechnical 31	Highway Engineering 42
	Computing		Geotechnical 32	Final Year Project* 15ECTS CREDITS
	Instrumentation		Environmental Engineering	
	ElectroTech			

Fig. 1: Modules within the programme differentiated by stream.

Communication, Management and Engineering Practice and **Attitudes**, which includes Sustainability and Societal skills. The definitions were co-created with structural engineering students and are as follows [14]:

- **Core Technical**: has a strong grounding in mathematics and science within structural engineering. This includes the fundamental principles of structural engineering, material behaviour, engineering equations and problem solving.
- **Technology and Digitisation**: is able to learn and use new technologies and digital advancements in analysis, testing, communication and collaboration.

- **Communication:** can effectively exchange information through a variety of diverse means and with diverse groups in various settings and circumstances.
- **Management:** can manage themselves and others in keeping on track towards an end goal.
- **Engineering Practice:** understands and follows the protocols, processes, rules and regulations of practicing within this field.
- **Sustainability**: has a working knowledge of the impact of design choices on sustainability and targets the reduction of impact on the planet and its natural resources.
- **Societal**: has an understanding of how they can impact society either directly or indirectly, and makes efforts to give back to the community, understanding the inseparability of structure or structural engineering practices and people and place.

2.3 Survey

The skills identified were then used in a survey of lecturing staff to identify where within the current curriculum the students are provided with the opportunity to develop these skills and whether the skills are assessed. 11 of a total of 17 lecturers participated in the study. Lecturers were provided with the definitions and action learning sets developed in Work Package 1 for each skill.

Question 1 asked *"Do you think the student has an opportunity to develop this skill while completing this module?"* The options were *Yes*, *Yes But Limited* and *No*. This question was asked in order to provide insights into what skills we are currently developing in our modules.

Question 2 asked *"If yes, what aspect of the module &/or assessment aids the student to develop this skill?"* This question allowed us to further understand the extent of teaching and assessment of each skill and the relative importance of each skill within each module.

3 RESULTS

The results of the survey were initially compiled in a heat map The opportunity to develop each skill was assessed using a pie chart for each year. Figures 2,4 and 6 show pie charts split between the 7 professional skills based on answers to Question 1. An answer of 'Yes' to Question 1, means that the skill was explicitly taught and assessed. An answer of 'Yes, limited' means that while the skill may have been taught, it was not explicitly assessed. Modules were weighted based on the number of ECTS credits available for the module. When compiling the pie chart for a 5 ECTS module, answers of 'Yes' were given a value of 1, answers of 'Yes, limited' were given a value of 0.5 and answers of 'No' were given a value of 0. For 10 and 15 ECTS credit modules, these values were increased by a factor of 2 and 3 respectively. This gave insights into which skills were being given the most and least opportunities to be developed.

Figures 3,5 and 7 show the corresponding bar charts for each year. These charts were produced to assess the percentage of modules where the opportunity to develop a skill exists versus the percentage of modules where the skill is actually assessed.

3.1 Limitations

It is recognised that not all lecturers responsible for the delivery of modules participated in the study, furthermore the results of the survey rely on the opinion of the lecturer in terms of the extent to which the skill is developed and the categorisation of subject material or activities into skills. The weightings applied to answers in Question 1 are somewhat arbitrary and were chosen by the authors to allow a high level overview of skills development opportunities in the course to take place. The survey did not assess the student's level of performance in these skills or the stages of skill development across various years.

4 DISCUSSION AND CONCLUSIONS

From Figures 2,4 and 6 it is clear to see that the opportunities for development of each skill is quite dispersed and one skill is not totally dominant. This is somewhat surprising given the technical nature of all but one subjects in each year. Below is a brief discussion of the opportunities for development of each skill.

Core Technical: From Figures 2,4 and 6, we can see that the greatest opportunities for skill development lie in Core Technical Skills. From Figures 3,5 and 7 we can see that there is an opportunity to develop Core Technical skills in almost all modules in each year. There is no significant drop off when looking at whether the skill is assessed, as Core Technical skills are a major focus of most modules.

Technology and Digitisation: The opportunity for development of this skill appears in 50% of modules in year 2, 83% of modules in year 3 and 67% of modules in year 4. Unsurprisingly, we can see a large drop off when looking at where the skill is actually assessed. This stems from the fact that technology is merely used as a communication tool in some instances. As an illustration, where a lecturer gave a Yes response to Question 1, in Question 2 they stated, "*The lab exercises include the use of structural analysis software".*

Communication: From Figures 2,4 and 6, we can see that there is an opportunity provided to students to develop Communication skills to some degree in 100% of subjects in 2nd year, 83% in 3rd year and 92% in 4th year. This is somewhat surprising given industry criticism of graduate skills in this area. When we look at where the skill is actually assessed, Communication drops significantly. This is unsurprising as these skills may form part of modules but may not be a major component of assessment.

Management: From Figures 2, 4 and 6, for an engineering degree, there would appear to be consistent opportunities in each year to gain skills in this area. Referring to Figures 3, 5 and 7, these skills are also assessed in 25% of modules in 2nd year and 3rd year and 42% of modules in 4th year.

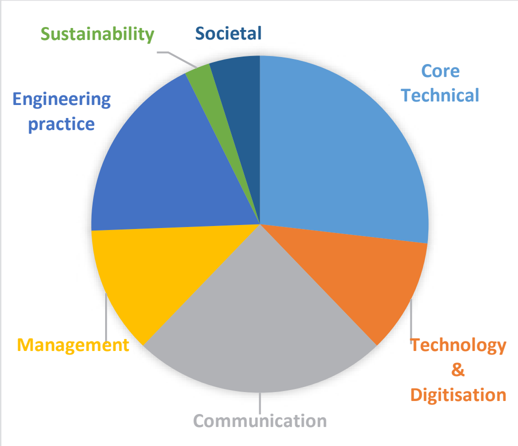

Fig. 2. Year 2 – Opportunities for skills development within modules

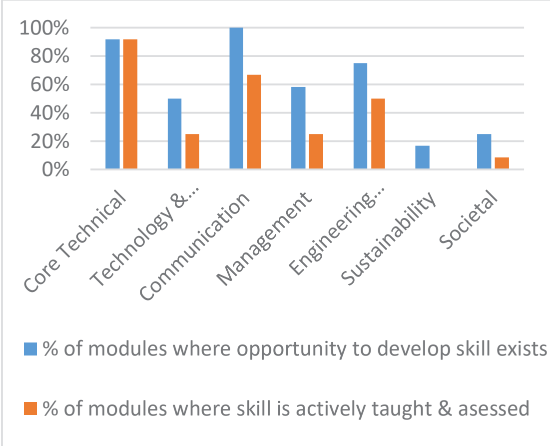

Fig 3. Year 2 - Comparison of opportunity for skills development and current assessment

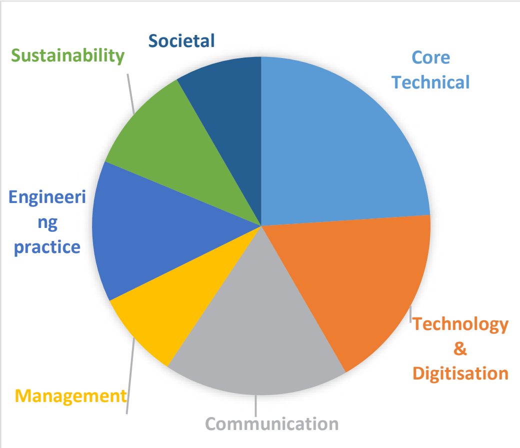

Fig. 4. Year 3 – Opportunities for skills development within modules

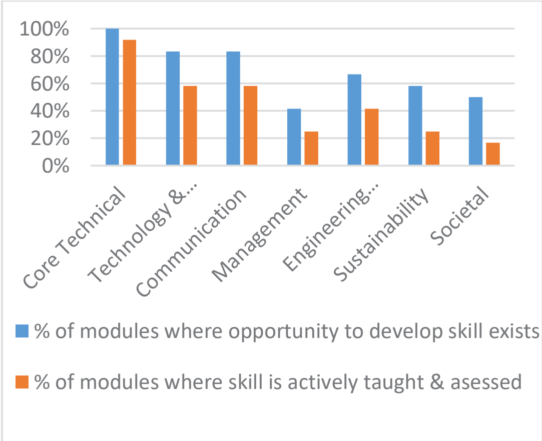

Fig 5. Year 3 - Comparison of opportunity for skills development and current assessment

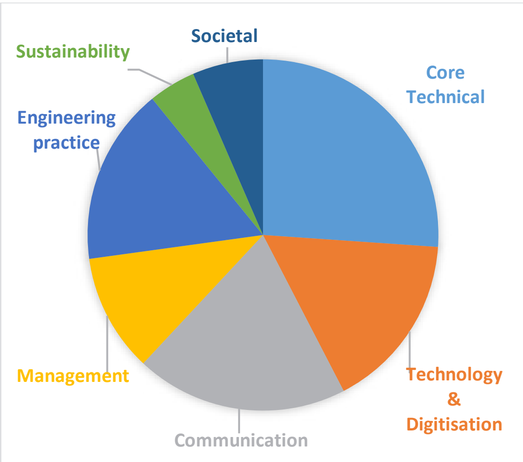

Fig. 6 .Year 4 – Opportunities for skills development within modules

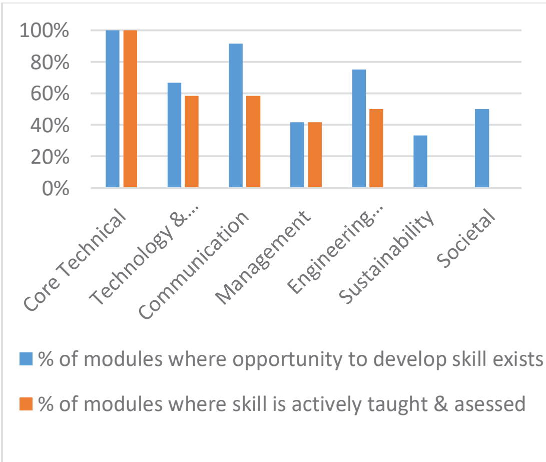

Fig 7. Year 4 - Comparison of opportunity for skills development and current assessment

Engineering Practice: From Figures 2, 4 and 6, the opportunity to develop skills in Engineering practice holds a consistently strong share among other skills. It's relative share drops from 2^{nd} to 3^{rd} year and only partially rebounds in 4^{th} year. This is somewhat surprising as one might assume that opportunities to mimic the work of an engineer would increase through the years.

Sustainability: From Figures 2, 4, and 6, it is clear that while Sustainability forms an active part of the curriculum in 3^{nd} year, it currently forms a very small component in 2^{nd} and 4^{th} year. We can see From Figures 3, 5, and 7 that sustainability is not explicitly assessed in these years.

Societal: From figures 2, 4, and 6 it is clear that while Societal fares slightly better than Sustainability, it is the second last ranked skill in terms of opportunity for development. We can see from Figure 7 that Societal is not explicitly assessed in this year.

When looking at the course overall, there is a good distribution of skills development. When ranking skills development opportunities, the following is the order observed from the survey: 1-Core Technical, 2-Communication, 3-Engineering Practice, 4-Technology and Digitisation, 5-Management, 6-Societal and 7-Sustainability.

A key question that the literature does not answer is, how much opportunity should be provided in an engineering programme to each of these skills? Based on the authors' experience, in the past, this outcome would seem largely appropriate. However, one of our aims is to orientate the views of the student towards the challenges of the future of our planet and it's people. Therefore, it is clear that there is a need to embed more opportunities in the course to develop societal and sustainability skills. A sustainability module has been identified as an immediate requirement as well as further developing a society and sustainability thread throughout each year. Also, the assessment of these skills is a clear priority given the very low survey results in the assessment of these skills, as it is well established that assessment drives learning.

4.1 Future Research

The next stage of this research involves a review of the development of these skills and their threads through the years with reference to the results of Question 2 of this study. This will inform the development of new learning outcomes, teaching activities and assessment techniques in the areas of societal and sustainability skills and will provide a clearer picture as to where the skills need to be integrated into the existing programme.

5 SUMMARY AND ACKNOWLEDGEMENTS

This study was undertaken to create a picture of the content of our current programme in an effort to identify opportunities where there could be a rebalance of the skills that would prepare our structural engineers for the future. What emerges is a reassurance that there is already an acknowledgment of the balance of skills needed, but more exciting, that there is an openness from the lecturing staff as to the opportunities for skills development, in particular in relation to the concepts of society and sustainability.

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THE RELATION BETWEEN AUTONOMY AND WELL-BEING IN HIGHER EDUCATION STUDENTS DURING THE COVID-19 PANDEMIC

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Conference Key Areas: *Social Aspects and Communication in Online Learning, Essential Elements for the Online Learning Success*

Keywords: *autonomy, well-being, online learning, pandemic*

ABSTRACT

During the COVID-19 pandemic, higher education has drastically moved online, which has increased the importance of autonomous learning by students. A decrease in students' well-being has meanwhile been registered across the globe. In this study, we examine which learning characteristics increase student well-being under the pandemic constraints. We investigate students' well-being, specifically burnout, amotivation, and study engagement, and their relation to learning autonomy. Two types of autonomy were included: autonomy at the student-level and autonomy at the instructor-level, measured via the instructors' communication and support provided for online learning. Our analyses show that amotivation and burnout correlated negatively with both kinds of autonomy. Similarly, student engagement correlated positively with both kinds of autonomy. A multiple regression showed that student-level autonomy was the only variable to significantly predict all three well-being variables, while instructor support predicted only study engagement and burnout. Instructor communication did not predict any well-being variables. Implications, limitations, and future directions for the role of autonomy in online learning are discussed.

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1 INTRODUCTION

Well-being and mental health levels have decreased significantly during the current COVID-19 pandemic. This decrease has been confirmed across the globe, including samples from Hong Kong, United Kingdom, Spain, United States, Denmark[1], and Bangladesh[2]. The pandemic has also forced higher educational institutions to move online at short notice. A study[3] found that most faculties and administrators have started transitioning towards online teaching methods, even if they did not have any previous experience with them. Social distancing policies have led to less face-to-face, direct support from the educational staff.

For online learning to take place, students need to become autonomous/independent learners[4]. Autonomy is also one of the main tenets of self-determination theory, which asserts that basic psychological needs must be met for higher motivation, self-development, and well-being to be achieved[5][6][7]. Two other important factors are relatedness and competence[5][6][7]. When the need for autonomy is met, students become more motivated and more likely to demonstrate higher study engagement, which leads to higher performance[6][8][9]. High levels of autonomy also have a positive effect on well-being factors such as lower levels of burnout[10]. Autonomy is usually measured at the student-level, describing how students perceive their autonomy when studying. However, autonomy is a dynamic, socially defined construct[5][11]. This implies that to get a better understanding of its effects, we also need to look at how students interact with their instructor and environment.

In this study, we explore how students' self-reported autonomy had an impact on their motivation and well-being, measured via amotivation, study engagement, and burnout, during the COVID-19 pandemic. We also consider how students' instructors supported and communicated with students to facilitate their autonomy when studying. Such interaction between the students and instructors has been confirmed to have a positive impact on their autonomy[9][11][12]. Thus, we made a clear distinction between self-reported student-level autonomy, and instructor-level autonomy, conceptualized as instructor support and communication. Our research question is: What is the relation between student-level and instructor-level autonomy, and well-being during the COVID-19 pandemic? We hypothesized that student-level autonomy and instructor-level autonomy had a positive relation with each other and with study engagement. Student-level, instructor-level autonomy, and study engagement had a negative relation to amotivation and burnout. We also expected that student-level autonomy and instructor-level autonomy positively predicted study engagement, and negatively predicted amotivation and burnout.

2 METHODOLOGY

1.1 PARTICIPANTS

Participants were recruited using a random sampling method and included all students of one faculty (three bachelor's and four master's programs) at Eindhoven University of Technology. Data were collected through a self-reported questionnaire, at two different points in time: between November and February 2021 for the 1st and 2nd quartile of the 2020-2021 academic year. A total sample of N = 2404 was recorded, with a final sample of N = 1231, after removing incomplete observations (N_{Q1}= 617, N_{Q2}= 616). The data collection was approved by the ethical committee of the university.

2.2 MEASURES

The survey consisted of a wide variety of questions related to students' well-being as well as course-specific perceptions. Below, only the questionnaires analyzed in the current study are discussed. The well-being of the students was conceptualized through amotivation, measured via 4 items (ex. "I really felt that I was wasting my time at university") with a Cronbach's α= .90, burnout via 8 items (ex. "While I was studying, I often felt emotionally drained") with α= .87, and study engagement via 4 items (ex. "I was immersed in my studies") with α= .90. Autonomy was measured at the student-level via 5 items (ex. "I could decide on my own what to work on during the course weeks") with α= .68, and at instructor-level through instructor communication, 3 items (ex. "Overall, the instructor for this course helped to keep students engaged and participating in productive dialog") with α= .85, and through instructor support, 3 items (ex. "The teacher actively facilitated my understanding of the learning materials") with α= .71. All items were measured on 1-7 Likert scales.

2.3 STATISTICAL ANALYSES

Descriptive analyses were used to obtain characteristics of the sample. Bivariate correlations were used to assess relations between student-level autonomy, instructor support, instructor communication, amotivation, burnout, and study engagement. We used three multiple regression analyses to predict amotivation, burnout, and study engagement, respectively. For each, the predictors were student-level autonomy, instructor support, and instructor communication. The estimates of the strengths of associations were demonstrated by the standardized β coefficient with a 95% confidence interval (CI). A p-value of ≤.05 was considered significant.

3 RESULTS

3.1 DESCRIPTIVE VALUES

Table 1 shows the descriptive values of all variables. These values show that the means change across quartiles, but only slightly. Burnout and amotivation increased between Q1 and Q2 of the 2020-2021 academic year, while study engagement decreased. We found all three autonomy measurements decreased from Q1 to Q2 of the 2020-2021 academic year. We will follow-up on these findings with correlation analyses.

Table 1. Means and Standard Deviations of All Study Variables Across Four Quartiles

	Q1 2020-2021 (n=617)			*Q2 2020-2021 (n=616)*		
Variable	*n*	M	SD	n	M	*SD*
Student Autonomy	617	4.91	0.84	616	4.84	0.90
Instructor Support	616	4.63	1.17	615	4.26	1.18
Instructor Communication	616	4.71	1.29	616	4.51	1.31
Burnout	617	4.16	1.05	493	4.51	1.13
Study engagement	617	3.98	1.01	493	3.68	1.11
Amotivation	617	2.31	1.29	493	2.55	1.49

3.2 CORRELATIONS

Table 2 shows the correlations between the measured variables. Almost all correlations were significant, which is no surprise given the large sample size. The well-being variables correlated as expected: study engagement negatively with burnout (r(1107)= -.53, p< .001) and amotivation (r(1107)= -.41, p< .001), while burnout and amotivation correlated positively with each other (r(1107)= .39, p< .001). According to Cohen's rule of thumbs, these three correlations can be considered medium to high. Study engagement correlated positively with student autonomy (r(1107)= .34, p< .001) and both instructor communication (r(1106)= .15, p< .001) and support (r(1106)= .19, p< .001). As we can see, study engagement has a medium relation with student-level autonomy, but small to medium with instructor-level autonomy. Amotivation had a medium to high negative correlation with student-level autonomy (r(1107)= -.34, p< .001) but small negative correlation with instructor support (r(1106)= -.09, p= .003) and a non-significant correlation with instructor communication (r(1106)= -.06, p= 053). Burnout had a medium to large negative correlation with student-level autonomy ($r(1107)= -.38$, $p< .001$) and small to medium negative correlation with instructor support ($r(1106)= -.15$, $p< .001$) and with instructor communication ($r(1106)= -.09$, $p= .004$). Student-level autonomy had small to medium positive correlations with instructor support ($r(1229)= .19$, $p< .001$) and instructor communication ($r(1229)= .13$, $p< .001$). Instructor support and instructor communication positively correlated with each other ($r(1230)= .64$, $p< .001$). These correlations show that student-level autonomy had medium to large effect sizes with all three well-being variables, while instructor support and instructor communication only small to medium effect sizes. We found a non-significant relation between instructor communication and amotivation. Student-level autonomy also had small to medium effect sizes with instructor support and instructor communication.

Table 2. Pairwise Correlations Between the Variables, and Sample Sizes

Variables	*1*	*2*	*3*	*4*	*5*	*6*
1. Study engagement						
2. Amotivation	-.41*** 1108					
3. Burnout	-.53*** 1108	.39*** 1108				
4. Student Autonomy	.34*** 1108	- .34*** 1108	-.38*** 1108			
5. Instructor support	.19*** 1107	-.09*** 1107	- .15*** 1107	.19*** 1230		
6.Instructor communication	.15*** 1107	-.06 1107	-.09** 1107	.13*** 1230	.64*** 1230	

*p< .05, **p< .01, ***p< .001

3.3 MULTIPLE REGRESSION ANALYSES

First, a multiple regression analysis was calculated to predict study engagement based on student-level autonomy, instructor support, and instructor communication. The regression was significant ($F(3, 1105)= 58.87$, $p< .001$) with an adjusted $R^2= .14$. Student-level autonomy ($\beta= .32$, $t= 11.28$, $p< .001$) and instructor support ($\beta= .09$, $t= 2.56$, $p= .011$) had significant effects. Student-level autonomy and instructor support significantly predicted study engagement, explaining 14% of the variability. Student-level autonomy had the highest effect size of the two significant relations. A second multiple regression analysis was calculated to predict amotivation based on the three autonomy variables. The regression was significant ($F(3, 1105)= 49.86$, $p< .001$) with an adjusted $R^2= .12$. Student autonomy ($\beta= -.34$, $t= -11.81$, $p< .001$) was the only significant predictor. The model explained 12% of the variability with only one significant predictor. Finally, a multiple regression analysis was calculated to predict burnout based on the three autonomy variables. The regression was significant ($F(3, 1105)= 65.67$, $p< .001$) with an adjusted $R^2= .15$. Student autonomy ($\beta= -.36$, $t= -12.89$, $p< .001$) and instructor support ($\beta= -.09$, $t= -2.56$, $p= .012$) had significant effects. The model explained 15% of the variability, the highest amount of the three variables we predicted, with two significant predictors. The results partially confirmed our hypotheses, as student autonomy significantly predicted all three well-being variables, while instructor communication did not predict any. Instructor support significantly predicted study engagement and burnout. The explained variance ranged between 12% for amotivation to 15% for burnout.

4.1 DISCUSSION

Our study took place during the COVID-19 pandemic, a difficult time that changed how higher education approached learning. Our aim was to study the relation between the learning autonomy of higher education students with their mental well-being. We found autonomy, both at the student and the instructor-level, to have negative relations with burnout and amotivation, and positive relations with study engagement. Our findings support our hypotheses, showing that autonomy, both at the student and at the instructor-level, is important to consider when looking at students' well-being. Autonomy is essential in becoming intrinsically motivated. Such motivation contributes to a student becoming actively involved in learning and internalizing their goals[7]. Study engagement and higher well-being in general are direct consequences when the need for autonomy is met. Our findings fall in line with previous findings, as we found that autonomy at the student-level was the strongest predictor of study engagement, burnout, and amotivation in our study. Student-level autonomy was the only variable to significantly predict amotivation, burnout, as well as study engagement. This shows that autonomy, as perceived by the student, is the most important facet when looking at general learning autonomy. This has various implications when approaching autonomous studying online as a whole. It can be that the environment and instructor lead to the perfect autonomous learning, but students can still feel controlled and underperform. This implies that autonomy targeted practices need to put the students and their beliefs at the forefront.

Online courses give teachers the role of facilitators more than anything. This means that their communication is essential as they can directly encourage students, or indirectly by acknowledging students' accomplishments. The feedback provided by instructors can also play a role in supporting students in their learning. We found that instructors' support did play a direct role when predicting study engagement and burnout of their students. This refers especially to the techniques that instructors applied during courses, such as appropriate feedback and useful Q&A sessions. Each course has different demands, but also provides different resources for students to efficiently meet those demands. Resources can be directly relevant to the courses' demands, such as feedback and Q&A sessions, but there are also indirect resources, such as general non-directed communication between students and the course instructor. Our findings show that providing directly course relevant resources has a higher impact on well-being than providing indirect resources. Since both measurements looked at how the instructor interacted with the students, we can see that the type of contact and its perceived effectiveness played a higher role in well-being than general communication. Students respond more positively to approaches which target course relevant questions and want their communication with the instructor to be meaningful and helpful. However, both forms of interactions between instructors and students are strongly interconnected; these variables had the highest correlation in our study. It is expected that they share a high amount of variance, and we advise that future studies consider them together. Resources such as support and communication provided by the instructors is easier to address and can be changed more easily compared to self-reported student autonomy, providing a good target for future policies.

These variables represent only two of possible ways in which instructors can enhance students' autonomy and performance. Instructors' feedback and lectures are important in the online environment, but the way in which instructors react and communicate with their students is more important. These seem to go hand in hand, but a clear difference can be made between method and quality. We found instructor support to be more important when predicting students' well-being than general communication. Support is still a form of communication, but more direct and focused specific on the course content and learning outcomes. Thus, we argue that beyond the common ways in which teachers keep in contact with their students, they can play a bigger role in students' well-being by focusing more on direct, relevant feedback. This aspect is important since meetings can take place easier and more often online, due to their accessibility and convenience, but their number or type should not be used as an indicator of their effect on students. The COVID-19 pandemic offers a good justification to try out different ways of connecting students to their teachers, but the content and its quality should be emphasized and kept in mind when such interactions take place.

4.2 LIMITATIONS

The study took place over half an academic year during the pandemic. While it has a large scale, it still suffers from various shortcomings. A definite one is that teachers have different objectives and employ different structures from each other when organizing a course. This can affect the amount but especially the type of communication and support instructors offer. For example, less lectures could mean less communication and less support, but the same course could have different methods to communicate and support students, such as higher number of short, small group meetings with the coordinator, more regular announcements and Q&As, and more literature with specific weekly goals provided. Such differences need to be accounted for when looking at instructor-level autonomy to better understand how it contributes to students' autonomy when studying. The way in which autonomy was measured in the current survey might also have implications for our results. Self-reported student autonomy seems a straightforward way to measure it, but its interpretation is highly dependent on students' view of their own learning behavior. This can be affected by previous learning experiences, learning strategies, time management, and individual goals. Similarly, while we know that the learning environment plays an important role in students' autonomy, it is not clear yet how to measure such an interaction and what is the exact role of the instructor in the environment. Teacher support and communication are a good measure for autonomy supportive variables, but they are not the only ones.

4.2 FUTURE DIRECTIONS

We emphasized the important role that teachers play in their students' well-being, but it is important to keep in mind that the most important factor is how students themselves perceive their autonomy when learning. This brings the problem at a more individual level. While there are certain methods already in practice on how to keep students' autonomy at a high level, mostly through the teacher[9][12], they are hard to adapt to each student. Future research should approach the problem and address autonomy directly, at an individual level. While instructors' communication did not significantly predict any of the well-being variables when controlling for student-level autonomy and instructor support, it did positively correlate with well-being and the other forms of autonomy. Communication could be mediated by other forms of autonomy, acting as a platform on how support is provided or even enhancing it. A similar argument can be formulated around instructor-level autonomy all together. Instructor-level autonomy could be a mediator between student-level autonomy and well-being. Further research is needed to examine its exact role.

4.3 CONCLUSION

To conclude, students' autonomy plays an essential role when looking at their well-being and motivation. Instructors' support should especially be considered when trying to reach such objectives during times of social distancing and online learning. Although the instructor communication is important, it plays a lesser role than relevant, direct support regarding learning materials. Educational policies, especially those related to online learning, need to approach such aspects explicitly. Employed techniques need to help teachers understand the importance of autonomy and how their academic interactions can play major roles in well-being and motivation of students.

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A STRUCTURAL EQUATION APPROACH TO INVESTIGATE DIFFERENT CONSTRUCTS OF PROFESSIONAL IDENTITY DEVELOPMENT FOR ENGINEERING STUDENTS

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ABSTRACT

Many engineering students experience difficulties in their professional career orientation as a result of the large number of career options presented in the broad engineering field. This has been linked to a hampered school-to-work transition and difficulties in career decision-making. Successful stimulation of a professional identity can be achieved by providing career guidance that aims to promote several key constructs underlying identity development, including *career exploration*, *awareness,* and *confidence*. This provides students with both a vocational and self-sense that prepares them better for their future career. Previous researchers often focused on a restricted set of underlying constructs, mostly in non-engineering students. This study overcomes these limitations with an in-depth analysis that examines five constructs simultaneously to contribute to a more general view of professional identity. By using structural equation modeling on the survey data, we aim to provide insights in the overall interplay of the constructs in the specific context of 624 Belgian engineering students at KU Leuven. We determine correlations between constructs and examine how these constructs differ for several personal variables. Results indicate substantial interconstruct correlations with construct differences for the phase of study, vocational

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interest, engineering persistence, and a small effect for parental occupation, but no effects for gender. These results contribute to a more general understanding of the professional identity of engineering students and the implications for career guidance during their education.

1 INTRODUCTION

Deciding on a future career is considered one of the most important decisions students have to make [1]. However, engineering students often experience difficulties in this process. Several problems have been linked to this difficult orientation. First, some engineering students lack an understanding of the engineering profession or what it requires to be an engineer, and are not aware of the myriad career options [2]. Second, the engineering education seems to show a low cohesion with the professional world as student's values, skills and expectations do not always align with practice. These problems hamper their career orientation and their transition from academia to the engineering world [3].

The development of a professional identity can support the career orientation. Developing such an identity is the fundamental aim of educational career guidance [4], thereby facilitating the professional transition. In this process, a good understanding of the professional engineering identity is required, along with the needs of the engineering students.

When focusing on identity research in engineering education, several limitations in the current body of literature are observerd [5]. First, research on professional identity in engineering is scarce. Earlier research mainly focused on non-engineering students. Second, professional identity is considered a multifaceted concept. However, most studies have focused on specific aspects of professional identity which hindered to fully understand its broad scope. The purpose of this study is to provide a more comprehensive view on the professional identity of engineering students. Improving its understanding can contribute to essential career guidance.

2 BACKGROUND

2.1 Professional identity: a multiconstruct concept

In the process of professional identity development, students gain personal and vocational knowledge that allows them to identify their abilities, interests and aspirations and let them align these with the vocational possibilities and their required competencies [4]. An important aspect of professional identity for career guidance is its multifaceted characteristic. Namely, it is widely recognized that professional identity development is guided by several underlying constructs, including *career exploration*, *career awareness*, and *career confidence*, among others. (1) *Career exploration* reflects the behaviors associated with the information gathering to build one's vocational knowledge [6]. (2) *Career awareness* shows one's knowledge and understanding of the vocational possibilities and the associated competencies [7]. In this study, the construct of *career awareness* was operationalised by *professional roles awareness* and *competence awareness*, which has proven relevance before [8]. These constructs are based on Craps *et al*. (2021) who developed a competency based professional role model for future engineers comprising product leadership (focus on radical innovation), operational excellence (focus on process and product optimisation) and customer intimacy (focus on client tailored solutions), and their required non-technical competencies [9]. (3) *Career confidence*, here again conceptualized as *professional role confidence*, covers two subconstructs as reported by Cech *et al*. (2011): *role-fit confidence* and *competence confidence*, referring to the confidence that a professional engineering role corresponds to one's interests and values, and the confidence in one's skills required for that role [10].

2.2 Professional identity differs over personal factors

A second important aspect regarding professional identity is that construct differences exist between students regarding multiple personal factors such as their socio-economic status [11], phase of study [12], family support [13], gender [14,15], or persistence in an engineering career [10]. However, these factors have been mostly identified throughout studies with non-engineering students.

2.3 Professional identity and career guidance

Both the construct associations and the personal variables affect the implementation of educational career guidance. First, career guidance programmes can be designed to specifically focus on desired aspects of professional identity. Second, the presence of personal factors clarify that guidance can vary according to the needs of the corresponding target group. Such adequate career guidance for engineering students relies on a clear understanding of their professional identity.

3 AIM OF THE STUDY

This study aims to contribute to the comprehensive understanding of professional identity in engineering education by simultaneously focusing on multiple identity constructs within the same cohort of students. Our research focus is to, first, examine the association structure between the constructs, and second, determine construct differences for five personal variables, i.e. gender, parental occupation, the phase of study, vocational interest, and persistence in engineering careers using structural equation modeling techniques. In the final section, we discuss some supportive insights for educational career guidance.

4 METHODOLOGY

4.1 Participants

Survey data was collected from 624 engineering students of the Faculty of Engineering Technology at KU Leuven in Belgium. Participants were predominantly male (85% vs 15%), which corresponds with the university's engineering population. All possible phases of study were included: first bachelor year (32%), second bachelor year (22%), third bachelor year (23%), the master year (17%), and a transfer programme prior to the Master's programme for graduates of technical University College (6%). Ethical approval was sought and obtained for this study from our university's Ethics Committee (G-2019 03 1596) and participants have consented to be part of this research. They were informed that their participation was voluntary and that the analysis would be conducted anonymously.

4.2 Survey

Data was collected cross-sectionally via a 10-minute electronic survey using Qualitrics. Students participated in May 2019 or 2020. In a first part of the survey, five sets of Likert scale questions were implemented, each probing the student's attitude towards one of the five professional identity constructs: (1) *Career exploration* (8 questions, Cronbach's alpha: 0.83) probed the extend of different information seeking behaviors (e.g. "I go to job fairs or company events"). (2) *Professional roles awareness* (3 questions, Cronbach's alpha: 0.57) probed their understanding of the professional engineering roles (e.g. "I understand the description of the engineering roles"). (3) *Competence awareness* (4 questions, Cronbach's alpha: 0.52) probed their understanding of the competencies associated with the professional engineering roles (e.g. "I recognize most of the competencies in the professional roles model"). (4) *Role-fit confidence* (6 questions, Cronbach's alpha: 0.75) probed the confidence towards their desired engineering role (e.g. "The engineering role I chose is the most suitable one for me"). (5) *Competence confidence* (4 questions, Cronbach's alpha: 0.53) probed the confidence in their non-technical skills (e.g. "I possess the required non-technical competencies to grow in this engineering role"). This, and *role-fit confidence*, was based on the survey of Cech *et al*. (2011).

In a second part, the following background information was collected for five personal variables. One survey question indicated whether the student could identify with one or a combination of the professional engineering roles as developed by Craps *et al*. (2021) ('yes': 84%, 'no': 16%), this variable is referred to as vocational interest. Other questions asked whether one of the parents was an engineer ('yes': 29%, 'no': 71%), or whether the student considered another job outside engineering ('yes': 16%, 'no': 37%, 'sometimes': 47%), which represent parental occupation and engineering persistence respectively. Gender information and the phase of study were provided by the university.

4.3 Statistical analysis

The constructs were operationalized according to the exploratory factor model developed by De Boever *et al.* (2021) [16]. First, a confirmatory factor analysis (CFA) was employed to validate this factor model, and second, construct differences were examined for five personal variables using structural equation modeling (SEM). This was performed by including the variables gender, parental occupation, phase of study, vocational interest, and engineering persistence in the CFA model. Both the CFA and SEM used 20 multiply imputated datasets to account for missingness, which maximally amounted 15% in the survey. The model fit was assessed using the averaged model fit indices for the comparative fit index (CFI), Tucker-Lewis index (TLI), root mean squared error of approximation (RMSEA), and standardized root mean squared residual (SRMR). Values above 0.90 for CFI and TLI, and values below 0.08 for RMSEA and SRMR signified a well-fitting model [17]. Ordinal categorical CFA and SEM were used because of the categorical nature of the Likert scales, which employed polychoric correlations and the diagonally weighted least squares (DWLS) estimator. Reported factor loadings were obtained using standardized factors only, which for categorical variables in the SEM indicate the difference in standardized construct level for a respective group compared to the reference group. The mice package [18] in Rstudio was used for multiple imputation, and the semTools package [19] was used to perform the CFA and SEM on the multiply imputed data.

5 RESULTS

5.1 Professional identity constructs are considerably correlated

Based on unsatisfactory modification indices exceeding a value of 20, three error correlations were introduced in the CFA model between survey items with linguistic similarities, which improved the model with an adequate fit (initial vs final: CFI=0.955 vs 0.972, TLI=0.949 vs 0.968, RMSEA=0.057 vs 0.046, SRMR=0.065 vs 0.058) and appropriate factor loadings (Figure 1).

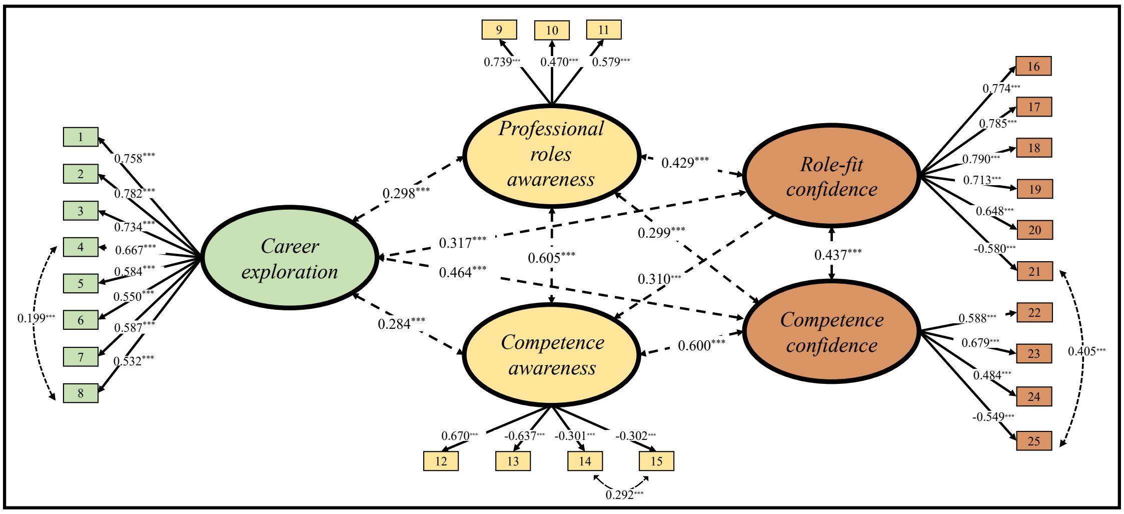

Figure 1. Final CFA model. Factor correlations and correlated errors are presented by the double-headed arrows between the constructs (ovals) and items (rectangles) respectively. Significance levels are indicated with asterisks (0.05>≥0.01>**≥0.001>***).*

From the final CFA model (Figure 1), all correlations between the constructs show significant positive values between 0.28 and 0.60. This suggests both an appropriate discriminant validity between the constructs, and substantial interconstruct associations. Higher levels in one construct are thus related to higher levels in another construct. The largest interconstruct correlations were observed between *professional roles awareness* and *competence awareness*, and *competence awareness* and *competence confidence*. The associations with the two confidence constructs, i.e. *role-fit confidence* and *competence confidence*, were different for *career exploration*, and *professional roles* and *competence awareness*, while the associations for *career exploration* with the awareness constructs were similar.

5.2 Professional identity constructs show differences for multiple variables

Construct differences were examined for five variables, i.e. parental occupation, gender, engineering persistence, phase of study, and vocational interest. This model had an acceptable fit (CFI=0.938, TLI=0.958, RMSEA=0.047, SRMR=0.062). The results are comprised in Figure 2, showing the significant construct differences between the variable's categories and their respective reference category.

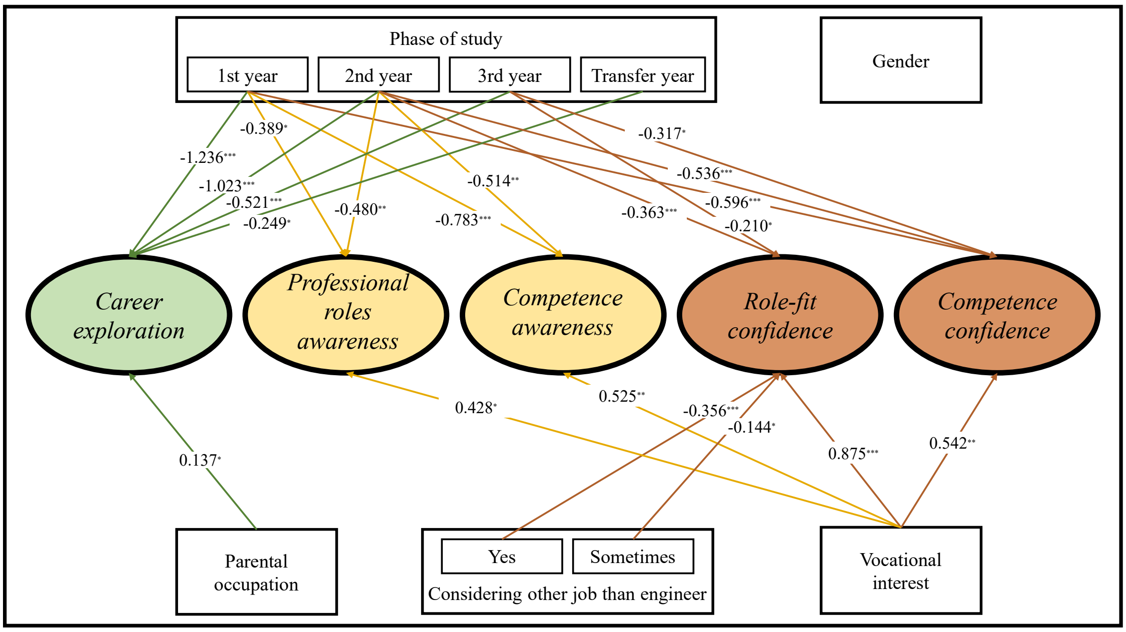

Figure 2. SEM. Reference categories are 'no' (engineering persistence, middle bottom row), the master year (phase of study), female (gender), 'not an engineer' (parental occupation), 'no' (vocational interest). The measurement model in Figure 1 was used to determine the constructs, which was omitted here in the visualization for clarity, and only significant effects are shown.

2.2.1 Parental occupation

The professional identity of engineering students did not seem to be influenced substantially by whether one of their parents was an engineer or not, as only a weak effect was observed for *career exploration*. This effect indicated a slightly increased level of *career exploration* when at least one of the parents was an engineer.

2.2.2 Gender

No differences between males and females were noted for any of the constructs, suggesting a similar professional identity.

2.2.3 Phase of study

Multiple effects were noted for the bachelor years regarding all constructs. *Career exploration* was reduced for students in the first, second and third bachelor year compared to the master year. The increasing loadings over the later bachelor years might suggest that *career exploration* increases when progressing the programme. Similarly, *competence confidence* seems to increase over the three bachelor years. On the other hand, only first and second year students showed decreased levels for *professional roles* and *competence awareness*, while *role-fit confidence* was decreased for second and third year students compared to master students. Finally, transfer students and master students showed similar construct levels, with the exception of *career exploration*, which was reduced in transfer students.

2.2.4 Vocational interest

Whether students were able to identify with a professional engineering role (vocational interest) was independent of considering another job outside engineering (engineering persistence) ($p=0.92$, $\chi^2=0.175$, $df=2$). Students that could identify with an engineering role showed higher levels for all constructs except *career exploration*, with the largest increase noted for *role-fit confidence*. Further exploration did not demonstrate clear differences between professional roles.

2.2.5 Engineering persistence

Students who were considering another job outside engineering showed lower *role-fit confidence* compared to students who were aiming for an engineering career. No differences were noted in *career exploration*, *competence confidence*, and *competence awareness*. However, a borderline insignificant effect was present for *professional roles awareness* (p=0.054, loading=-0.289), suggesting a reduced understanding of the professional engineering roles for students that considered a non-engineering job. Additionally, students who were still undecided about the engineering field also showed lower *role-fit confidence*, with a difference that is markedly smaller than for the former group (-0.144 vs. -0.356). Borderline insignificant effects were also observed for *professional roles awareness* (p=0.065, loading=-0.215) and *career exploration* (p=0.058, loading=-0.106).

6 DISCUSSION

Developing a professional identity is fundamental in student's career orientation, making this an active research field providing essential implications for educational guidance programmes. The present research aimed to expand the understanding of the professional identity of engineering students, which is a research population that did not receive much attention yet. Using structural equation modeling techniques, we simultaneously examined distinct constructs that are associated with professional identity development in engineering students to provide an in-depth exploration of these constructs in the same cohort.

Our results rehighlight the general perception that professional identity is a complex and multifaceted concept. We first demonstrated a positive association structure between five constructs, which had not been reported before in the same cohort, providing an in-depth overview of the multifaceted aspect of professional identity. This circumvents potential extrapolation issues between different cohorts resulting from cultural or other differences [1,11]. These results suggest that the underlying identity structure in engineering students follows similar mechanisms as in other student populations since positive construct associations have also been reported for high school students and non-engineering students [11,20].

The second result identifies several personal factors for each construct. Results demonstrated construct differences for phase of study, which has been identified in previous studies as well [12]. Developmental differences during student's education have been explained before in light of increasing experience [21]. Our results support this belief since gradual construct changes are present over bachelor years that might suggest increasing levels for most constructs. Interestingly, *professional roles awareness* seems to decrease slightly after the first bachelor year, which might result from the unrealistic expectations of first year students regarding the engineering field at the start of their education, as stated elsewhere [22]. On the other hand, no gender differences were noted, while before, STEM and engineering males have also demonstrated higher *role-fit* and *competence confidence* [14,15]. These different findings might result from methodological and cohort differences. Also only one effect was noted for parental occupation, i.e. on *career exploration*, despite that parental influences have been considered key in the developmental process [13]. However, those studies mainly focused on parental support instead of parental occupation. A study with German high school students did suggest a larger *career exploration* when the educational track corresponded to that of the parents [23], as suggested by our results. The low number of parental effects might suggest that having an engineering parent does not add substantially to the professional identity development after pursuing the engineering major. Finally, lower construct levels were noted for students who could not yet identify with an engineering role, or who were considering another job outside engineering. These vocational interest and engineering persistence variables have been of little focus so far in studies investigating construct differences. However, in agreement with our results, an association was observed before between *role-fit confidence* and engineering persistence in engineering students [10]. Additionally, the same study showed that *competence confidence* was indifferent for persistence, which is also consistent with our analysis. Further investigation of the other construct differences for vocational interest and engineering persistence might be relevant to understand their occurrence in students.

4.1 Implications for career guidance

Our results provide several implications for career guidance in engineering education. First, the positive association structure among the identity constructs suggests the possibility to stimulate specific constructs through other constructs. Second, the correlations in our analysis showed that stronger and weaker links are present, suggesting that putative stimulation effects might differ considerably between constructs. Third, the examination of personal factors suggests that students without a clear vocational interest could benefit from a broad guidance intervention.

4.2 Limitations and future research

Additional research is required to unravel the explicit directional influence of one construct on another, which is not captured in the reported correlations. This would provide insights on both the direct and indirect stimulation of one or more constructs by another, presenting a more effective way for developing career guidance. Also, the construct differences over the bachelor years in our cross-sectional data are only suggestive for construct evolutions during the programme. This should be further addressed in a future longitudinal study that follows construct changes in the same individuals over time to investigate the evolution in professional identity in engineering students.

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TRIGGERING REFLECTION AND META-COGNITION IN PHYSICS PROBLEM SOLVING

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ABSTRACT

Self-regulated learning strategies support learning. Recently, the Learning Companion, a tool carefully grounded in theory and designed to promote self-regulation while students solve engineering problems, was introduced by Tormey et al. The companion presents students with a standard questionnaire for each problem, including a predefined list of generic difficulties related to quantitative problem solving. Ample scientific research has, however, indicated that metacognition is most effective when it takes place in a domain-specific context. The goal of our research is to determine the feasibility and impact of a "Disciplinary Learning Companion" (DLC), building on topic-specific rather than generic questions.

In the paper we first present the DLC and connect it to the theoretical frameworks of self-regulation and metacognition. Second, we present a case study of the DLC executed within a 1st year mechanics course. On the quantitative side we connect the interaction of students with the DLC to their learning skills measured using a validated questionnaire and their academic achievement. On the qualitative side, we present the findings of interviews with teaching assistants. Based on the results we present recommendations regarding the further development and research around "disciplinary companions" to induce students' self-reflection when solving engineering problems.

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1 INTRODUCTION

Self-regulated learning strategies support learning. Not only is there a strong theoretical support for this claim [3], also intervention studies have shown that self-regulation is associated with academic achievement [4]. Self-regulation is a widely-used term that, nevertheless, lacks a clear definition. Depending on the particular theoretical model consulted, it can focus on metacognition, i.e. …, or also include elements of affect and motivation. [2]. Feedback is a potentially very powerful tool to impact learning and achievement, but different types of feedback can have different (levels) of impact [6]. Feedback can therefore also play a role in triggering of meta-cognition and self-reflection as Hattie and Timperley [6] state: “Feedback that attends to self-regulation is powerful to the degree that it leads to further engagement with or investing further effort into the task, to enhanced self-efficacy, and to attributions that the feedback is deserved and earned. When feedback draws attention to the regulatory processes needed to engage with a task, learners’ beliefs about the importance of effort and their conceptions of learning can be important moderators in the learning process.” One way to provide feedback is through Learning Analytics Dashboards [5]. They can provide a visual display of students self-regulation based on digital traces collected such as behavior in online learning environments or reflection tools, but also more “old-fashioned” data such as survey data or student background information can be used. Recently, the Learning Companion, a tool carefully grounded in theory and designed to promote self-regulation while students solve engineering problems, was introduced by Tormey et al [1]. The companion presents students with a standard questionnaire for each problem including a predefined list of generic difficulties related to quantitative problem solving. Ample scientific research has however indicated that metacognition is more effective when it takes place in a domain-specific context. Furthermore, feedback is more powerful when it supports the building cues and information regarding wrong hypotheses and ideas [6], which is potentially, and therefore part of our hypothesis, easier in domain-specific reflections. Next, developing particular conceptual knowledge in engineering subjects is difficult, not well-understood yet, but definitely requires particular attention [7]. The goal of our research is to determine the feasibility and impact of a "Disciplinary Learning Companion" (DLC), building on topic-specific questions rather than generic questions to trigger reflection with students during or after scientific problem solving.

The Disciplinary Learning Companion is clearly inspired by the EPFL Learning Companion [1], which was designed to improve students’ skills in problem solving in scientific and mathematical problems in the context of science and engineering degree programmes. In particular, the Disciplinary Learning Companion aims at offering an alternative to the “diary” of the EPFL Companion. This is the component where students reflect after they have worked on a set of mathematical problems in class (exercise sessions). Students then complete a standardised diary questionnaire in the EPFL Learning Companion for each problem, logging the number of problems they attempted, whether they succeeded or not as well as the difficulties they encountered in the process [1]. The questionnaire is called “standardised” as it is a predefined list of difficulties related to quantitative problem solving. As such, these questions do not relate to particularities of each question but rather address the more general processes of scientific problem solving. The Disciplinary Learning Companion on the contrary aims at offering students problem-specific questions, in particular inspired by the conceptual difficulties in the domain at hand (mechanics in this paper) [7]. The focus on domain- and even course-specific (conceptual) difficulties contains the possibility for more topic-specific feedback related to the particular subject, which can have higher impact on students' learning and development. An obvious disadvantage of the problem-specific questions in the Disciplinary Learning Companion is the additional time needed for development of the reflection questions and the feedback, as they will have to be developed separately for each particular problem. With the Disciplinary Learning Companion we want to research whether the disciplinary-focus leads to higher impact on students' reflection and learning, and if this higher impact can justify the higher development cost. Additionally, to "manage" the development cost and to ensure quality of the problem-specific questions developed for the Disciplinary Learning Companion, we aim at developing a structured process and connected with that, guidelines that allow teaching teams to build these questions in co-creation while taking into account the research on domain-specific conceptual difficulties [7]. In this paper we present for the first time our idea of the Disciplinary Learning Companion, the five domains that aim to provide structure to the reflection connected to a specific problem, the theoretical foundation of the learning companion, and the results of a first pilot.

2 DISCIPLINARY LEARNING COMPANION: WHAT AND WHY?

2.1 What is the Disciplinary Learning Companion?

The goal of the Disciplinary Learning Companion is to make students reflect on scientific problems they are typically solving in the context of a higher-education science course. The Disciplinary Learning Companion is a self-reflection tool that students use independently during or after they solved a single problem or a set of problems, and that presents problem-specific questions and feedback to trigger the students' reflection. We identified, based on research on science problem solving, five key dimensions to structure the reflection questions: 1) Strategy Plan, focusing on the fact that students use a well-considered strategy to tackle the problem or not; 2) Concepts, focusing on the domain-specific concepts needed to solve the problem (e.g. developing a free-body diagram in mechanics); 3) Mathematical model, i.e. whether students can translate their conceptual understanding to mathematical formulas (e.g. equilibrium of forces); 4) Computations, i.e. whether students can correctly solve the mathematical model obtained; and 5) Interpretation, i.e. whether students can interpret the obtained solution (e.g. are the magnitude, sign, and units of my solution as expected?). Table 1 provides for each of the five dimensions an example of a reflection question from the Disciplinary Learning Companion used in the pilot of this paper (statics problem in a mechanics course).

Table 1: Example of reflection questions (statics problem in a mechanics course) from the Disciplinary Learning Companion used in the pilot of this paper for each of the five dimensions.

Strategy plan *Did you use a strategy plan to solve the question?* *No, I did not have an explicit strategy plan:* □ *I did not make my plan explicit.* □ *I did not have a strategy plan.* *Yes, I did have an explicit strategy plan consisting of:*

□ *determining my strategy plan* □ *splitting the problem in subproblems: in this case determining the center of gravity for the different bodies* □ *solving subproblems: in this case combining the center of gravity of the different bodies into the center of gravity of the whole structure* □ *reflect on the obtained result.*	
Concepts *Which of the following components were part of your free body diagram?* □ *column* □ *beam* □ *ground*	**Mathematical model** *How did you apply the generic formula* $\vec{r_c} = \frac{\sum_{i=1}^{N} \vec{r_i}\, m_i}{\sum_{i=1}^{N} m_i}$ *to calculate the center of gravity of the whole structure from the centers of gravity of the different bodies to this particular context?* *(answers show possible elaborations of the formula, or the "I do not know option".*
Computations *Were you able to calculate the center of gravity of the whole structure correctly from the mathematical model?* □ *yes* □ *no* □ *I was not able to determine the mathematical model*	**Interpretation** *Did you check if the obtained solution was feasible?* □ *No* *Yes, I did the following* □ *check the units of my solution* □ *check if the obtained position is feasible both in sign (positive/negative) and in magnitude (e.g. center of gravity is within the outer dimensions of the whole structure)*

2.2 How is the Disciplinary Learning Companion grounded in theory?

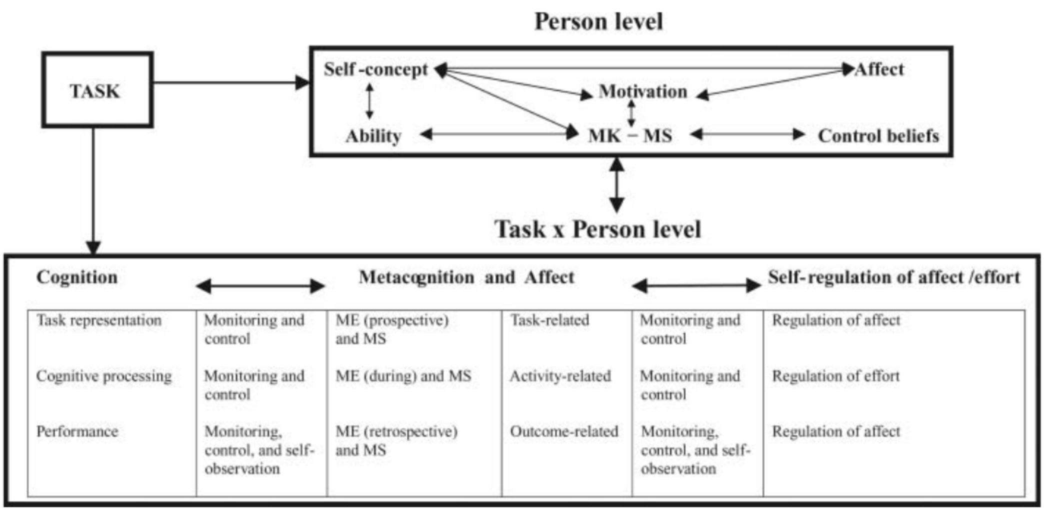

Figure 1: The Metacognitive and Affective model of Self-Regulate Learning (MASRL) of Efklides [2]. MK= metacognitive knowledge, MS = metacognitive skills

We situate the Disciplinary Learning Companion in the Metacognitive and Affective model of Self-Regulate Learning (MASRL) of Efklides [2], also presented in Figure 1. The Disciplinary Learning Companion focuses on supporting the metacognitive monitoring and control (cognitive loop) in the Task x Person level of the MASRL model, where the specific task processing (cognition) occurs. In particular, the companion focuses at supporting the self-observation of students by providing external triggers (reflection questions and feedback in the companion). These triggers should induce internal metacognitive experiences. Supported by repeated application of the Disciplinary Learning Companion, these experiences hopefully change the students' metacognitive knowledge (e.g. the five domains important for solving mechanics problems, or possible ways to interpret a solution of a problem) and metacognitive skills (e.g. reflecting on the strategy to tackle a problem, and interpreting the solution of a problem) at the Person level.

3 THE DISCIPLINARY LEARNING COMPANION IN ACTION

This section describes the implementation of a pilot of a Disciplinary Learning Companion implemented in the first semester of academic year 2020-2021 and formulates the research questions we answer in this paper.

3.1 Context

The pilot of the Disciplinary Learning Companion was organized around a mid-term test of the course Applied Mechanics, part 1 with first-year students of the Bachelor of Engineering Science and the Bachelor of Engineering Science, Architecture at KU Leuven in Belgium. Applied Mechanics, part 1 is a course where a rather limited set of theory should be acquired to solve simplified but realistic engineering problems related to statics, kinematics, and dynamics. Based on the success rate of students, this course is the hardest course of the first-year, resulting in a typical pass rate of 40% (without resit). To support the first-year students in their academic integration, the faculty organizes mid-term tests. These mid-term tests offer new students in the program a first realistic exam experience. The result of the mid-term tests is taken into account in the final course grade (25%), provided that the student passed the mid-term test and provided that the inclusion of the mid-term test grade improves the final grade. Based on a random assignment of tests to two student groups, only half of the Engineering Science students is assigned to the Applied Mechanics, part 1 mid-term test. All Engineering Science Architecture students take part in the mid-term test of Applied Mechanics, part 1 (no random assignment). In total, 355 students could participate to this mid-term test, which is a two-hour long multiple-choice test with 4-5 engineering problems to solve.

The Disciplinary Learning Companion was used to support students in their preparation for the mid-term test. A reflection exercise built around last year's mid-term test was provided on the Virtual Learning Environment of the course. In particular, a learning pat was constructed consisting of four steps: 1) Solve the mid-term test of last year, 2) Compare your solution with the model solution, 3) Reflect using the Disciplinary Learning Companion, 4) Engage with the feedback, construct a plan, and/or request for help. Remark that students did not have to enter the Disciplinary Learning Companion to see last year's mid-term test, nor the solution.

The Disciplinary Learning Companion was implemented in the Qualtrics survey tool and structured around the five key dimensions highlighted in Section 2 with reflection questions focusing on the five dimensions of Strategy plan, Concepts, Mathematical Model, Computations, and Interpretation. For each of the five problems of the mid-term test, questions focusing on the above five dimensions were designed (in total 29 questions). In the Companion, for each problem, students get feedback based on their response. This feedback points to possible and typical errors, additional explanations in the course text, the model solution, ways to improve, etc. At the end, overarching feedback was provided with a total score for each of the five dimensions and with pointers to additional help.

With the implementation of the pilot, we aim to answer the following research questions: From the **quantitative side**: What are the relations between 1) the scores of students on the five dimensions of the learning companion, 2) completion of the reflection module and achievement in the mid-term test, 3) completion of the reflection module and two learning skills: use of test strategies and motivation, and 4) students' score on the five dimensions in the companion and their achievement in the mid-term test. Motivation and use of test-strategies were measured using the LASSI survey at the beginning of the academic year. From the **qualitative side**: 1) What is the feasibility of developing a Disciplinary Learning Companion, and 2) What are teachers' views on the potential usefulness of a Disciplinary Learning Companion.

3.2 Methodology

We used a quantitative and qualitative approach to evaluate the pilot of the Disciplinary Learning Companion. Both analysis aimed at gaining better understanding on how to improve the companion for future use throughout an entire course. To answer **the quantitative** research questions, we tracked students' answers in the Disciplinary Learning Companion, and measured motivation and use of test-strategies using the LASSI survey that we administered at the beginning of the academic year.
To answer the **qualitative** research questions we set up three focus groups with teaching assistants (7 participants) and tutors (three participants). Unfortunately we did not manage to recruit students for the focus groups. The focus groups were transcribed and then analyzed using a thematic analysis by one of the principal investigators.

3.3 Quantitative findings

From the 355 students who could participate in the mid-term test, only 332 actually participated. From these students, only 47 (13%) entirely completed the Disciplinary Learning Companion in their preparation. (RQ1) We found that students' scores on Concepts and Mathematical model were positively correlated (Spearman $r(47)=0.46, p<0.0015$), as were the scores on the Strategy plan and the Concepts (Spearman $r(47)=0.34, p=0.02$). Other dimensions were not correlated. (RQ2) We found that students that completed the reflection module score significantly higher on the mid-term test compared to all students (Mann-Whitney, $p=0.028$). (RQ3) Completion of the companion was not correlated to students' motivation ($p=0.29$) nor use of test-strategies ($p=0.32$). (RQ4) We found no relation between students' scores on the mid-term test and companion score's on Strategy plan ($p=0.30$) and Concepts ($p=0.18$), the only two dimensions where we hypothesized a correlation.

3.4 Qualitative findings

For reporting purposes we refer to teaching assistants and tutors as TAs.
Time-investment: TAs stated that students will probably consider the module to be too time-consuming, and that it is better to spread the reflection over different

modules and over time. A positive aspect is that the module can be completed asynchronously.
Feedback: TAs indicated that the feedback contains too much repetition and should be more concise, e.g. referring with a pointer to repeating explanations. A strong point is that different solution strategies are shown in the feedback, but there could be even more room for different solution strategies. It was particularly appreciated that students got supportive messages when the answer was correct, while still stating "do you know why this is correct?" to offer some elaborations. The specificity of the feedback is important and could even be improved at some points. The feedback could focus more on how to obtain a better Strategy plan, Mathematical model, etc. It was considered a good point that the feedback contains pointers to the course text and that typical errors were provided, while the latter could still be improved.
Content: TA's appreciated the emphasis on the methodological approach, which they are not always able to provide during the exercise sessions. This emphasis however might be "over the top" for simple problems. The fact that reflection questions were tailored to the specific problem was considered very good, but is expected to increase the work load to build such a module. Therefore there is a balance between specificity and work-load and transferability. The "Interpretation" dimension was considered very important. It would be an opportunity that student also reflect on how they would approach the problem in case of some small variations.
Platform and lay-out: TA's stated that the implementation of the Disciplinary Learning Companion allows for a good combination of independent work and personal feedback and appreciate the interactivity. TA's disagreed on whether the model solution should be offered as a whole before reflection (they get the overview) or that it should be integrated it in the reflection module (step-by-step and they are pushed to use the reflection module). Related to this, they also disagreed if it would be most optimal to first solve the problem and then reflect in the companion, or to solve the problem while reflecting in the companion. The five dimensions could also be readily recognized from the companion. TA's disagreed on whether all five dimensions offer sufficient added value, some found all essential while others only found Strategy and Interpretation important. They all agreed that these five dimensions will only be useful for a student if they are also used in the exercise sessions, such that students can really understand these dimensions. The interface of the companion should be improved such that student can go back and forth in the reflection rather than forcing them to stay on a linear path. TA's had some particular feedback regarding the visualization in the Learning Companion which is not elaborated further here. The reflection in the companion was very elaborate, which might scare away students, therefore one should pay attention to keep the companion lightweight enough. Finally, TA's stated that the feedback should encourage students more to retry (a particular element of) the problem if they failed to solve it.
Integration in the course: TA's disagreed on whether the reflection in the companion should be mandatory or not. It would be useful anyway to provide students with guidelines on when reflection is useful. Integration of the Learning Companion in the exercise sessions was considered to be very important: this could be done as part of the preparation of an exercise session. Tas considered this particularly important for first-year students who are suspected to not have enough intrinsic motivation and self-regulation to plan the reflection themselves. The

professors of the course should also indicate the importance of the reflection in the companion. Frequency and length have to be balanced: it should be frequent enough such that students generate a habit of completing the companion and substantial enough to show the importance, but it should be not too frequent or too long such that it does not overload the students. TA's stated that a more elaborate module before a test and shorter modules each week could offer a good balance.
Building new reflection modules: TA's indicated that they would be willing to build own reflection modules in the companion if proper guidelines and support are provided, and that they would also adapt the exercise sessions to more explicitly connect the solutions of problems to the five dimensions. However, they feared that it might be challenging to find the time to build specific reflection module connected to each exercise session. TA's found that the reflection should be an integral part of the entire program and not only of a single course, and that the importance of reflection should be emphasized more in the TA training.
Goal and purpose of the companion: TAs stated that the companion stimulates reflection skills that a student should obtain anyway and that it makes things that good students do spontaneously more explicit, such that weaker students can more easily learn this. TA's thought that only a small subset of students would spontaneously transfer the reflection to other courses even after using the companion, while repeated use of the companion might cause student to change their approach unconsciously. The companion is believed to offer guidance of students in their solution process, while the added value for students that can already solve the problem is possibly limited. TA's appreciated that the companion focuses on reflection and find this missing in other platforms such as Pearson's Mastering Physics. They found the companion to offer a good format for personal feedback and a good addition to model solutions, allowing to gain new insights without having to redo problems.

4 DISCUSSION, FUTURE WORK, AND CONCLUSION

This paper presented the ideas behind the Disciplinary Learning Companion, a first development of the Disciplinary Learning Companion, and a preliminary quantitative and qualitative analysis based on a small pilot. The first pilot only presented a limited set of evidence considering that the companion was just used for one reflection module, which also resulted in a minority of the students actually using it.

While the quantitative results indicated that use of the companion is correlated with academic achievement, we want by no means indicate a causal relation. In fact, we rather would state that this result merely shows that the learning companion probably attracted the students that are preparing better for the mid-term test, which therefore obtain on average a higher test score. The quantitative results point to the need for future research on the impact of the companion on reflection and learning. A particular point of attention is to investigate further if the score on the five dimensions of problem solving are related to learning, and could therefore provide a pointer for feedback to students and teachers.
With the qualitative results we can conclude that tutors and teaching assistants see the potential of the Disciplinary Learning Companion, and very importantly, see it feasible, provided proper support, to develop reflection modules themselves connected to particular problems they are teaching. Based on this promising results, and building on the points of improvement we are currently deploying an improved

version of the Disciplinary Learning throughout a full course of engineering mechanics, which allows us to further investigate our hypothesis of higher impact on learning with the Disciplinary Learning Companion compared to a non-disciplinary companion. At the same time, we are developing more visual feedback to students and teachers, including more high-level feedback on self-regulation and student's developments over time. This would allow to move in the direction of Learning Analytics Dashboards [5], similar to the EPFL Learning Companion [1].

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DIVERSITY, EQUITY, AND INCLUSION IN ENGINEERING EDUCATION: AN EXPLORATION OF EUROPEAN HIGHER EDUCATION INSTITUTIONS' STRATEGIC FRAMEWORKS, RESOURCES, AND INITIATIVES.

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ABSTRACT

Significant efforts have been made to promote gender equality in higher education (HE) in Europe. Examples include the establishment of the Athena Swan Charter in the UK in 2005 and the 2019 launch of the Irène Curie Fellowship scheme by Eindhoven University of Technology. But which initiatives address broader diversity, equity, and inclusion (DEI) challenges in HE? And which are specifically focused on engineering education?
This exploratory study aims to improve our understanding of the ways in which a set of European HE Institutions engaged in engineering education address DEI at an organisation level, and how this is communicated within the public domain. The analysis of online data provided by a purposive sample of institutions is guided by the following research questions (RQ):

1. How is DEI addressed and defined in institution-wide strategic frameworks?
2. How many institutions describe having an institution-wide DEI organization?
3. What specific policies around DEI are being developed, and what areas are mentioned, defined, and prioritized?
4. What structures and resources noted as part of their DEI activities are specific to engineering faculties and departments?
5. What engineering-specific DEI initiatives exist that are not available in the public domain or are not written in English?

Our sample is composed of the host institutions of the authors of the paper, and represent different European countries: Belgium, Denmark, France, Ireland, Portugal, Switzerland, and the UK. The findings of this exploratory study will be used to inform the design of a large-scale survey to identify DEI practices across the SEFI community.

1. INTRODUCTION

1.1 Motivation

A recent New York Times article [1] posed the question “What does it mean to say ‘I’m in favor of diversity’ when you haven’t even reckoned with what the state of diversity is in your own institution?”. Whilst the article focused on academic publishing, the same could be asked of engineering education in Europe. The current paper represents the beginning of our attempts to map how diversity, equity, and inclusion (DEI) are defined by our institutions.

SEFI has been engaged in diversity, equity, and inclusion. In its Diversity Statement, SEFI affirmed to “continually review its policies and practices to fulfil this commitment and to ensure that it influences SEFI’s activities and liaisons” (2018). Respect for diversity and different cultures, as well as institutional inclusiveness, are core values adopted by SEFI’s Board of Directors. More recently, and following SEFI’s Position Paper on Diversity, Equality and Inclusiveness in Engineering Education [2], SEFI and ASEE produced a joint statement [3] calling for examination, reflection, and active promotion of diversity, equity, and inclusion in engineering.

However, it is our experience that definitions of diversity and inclusion vary considerably between institutions, and that many initiatives are concerned only with widening the participation of women in engineering. Although gender imbalance remains a critical issue in the European engineering context, this narrow definition of diversity is inadequate to represent the different aspects that simultaneously form essential aspects of people’s identities and can lead them to experience exclusion, stereotyping, and microaggressions [4]. We argue for the importance of clear, comprehensive definitions of DEI and why data on the current way these terms are used by European engineering institutions can help us increase awareness of diversity, equity, and inclusion issues, but also identify, share, and celebrate good practices and initiatives across the SEFI community.

1.2 Literature review

A number of recent studies, such as the 2018 McKinsey Report [5], assert that diverse and inclusive teams are more creative, providing their companies with a competitive advantage. Many companies have established policies to both promote diversity in their hiring practices and encourage more inclusivity in the workplace. However, more effort is needed in this regard. Hilary Leevers, Engineering UK chief executive, writes [6]: “While engineers have responded fast, flexibly and with huge personal commitment at this time of corona-crisis – we know that it could have been better. We know this because workforce diversity improves innovation, creativity, productivity, resilience and market insight and the engineering workforce could and should be much more diverse.” Also, to fill in the continued shortage of engineers, Neelie Kroes [7] states that education and industry should focus on underrepresented groups and make Europe stronger. The latter is also highlighted by IEEE Innovation [8]: “Although 80% of future professions will require STEM expertise by 2020, millions of students in under-resourced communities lack the opportunities necessary to prepare for careers in these fields.” Engineering stereotypes can also play into the difficulties experienced. Pawley [9] observed that engineering schools often characterise “the ideal student” as a young, single White male. Assumptions about who engineering students are can negatively impact students from underrepresented groups. While this research was US focused, many in Europe will agree that this is also germane to European engineering schools - engineering education, research and practice lacks diversity of people and cultures, which ultimately affect the diversity of approaches to teaching, learning and research, and diversity of knowledge and skills.

But what does ‘diversity’ mean? “Equality, equity, diversity and inclusion are terms that are often used interchangeably, despite the fact that they may mean different things.” [10, p.23].

Diversity is the presence of differences within a given setting. In the educational sphere and in the workplace, that can mean differences in race, ethnicity, gender, gender identity, sexual orientation, age and socioeconomic class. According to the INVITED Report [10, p.23], diversity is “a multi-dimensional concept, dependent on the cultural context and level of awareness of difference. Certain dimensions of diversity have received particular attention because the groups identified as either under-represented, disadvantaged or vulnerable (or any combination of these three). In terms of gender, there is a clear under-representation of women in academic and leadership positions”.

Equity is the process of ensuring that processes and programs are impartial, fair and provide equal possible outcomes for every individual. ‘Equity’ goes beyond ‘equality’, as it “includes needs-based support to level out relative disadvantage. It thus often comes along with measures such as positive action or positive discrimination. Equity also takes into account that there are often structural barriers towards participation which, if they cannot be removed, make such needs-based individual support necessary.” [10, p.44].

Inclusion is the practice of ensuring that people feel a sense of belonging in a given community. This means that every person within the community making up an HEI feels comfortable and supported by the organization. Inclusion requires “awareness about different aspects of diversity” [10, p.44].

2. METHODOLOGY

This study adopts a critical discourse theoretical framework for analysing and assessing how diversity, equity and inclusion are communicated via university websites, and defined in strategic documents, such as mission or diversity statements. The approach works well because “website content is a form of institutional discourse” [11, p.67] and the internet provides “a rich cultural data source” [12, p.247] particularly about the higher education institutions (HEIs) in Europe that provide engineering education and participate in SEFI. Merkl [13] looked at the diversity statements of 11 universities in the United States, identifying themes to assess what they addressed equality and to “identify whether university Diversity Statements aid in maintaining or disrupting inequality in the university” (p.ii). Merkl proceeded to focus on 4 universities that were selected for maximum variation. She “compared the Mission Statement to the Diversity Statement, analyzed common university statistics, and evaluated website pictures” and then “conducted a cross-case analysis to identify patterns and considered the implications of those patterns” (p.ii).

At this initial pilot phase of our study, we have focused on the eight host institutions of the authors of this paper. Lažetić [14] studied HEI websites of a similar European sample; his study used content analysis alongside MANOVA to assess messages of corporate branding versus public-service orientations of the sampled HEIs. Similarly, Creamer and Ghoston [15] conducted a content analysis of the mission statements from 48 random colleges/schools in the United States, followed by a quantitative phase to explore the correlation between the inductive codes and three measures of the representation of women among those same colleges of engineering. To date, our research team has harvested publicly available data, organized it in tabular format, and conducted initial analysis. As we progress from this pilot to full study, we will adopt either Pauwels' [12] six-step process for assessing websites from perspectives that are both medium-specific and socio-cultural, or Merkl's [13] approach, to explore RQ1: How is DEI addressed and defined in institution-wide strategic frameworks? This paper focuses on the description of the institution as a DEI organisation, its policies and priorities (RQ2, RQ3) and engineering-specific structures, resources and activities (RQ4, RQ5).

2.1 Institutions

The eight institutions included in this exploratory study are: 1) Technical University of Denmark (DTU), Denmark; 2) École polytechnique fédérale de Lausanne (EPFL), Switzerland; 3) Instituto Superior Técnico (IST), Portugal, 4) University of Leuven (KU Leuven), Belgium; 5) École Polytechnique de l'Université d'Orléans (Polytech Orléans), France; 6) Swansea University, United Kingdom/Wales; 7) Technological University Dublin (TU Dublin), Ireland; 8) University College London (UCL), United Kingdom/England.

3. RESULTS

This section summarizes the main findings of the following research questions:

- RQ2. How many institutions describe having an institution-wide DEI organization?
- RQ3. What specific policies around DEI are being developed, and what areas are mentioned, defined, and prioritized?
- RQ4. What structures and resources noted as part of their DEI activities are specific to engineering faculties and departments?
- RQ5. What engineering-specific DEI initiatives exist that are not available in the public domain or are not written in English?

An overview of these findings, as well as a brief description of each university (type of institution, population, and female ratio) is provided in Table 1.

4. DISCUSSION AND CONCLUSION

Of the institutions examined, almost all have an institution-wide DEI organisation while departmental or faculty-wide policies in engineering are prevalent in most cases. The area that is prioritised in most institutions is gender balance, followed by disability, while socioeconomic background and other areas are also mentioned. Engineering faculties appear to focus on gender balance. This is in line with existing research on diversity in engineering, which indicates that gender tends to monopolise the discourse on DEI.

Table 1. Overview of DEI focus and activities

University	Type	Population	Female ratio	Institution wide DEI (main) focus	Institution wide DEI activities	Engineering specific DEI themes	Engineering Specific DEI activities/ resources	Engineering Specific DEI initiatives not in the public domain
DTU	Public. Technical university. University focused in technical and natural sciences.	DTU has a student population of 11,200 students, and employs more than 6,000 staff.	Across all disciplines, 31% of the enrolled students are female, and 38% of staff are female.	Gender, ethnicity, age, sexual orientation, culture, educational background, physical ability	Recruitment practices DEI Strategy DEI teams and working groups Senior manager (provost) with DEI responsibilities	N/A	N/A	Bias training for staff
EPFL	Public. Research intensive technical university. Specialized in natural sciences and engineering.	Over 12,000 students and 4,000 researchers from more than 120 different countries.	Approximately 30 % of students are female	Gender (LGBTQ+) (Ethnicity) (Disability)	DEI Strategy Senior manager with DEI responsibilities Vice presidency for Sustainable Transformation	N/A	N/A	Recruitment practices Bias training Training for students' project teams
IST - University of Lisbon	Public. Research University. School of engineering and technology.	It has 11.000 students of 60 nationalities, 700 academic staff, 25	28% of IST students and 26% of academic staff are female	Gender	CIEG (Interdisciplinary Centre for Gender Studies).	Gender	Diverse recruitment policies. Policies to support female staff. Gender Balance Group tracks	

		research centres and more than 1.000 researchers.			PhD program in Gender Studies.		female staff and student numbers, organises activities such as the Maria Pintasilgo Prize for alumnae and liaises with external associations	
KU Leuven	Public Research University Comprehensive university, organised in 3 groups: Humanities & Social Sciences, Biomedical Sciences, and Sciences, Engineering & Technology (SET) (15 faculties incl. 3 engineering faculties)	KU Leuven has 60.687 students (22.356 in SET) from 150 nationalities (more than 12.500 international students), 21 605 staff members, 7637 researchers and professors (3786 in SET), 6236 Phd Researchers (Aug. 2020)	in SET faculties: 30% female students, 31% female researchers	Gender Age Ethnicity Nationality LGBTQ+ Religion Disability Neurodiversity Socio-economic background	DEI Strategy Senior manager with DEI responsibilities Dedicated DEI teams and working groups Staff and student networks/committees DEI training Diverse recruitment policies	Diversity of student cohort International students Career development (particularly with respect to gender)	Senior manager with DEI responsibilities Dedicated DEI teams and working groups Faculty level policy Integration with Institution level activities	Report Diversity (student inflow and outflow) per faculty (only accessible for DEI teams and working groups) KU Leuven SET: Strategy Document incl. DEI (only accessible by KU Leuven staff)
Polytech Orléans	Public. Polytechnic university (Grande École)	Yearly intake of 1000 undergraduates and 250	27% female students			Socio-economic Background		

		postgraduate students (Master's).						
Swansea University	Public. Research university. The College of Engineering (CoE) is one of 8 university colleges.	In 2019, the CoE delivered 22 UG courses to around 3500 students, 22 courses to 157 postgraduate students, and 27 PGR courses to 281 research students Approximately 30 % of UG students are international	17% undergraduate and 20% postgraduate taught and postgraduate research female students.	Gender Age Ethnicity LGBTQ+ Religion Disability Neurodiversity Personal Circumstances	DEI Strategy Dedicated DEI teams and working groups Diverse recruitment policies Staff and student networks/committees DEI training	Gender, BAME (Black, Asian and Minority Ethnic)	DEI Officer	
TU Dublin	Public. Technological University. TU Dublin is organized in 5 Colleges & Schools – one is the College of Engineering and Built Environment.	TU Dublin is the second-largest third-level institution in Ireland, with 3500 staff members, 29,700 students, 138	46% female staff, regarding student diversity: 2854 international students from 105 countries, 13% of student body classifies as mature, 5%	Gender Age Ethnicity LGBTQ+ Disability Socio-economic background	DEI Strategy Diverse recruitment policies RINCE (centre for research and practice on EDI) Projects: GE Academy;	N/A	ESTeEM, a mentorship programme for female students in Engineering and Computing to address gender equality	N/A

		nationalities and 3 locations in Dublin.	as access, and 8% as disabled		GenderEX; RESISTIRÉ; SAGE for interventions to advance gender equality TU Dublin EDI Fund supports innovative projects that promote EDI within the uni			
UCL	Public. Research university. UCL is organized in 11 faculties – one is Engineering Sciences	UCL has 43,800 students and 14,300 employees 53% of students are international and 37% of staff Of those, 6,317 students are within the Engineering Faculty	In 2019, in Engineering 31.5% of Undergraduates were female (55.5% in the whole of UCL), 45.9% of Postgraduates (66.5%), 35.8% of Postgraduate researchers (54.7%) and 36.9% of staff (53.2%)	Gender Age Ethnicity LGBTQ+ Religion Disability	DEI Strategy. Dedicated DEI teams and working groups. Diverse recruitment policies. Staff and student networks/committees EDI training	Same as institution-wide	Senior manager with DEI responsibilities. Dedicated DEI teams Faculty level policy Integration with Institution level activities. DEI UCL Engineering public website.	UCL Engineering: Equality, Diversity and Inclusion Strategy Document 2020-2030 (only accessible by UCL staff)

Initiatives to address diversity are centred around recruitment of students and staff, however recruitment is only the first step towards addressing balance in engineering. The appointment of a DEI officer or team, to ensure integration with institution-wide policies seems to be a common next step practice.

There are some indications of regional variation of institutions that demonstrate high awareness of a variety of DEI issues in their literature (DTU, KU Leuven, UCL etc.), which appear to be clustered in Northwestern Europe, as opposed to institutions elsewhere that focus mostly on one issue (IST) or use generic terminology (Polytech Orleans). This variation may be due to the level of detailed information shared in the public domain, but it can also be a reflection of the differences in local practice and cultural norms, as well as the variety of legal frameworks and education policies that govern universities across Europe. Further work will be required to investigate trends in a wider range of institutions, covering more European countries, especially of the East and South and they could further be complemented with observations of strategies and policies that are in place or are being planned.

The limited scope of this preliminary study does not permit a high degree of certainty in generalising the results. However, it is evident that among the institutions studied there are various interpretations of the definitions of diversity and inclusion, but initiatives tend to run along similar, relatively narrow paths. The ambiguity on what constitutes DEI affects how progress is measured, because different definitions and associations lead to different interpretations of the outcomes. There is therefore a need for better definitions of DEI, which will be the focus of the future work of this study. Policy evaluation is also needed to investigate best practice and to determine the causes of the apparent limited variation of initiatives, however this may also reflect self-selection bias, because the institutions examined are the authors' employers, that provide support for the authors' interest in DEI in engineering education.

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EXPERIENCES OF EUROPEAN ENGINEERING STUDENTS AND ACADEMICS IN THE UK: FINDINGS OF AN EXPLORATORY MIXED-METHODS STUDY

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ABSTRACT

In the UK Higher Education, 20% of all academic engineering staff and 12% of engineering students are European nationals. There has been much discussion about the impact of the UK's departure from the European Union in current and future relationships. However, prior to this study, no data on the impact of Brexit on engineering education and research, from the perspective of European students and academics, had been collected.

This study explores the impact of Brexit on European engineering students and academics experiences in UK Higher Education Institutions – their motivations to study and work in the UK, mobility, funding, and career prospects. The study adopted an exploratory mixed methods design. It began with a primary qualitative phase, where a diverse sample of 9 European engineering students and 15 academics were interviewed to explore their experiences following the Brexit decision. The key issues identified in this phase, via inductive and thematic analysis,

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were then explored in the following quantitative phase of the study, with a larger sample of European nationals – 89 engineering students and 104 academics – in an online survey.

The UK's engineering education is still attractive to a majority of European students and academics. However, changes in financial support for students, restrictions on freedom of movement and access to research funding are key decision factors when considering staying or leaving the UK. The findings of the study are also relevant for understanding the impacts on engineering research collaborations between the UK and higher education institutions in Europe.

1 INTRODUCTION

The United Kingdom has a long tradition of excellence in higher education and is recognised as being an important player in global engineering education and research. Regarding higher education, the UK attracts a far higher number of international academics of all disciplines, from all over the world, who teach and do research, than almost any other country in continental Europe, being only surpassed by Switzerland [1]. The engineering education sector relies on international mobility more than most sectors of society in terms of attracting experts from all over the world to research and teach in the UK and attracting international students.

Following the referendum, Mayhew [2] reflected on the implications of Brexit for the HE sector and identified three major areas – the impact on students, the impact on staff, and the impact on research funding. Mayhew also highlighted the freedom of movement for the sector as being critical in future EU-UK negotiations. The role of student and staff mobility, as a means to support UK universities research connections and competitiveness is also mentioned by Highman, "(…) future EU-UK relationships in research and science can only be properly implemented with the support and input of both academic and professional staff, while also including the student voice." [3, p.51].

To date, few studies have explored students' voices and, in particular, their career aspirations following Brexit: a study by McCroy and Thomson [4] focussed on UK undergraduates [4], and the study of Dodourova, Clarkin, and Lenkei [5] which included both British and non-British students.

Prior to this study, no data on experiences and perceptions about Brexit had been collected from European (EU) engineering students and academic staff, to understand better the impact of the UK's departure from the European Union on engineering education. The study reported here has collected and analysed data regarding the impact of leaving the European Union on mobility, funding, skills development, future study and career prospects of European nationals involved in engineering education in the UK.

2 METHODOLOGY

The study adopted an exploratory mixed methods design [6], collected and combined data from interviews (phase 1, qualitative) with and a survey (phase 2, quantitative) of EU engineering students and academics.

2.1 Interviews

A sample of 9 EU engineering students and 15 EU engineering academics were interviewed between October and November 2019, prior to the UK General Election, which occurred on the 12th December. A brief description of this sample is presented in Table 1.

In the interviews, students and staff were asked about: 1) factors they considered when choosing to study/work in the UK, career prospects they expected to have, and experiences and skills they were expecting to achieve; 2) their experience in the UK overall, and what impacts they had felt as a result of Brexit; 3) and what their career plans entail, and their preferences regarding leaving or remaining the UK.

Table 1. EU engineering students and academics (interviews)

Sample	Students	Academics
Sex	6 female, 3 male	3 female, 12 male
Degree/Position	5 undergraduates, 4 PhD students	4 researchers, 11 lecturers (teaching and research)
EU Nationalities	Danish, Dutch, Italian, Portuguese, and Romanian	Belgian, Bulgarian, Dutch, French, German, Italian, Portuguese, Romanian, Spanish
Universities location	5 universities: 3 England, 1 Northern Ireland, 1 Scotland	8 universities: 4 England, 2 Scotland, 1 Northern Ireland, 1 Wales

The transcripts of semi-structured Interviews were coded thematically to identify: (1) participants' motivations to come to study or work in engineering in the UK, (2) their experiences and future career plans, and (3) whether all of these were impacted by Brexit. Thematic analysis [7] of the interview was chosen as a methodological approach as there was an interest in finding themes in order to answer the research questions. The open-ended approach of the interviews was suitable for this methodology as thematic analysis "is not wedded to any pre-existing theoretical framework" [8, p. 81].

The key issues identified in this phase were used to inform the design of online surveys for students and staff

2.2 Survey

Due to the outbreak of COVID-19 pandemic, the launch of the online surveys were delayed to June 2020, after a pilot test with a convenience sample of 3 students and

3 academics. Due to a low response rate during summer term, the survey was kept open until September 2020. A total of 89 EU students and 104 EU academics completed the survey. An overview of this sample is presented in Table 2.

Table 2. EU engineering students and academics (survey)

Sample	Students	Academics
Sex	31.5% female	26% female, 62.5% male, 11.5% no answer
Degree/Position	37% PhD, 29.2% undergraduates, 25.8% Integrated Master's, 8% Master's (1-2 years degree)	31.8% reported 'Professor', 'Assistant Professor' or 'Associate Professor' as their job title; 21.2% 'Lecturer'; 13.5% 'Senior Lecturer' or 'Principal Lecturer' (13.5%); 10.6% 'Research Fellow', 'Research Assistant', 'Research Associate' or 'Postdoc fellow'.
EU Nationalities	22 nationalities. Most frequent: 14.6% Italian, 10.1% French, 9% German, 9% Romanian.	18 nationalities. Most frequent: 18.8% German, 17.9% Italian, 13.4% and French.
Universities location	13 universities: 94.4% England, 5.6% Scotland and Northern Ireland	37 universities: 71.2% England

3 RESULTS

The findings of the study are presented in the following three sub-sections: 1) EU engineering students and academics motivations to come to study/work in the UK, career prospects they expected to have, and experiences and skills they were expecting to achieve; 2) their experience in the UK overall, and what impacts they had felt as a result of Brexit; 3) what their career plans entail, and their preferences regarding leaving or remaining the UK.

3.1 Motivations

3.1.1 Students

Education. The interviews revealed that the international reputation of UK's universities and the desire to live abroad and have a different learning experience were common motivations to choose studying in the UK. Undergraduate students had the expectation to be taught in a more practical/hands-on approach and develop their technical English. Data collected in the surveys confirmed the importance of these same factors and motivations.

> [Italian undergraduate student] *(…) comparing to my home country (…) I would have learnt more about the theory and the background. I would have only used Italian. While in England, I would have learnt better English, more technical English, I would have more practical skills, more transferable skills (…) the English system is that they want you to get out there and work as soon as possible. While if I stayed in Italy, I would probably have become more of a researcher or an expert or something.*

Career prospects. Interviewed undergraduate students mentioned that the UK offers better job opportunities after graduation, especially at entry-level, in comparison to their home countries. For PhD students, UK universities offered more funded positions in their fields of interest and research opportunities than other European countries. These factors played an important role in their decision.

Funding. The vast majority of undergraduate and Integrated Masters students surveyed had a student loan, and all but two PhD students were fully funded. The interviews also highlighted that being eligible for Home/EU tuition fees for the whole duration of their degrees, as well as being able to access student finance, were key factors for undergraduate students. The follow-up survey confirmed that eligibility for a student loan, in the case of undergraduate students, and full scholarship, in the case of PhD students, was one of the most important factors when deciding to come and study in the UK, for more than 50% of the respondents.

3.1.2 Academics

Professional development. The UK engineering higher education sector was described as the "perfect environment" to develop both research and academic careers, offering good job opportunities, career progression and leadership positions in comparison to other European and non-European countries.

Distance to home country. On a more personal level, staying in Europe, or coming back to Europe after an experience abroad, was important to academics interviewed. This would mean they were able to stay at a short distance to their home countries and families. The English language was a key factor to choose the UK to pursue their academic careers. For these academics, speaking the language was essential to be able to fit into the UK's society.

> [Spanish academic] *In the UK you have the perfect environment to develop a normal engineering professional career or academic career (…) Apart from that, I speak some English, so maybe it was a work opportunity. It's not easy to move to a country. I do know the language; I know the culture. When I worked in [non-EU country], I had a good job, good salary but my [foreign language] was very limited. Plus, the idea that we can go to a place that is not your home country and start to live like a local, it is something that was important.*

The survey confirmed that easy travel between the UK and home country, more research and job opportunities in the UK than in other countries and being able to work and live in an English-speaking environment were the most important factors motivating their decision to come to work in the UK engineering education sector, regardless of whether academics had come to the UK prior or after the Brexit referendum.

3.2 Experiences

3.2.1 Students

Learning environment. Overall, students who were interviewed were satisfied with their decision to come and study in the UK and reported a wide range of positive experiences. Undergraduate students were particularly pleased with opportunities to engage in teamwork and problem solving. Being able to learn with international staff and students was a very positive aspect of their education and personal experiences in the UK.

The surveys confirmed that EU students' most valuable experiences of their time studying engineering in the UK were being part of a diverse and international university environment, quality of teaching and access to resources, as well as good links to industry.

> [German Integrated Masters student] *[I benefit from] meeting international and open-minded people from around the world, as well as learning in an industry-focused environment.*
>
> [Italian PhD student] *The chance of meeting people from all over Europe and the world, getting to know a variety of cultures and ways of thinking [was beneficial].*

The impact of Brexit. Most of those students interviewed who came to the UK after June 2016 said that Brexit had no substantial impact on their decision to study engineering in the UK. They mentioned being well informed about their ability to study in the UK. Two thirds of undergraduates, half of PhD students and one third of those on Integrated Masters courses surveyed maintained they would have come to study engineering in a UK university if they were making that decision today. For these students, quality of teaching and future prospects were the main reasons why. But for those who would not come to study if making that decision today, increasing costs incurred by EU students after Brexit (international fees), a potential reduction in jobs and research opportunities in the UK, and a general feeling of not being welcome, were their main concerns.

This was confirmed by the larger survey sample, with many students reporting that having to pay international fees, and not being eligible for a student loan/scholarship, would have been a major deterrent if they were making the decision to study engineering in a UK university today. In fact, only 8% of the surveyed undergraduate students would have come to study in the UK if not eligible for a student loan. The figures were 23.8% for Integrated Masters and 28.6% for PhD students.

> [Polish undergraduate student] *Without the student loan, I would not be able to study in the UK, thus I would not even think about paying International/Non-European tuition fees.*
>
> [Slovenian-Croatian PhD student] *As of last week, when it was announced EU students will be charged international tuition fees, my answer is no. Before I would still encourage others to apply to the UK.*

3.2.2 Academics

Working environment. The interviews revealed that, overall, academics were pleased with their experiences in the UK, citing good work conditions and being part of an international and collaborative environment as two of the most positive aspects. Universities were described as safe, supportive, and welcoming to EU and international staff.

> [Belgian academic] *I really, really enjoy the UK, working over here. In an academic setting, the institutions I worked so far, both of them and then contacts with other academic institutions – I always had the feeling that the general approach to research is a collaborative approach, where within the same institutes you're considered to be colleagues, working towards a bigger goal of striving and pushing the boundaries of what we know, and advance with research. Whereas in Canada and the States it was much more of a competitive environment amongst colleagues within the same department, which was something that I didn't really feel comfortable with.*

Career progression. In the survey, academics were positive about their career progression and access to resources, and less positive about their ability to secure EU research funding after the Brexit referendum.

> [French academic] *(…) I'm still very happy in the UK, I have to say. I'm very sheltered and protected. (…) It hasn't changed anything in my professional life. Three years ago, I got promoted as well. It hasn't affected my career pathway. I still feel supported by the university to the same level as any of my UK peers.*

The most valuable experiences of their time working as an engineering academic in the UK, among those surveyed, were the opportunity to work in an international, multicultural and multidisciplinary environment. Collaboration with national and international partners and access to research funding, as well as opportunities for career progression and good links to industry were also seen as very valuable.

The impact of Brexit. Many academics perceived these experiences as beginning to change negatively due to Brexit.

Less positive aspects among those interviewed were associated with an increased burden in academic administration, as well as unexpected teaching commitments by research staff, but this was not associated with Brexit or the UK.

When asked at interview about what changed in the last three years, many references were made about the negative impact of Brexit, immediate and future, on research capacity, collaborations, and access to funding and equipment. A few EU engineering academics reported being excluded from research proposals with European institutions

There were also mentions to the potential impact of Brexit on teaching and recruitment of EU students and staff. Some participants noticed a decrease in the number of EU applicants, particularly at postgraduate level.

One senior academic was particularly worried about the lack of information regarding potential changes in EU regulations in his engineering discipline/industry, and the future recognition of UK qualifications.

> [Italian academic] *The day UK leaves [the EU], will the PhD title be recognised in another EU country? Probably yes but we don't know. Will the UK be part of Horizon or the next main research programme from the EU? They say yes but we don't know. It's a mixed sort of thing. (…) we have a lot of regulations that come from the EU but do they want to diverge?*

Interviewed academics with links to the industrial sector acknowledged that some industries were already struggling to recruit highly skilled workers from EU countries but were optimistic about being able to secure future deals with the sector. To them, Brexit could be seen as an opportunity to establish new partnerships between UK's academia and industry, and open new research funding avenues.

> [German academic] *The good thing is that we're getting a lot of industry interest and these industry projects are easier to navigate (…) so we're generating income from that side.*

On a more personal level, academics were concerned about the state of the economy, restrictions to freedom of movement, and a general feeling of not being welcome. In general, academics in Scottish universities felt more welcomed than academics based in other regions. Two academics were very concerned about the impact of Brexit, and the lack of certainty, on their mental health and general well-being.

Most of those surveyed felt welcome in their own institution and in the broader engineering higher education community, but not particularly welcome in the UK.

To guarantee his rights and access to opportunities, one interviewed EU academic applied for British Citizenship to put his "mind at peace". Other two academics were considering applying in the future, since their plans were to remain in the UK indefinitely. However, personal factors would play an important role in their final decision.

All those surveyed who had British citizenship, a total of 9 academics, said that Brexit was the "major driver" to apply for it. These were mostly senior academics who were not considering moving out of the UK before retirement.Senior and highly experienced members of the academic staff, with permanent positions, expressed more concerns about the idea of having to relocate somewhere else. They feel they are in a stage of their careers where they need more stability and certainty about the future.

The academics who did not intend to apply for British citizenship described themselves as having a strong European identity and did not see value on being a citizen of a non-EU nation. In fact, for this group of academics, Brexit was the main reason not to apply for a British citizenship.

3.3 Plans

3.3.1 Students

Job opportunities. The interviews and surveys revealed that undergraduate and PhD students alike were concerned about the potential negative impacts of Brexit on the state of the economy, on their rights as EU citizens, and on their future plans in the UK. Despite this, more than half of those surveyed planned to stay in the UK after graduation, while some of those interviewed were particularly keen to stay in the UK for further studies, with undergraduate students particularly wanting to stay and develop their engineering careers in the UK.

Career progression and family plans. For the PhD students we spoke to, the willingness to stay in the UK was dependent on having access to job opportunities and research funds, as the UK was seen as an attractive place to pursue their future career plans as engineering academics. They made more references to the importance of feeling welcome and having family plans as important factors to consider in their decision to stay or leave the UK after Brexit.

3.3.2 Academics

Career progression. Most of the interviewees would like to remain in the UK, although many have already considered moving out – nine out of ten EU academics surveyed have considered moving out of the UK. If deciding to leave the UK, most were planning to do it in 2 to 5 years-time, and get back to their home countries, other European country (Switzerland, Germany, Netherlands and France were mentioned more frequently) or Canada.

The interviewees proposed that their ability and willingness to stay in the UK will be determined by opportunities for career progression and being guaranteed the same rights that EU nationals had before Brexit regarding: freedom of movement, access to EU research funding, and being treated as UK citizens. This was confirmed in the survey.

Many academics, in both interviews and survey, expressed concerns about the validity of the EU Settlement Scheme, the impact of a no-deal on UK's economy, and not feeling welcome as before. Reflecting these worries, only one third of the surveyed EU engineering academics would have come to the UK if they had to make that decision today.

4 DISCUSSION

The UK's engineering education is still attractive to a majority of EU students, at different levels of study. However, interview and survey data support the idea that EU undergraduate students who started their degrees after June 2016 were taking the opportunity to study engineering in the UK as a 'last chance' before changes to fees, funding, and visa requirements. Being eligible for home fee status and financial support were among the most important factors when making the decision to study engineering in the UK.

Whereas EU engineering academics agree that the UK's universities provide the resources and opportunities for career progression and research leadership, only one third of survey respondents would have come to the UK if they had had to make that decision today (at the time of the survey, June-September 2020).

One third of EU academics surveyed came to the UK as undergraduate and/or postgraduate engineering students. Many EU students plan to stay in the UK after graduation to work as engineers. However, changes to study conditions and the UK's points-based immigration system are seen as heavy barriers to EU nationals and are likely to have a negative impact not only on student and academic staff recruitment, but also on the UK's engineering research and innovation base, and on its much-needed, diverse and talented workforce.

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HOW DO STUDENTS REGULATE THEIR LEARNING IN CHALLENGE BASED LEARNING? AN ANALYSIS OF STUDENTS' LEARNING PORTFOLIOS

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ABSTRACT

Self-regulated learning (SRL) is one the key pedagogical principles of Challenge-based Learning (CBL) in engineering curricula. Students in CBL have the primary responsibility for planning, implementing, and evaluating their effort and progress. This study explores the use of learning portfolios as a pedagogical tool aimed to document students' SRL in a CBL course for 1st year engineering students. The research question was: How is SRL documented in a personal learning portfolio during a CBL course? Students were expected to work for 9 weeks with a group of peers on an open-ended challenge. Students were asked to complete a learning portfolio at 3 moments. In week 1, they were asked to set, individually, 5 disciplinary

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and 5 professional goals they wanted to achieve and in week 5 and 9 they were encouraged to reflect on the progress and attainment of those goals. Twelve students' learning portfolios were included for analysis in this study. Content analysis of the learning portfolios revealed that students in week 1, described goal setting and in week 5 described SRL processes such as monitoring and self- evaluation while in the final submission in week 9, students reflected on the attainment of their individual goals and the overall success of their project, revealing a need for balancing their own disciplinary and professional goals and the overall goals of group they were members of. The study suggests that learning portfolios provide a useful instrument to encourage SRL in CBL. Limitations and implications for education and research are discussed.

1. INTRODUCTION

1.1 Self-regulated Learning in Challenge-based learning

Challenge-based Learning (CBL) is a student-centered pedagogy becoming increasingly popular in engineering curricula [1] [2]. In CBL, learning starts from an open ended, real life challenge and students are given the freedom to think out of the box and design a project directed entirely by themselves [2] [3]. This implies that students need to show increased levels of agency, autonomy, and self-directedness [2]. For example, a study by Membrillio et al. [3] involving real life, open ended challenges in collaboration with an external industry partner, found that students experienced difficulties in regulating their learning, due to the increased complexity and uncertainty associated with the course. This suggest that Self-regulated learning (SRL) is an essential skill for effective learning in CBL. However, the way students regulate their learning in a CBL context has not received adequate attention in the literature. Thus, the aim of the present study is to assess how SRL is documented by 1st year engineering students working in a CBL course.

1.2 Theoretical Background: Self-regulated learning

SRL can be seen as an umbrella term that which entails metacognitive processes such as goal setting and monitoring, motivational processes like self-efficacy, mastery goal orientation or intrinsic task interest and behavioral processes such as, attention sustainment, choosing and structuring the learning environment [4] [5] One of the most widely used models of SRL is the cyclical model by Zimmerman [4] that is characterized by 3 cyclical iterative phases: forethought, performance, and self-reflection [6].

The forethought phase describes the processes of task analysis and self-motivational beliefs that take place before students engage with learning. In this phase, self-efficacy, outcome expectancies, intrinsic interest, and goal orientations are important. In addition, in the forethought phase, students engage in task analysis, which includes goal setting and strategic planning. In the performance phase, students systematically and actively engage in learning. In this phase, self-control and self-observation are key processes. Students exhibit self-control by engaging in strategies such as imagery, self-instruction, attention focusing, and others targeted at reaching goals. Self-observation includes self-monitoring and self-recording of learning progress. In the final phase, self-reflection, students' use of self-monitoring and feedback from the previous phase to form self- evaluations (self-judgment) and attributions about the causes of their performance. Students also react to their performance with self-satisfaction about achieving a certain goal and adaptive or defensive responses. Adaptive responses include adjustment and modification of motivational beliefs and task analysis, while defensive responses include emotional reactions to performances.

1.3 Portfolios and Self- regulated Learning

Portfolios represent a collection of evidence of students' learning [7] [8]. Portfolios are frequently used to support and document students' SRL processes such goal setting, monitoring or reflection [8] [9]. A study conducted by Mansvelder-Longayroux et al. [9] analyzed the content of student teachers' portfolios and made the distinction between in action-oriented and meaning-oriented activities described in portfolios. Action oriented activities describe what has been done and help students to become aware of what they know and what they are able to do. Meaning- oriented activities entail sense- making of an experience and understanding the underlying process of it. They found that students engage more often in action oriented activities when writing a portfolio. However, meaning oriented activities and reflection are also important for SRL and students' development, but students need additional support in order to reflect on their experiences [8]. A systematic review of the relationship between the use of portfolios and SRL suggested that influencing factors include students' supervision in SRL skills development, integration of portfolio into educational routine, regular coaching and scaffolding is provided to students to increase motivation, designing a portfolio to facilitate at least goal setting, task-analysis, plan implementation, and self-evaluation [7].

1.4 Research Question

The research question that guides the present study is: "How is SRL documented in a personal learning portfolio during a CBL course?" To answer this question, we analysed the written Personal Learning Portfolios that students wrote during a first year CBL course.

2. METHODS

2.1 Context and participants

For this study, we focused on one CBL course, taking place in Eindhoven University of Technology. This course is part of the educational initiative E3 (Eindhoven Engineering Education). In this course called E3-Challenge 1, first year engineering students from different disciplines can work collaboratively with a group of peers for 9 weeks on an open challenge, in which they can design, create and evaluate a product in the context of the UN Sustainable Development Goals. The challenges concern the following topics: Pulsar navigation, Wind energy storage, Healthy soundscapes in shared workspaces and Physics of life.

During the course, students were having meetings on a weekly basis with an expert on their case as well as weekly SCRUM meetings with a Teaching Assistant (TA) that supports them in group processes. By design this course is encouraging SRL by giving to students the primary responsibility for planning, implementing, and evaluating their effort and progress during the course. As part of the course, students were asked to write a portfolio to document their SRL at three times: in week 1, students had to set 5 disciplinary and 5 professional goals they would like to achieve during the course. In week 5 and week 9 they had to look back and on how they were progressing in achieving those goals. For all three submissions, students received individual written feedback and advice from the course coordinator and teaching assistants aimed to facilitate their SRL. The feedback focused on encouraging students to re-evaluate their initial goals, plan and evaluate them as part of SRL.

2.2 Data collection

Writing the Personal Learning portfolio was a mandatory deliverable of the course that counted for 30% of students' final grade. After the end of the course, we asked from students' permission to analyze their portfolios. Out of 30 students participating in the course, 12 students consented to include their portfolios for analysis in this study, which resulted in 3 submissions per students, in total 36 submissions. The Ethics Review Board of the University has approved this study.

2.3 Data analysis

Following the theoretical model of Zimmerman [4], we developed 21 a priori codes, corresponding to all elements of SRL phases of forethought, performance and self-reflection to analyze students' portfolios. Twenty additional codes were developed to group students' disciplinary and professional goals in submission 1. Content analysis was conducted using ATLAS.ti [10]. The main researcher analyzed all portfolios and an auditing procedure among all researchers was conducted to discuss the results of the coding process.

3. RESULTS

According to our analysis, submission 1 of students' portfolios aligned with the forethought phase. Submission 2 had examples of performance and self-reflection phase and examples of new goal setting corresponding to the forethought phase. Submission 3 focused on self-reflection. All 12 portfolios mentioned goal setting in submission 1 (5 disciplinary and 5 professional goals), monitoring of all goals in submission 2 and self- evaluation of achieved goals in submission 3. Our analysis also suggested that several elements of the SRL model by Zimmerman [4] were not documented at all in students' portfolios. Those included: strategic planning, self- efficacy, outcome expectations, time management in the planning of activities, imagery, interest incentives and self- consequences. Table 1 summarizes the codes developed based on the model of Zimmerman [4] [5] and the additional codes developed by the researchers. Table 1 also provides a description for each code, their frequency and the number of students who reported them.

Table 1. Overview of codes identified in students' portfolios

SRL phases	**A priori codes**	**Code explanation**	**Frequency**	**N of students**	**Portfolio submission**
PHASE 1. Forethought Phase					
Task Analysis					
	Goal Setting	*Goals set by students*			Submission 1 (week 1)
		Disciplinary goals			
		Understanding of concepts/ development of disciplinary knowledge	33	12	Submission 1 (week 1)
		Coding (e.g., using MATLAB, Python)	8	8	Submission 1 (week 1)
		3D printing	8	8	Submission 1 (week 1)
		Application of knowledge	7	7	Submission 1 (week 1)
		Literature search skills	3	3	Submission 1 (week 1)
		Professional goals			
		Teamwork	11	11	Submission 1 (week 1)
		Presentation skills/writing skills	7	7	Submission 1 (week 1)
		Communication skills	7	7	Submission 1 (week 1)
		Time management	6	6	Submission 1 (week 1)
		Management of meetings (minute taking, being chairman)	6	6	Submission 1 (week 1)
		Project management skills	6	6	Submission 1 (week 1)
		Leadership skills	4	4	Submission 1 (week 1)
		Creativity	3	3	Submission 1 (week 1)
		Design thinking	2	2	Submission 1 (week 1)
		Critical thinking	2	2	Submission 1 (week 1)
		Reflection	2	2	Submission 1 (week 1)

		Flexibility	2	2	Submission 1 (week 1)
		Giving and receiving feedback	1	1	Submission 1 (week 1)
		Risk taking	1	1	Submission 1 (week 1)
		Problem solving	1	1	Submission 1 (week 1)
	Strategic Planning	*Development of an action plan and needed strategies to achieve their goals*	Not reported	Not reported	Not reported
Self- Motivation Beliefs					
	Self-Efficacy	*Students' belief about their capability to achieve their goals*	Not reported	Not reported	Not reported
	Outcome Expectation	*Students' belief about the probability to succeed in their goals*	Not reported	Not reported	Not reported
	Task Value	*Relevance of tasks for achievement of goals*	11	4	Submission 1 (week 1)
	Interest	*Personal liking and interest of performing tasks*	10	7	Submission 1 (week 1)
	Goal Orientation	*Students' beliefs about learning purpose*	3	3	Submission 1 (week 1)
PHASE 2. Performance Phase					
Self-Observation					
	Monitoring	*Students' cognitive process to assess performance*	120	12	Submission 2 (week 5)
	Self-Recording	*Students' recording of actions to achieve certain goals*	6	6	Submission 2 (week 5)
Self-Control					
	Task Strategies	*Students' use of strategies to complete a task*	4	4	Submission 2 (week 5)
	Self-Instruction	*Students' own efforts to learn a task*	4	4	Submission 2 (week 5)

	Imagery	*Students' mental organization of information*	Not reported	Not reported	Not reported
	Time Management	*Planning the use of time for a certain task*	Not reported	Not reported	Not reported
	Environmental Structuring	*Students' actions to create an environment that facilitates learning*	3	3	Submission 2 (week 5)
	Help Seeking	*Students' request for help to others (teachers and peers)*	6	3	Submission 2 (week 5)
	Interest Incentives	*Students' self-given messages to remind their goals*	Not reported	Not reported	Not reported
	Self-Consequences	*Students' self-praise and self-rewards*	Not reported	Not reported	Not reported
PHASE 3. Self-Reflection phase					
Self-Judgement					
	Self-Evaluation	*Students' self-assessment of own performance in achieving their goals*	120 6	12 6	Submission 3 (week 9) Submission 2 (week 5)
	Causal Attribution	*Students' explanation about their success and failures*	14 6	8 6	Submission 3 (week 9) Submission 2 (week 5)
Self-Reaction					
	Self-Satisfaction	*Students' affective and cognitive reactions produced by self-judgement*	11	9	Submission 3 (week 9)
	Adaptive/ Defensive Decisions	*Students' willingness to perform a certain goal or task again in the future and to activate learning strategies*	11	5	Submission 3 (week 9)

3.1 Forethought phase

The analysis of submission 1 revealed that students were all able to identify and describe relevant disciplinary and professional goals related to the course.
Sixty disciplinary goals and 60 professional goals were identified. One student reported as one of his disciplinary goals the development of project management skills, but we decided to include this goal under the professional goals category. This resulted in 59 disciplinary goals grouped in 5 categories and 61 professional goals grouped in 15 categories (see Table 1).
Regarding task analysis, even though goal setting was prominent in all initial submissions, planning was not mentioned, meaning that students did not provide any plan on how they aimed to achieve those goals.
Regarding, self-motivation beliefs, only 4 students explained why setting these goals would be beneficial for them in the future (task value) and 7 students elaborated on their personal interest in pursuing their specific disciplinary and professional goals (interest).
For example the quote below shows the way students formulated their goals, describing the task value of the selected goals and their personal interest in pursuing them.

> *I aspire to improve my knowledge of physics through the Applied Natural Sciences course, not only for the sake of this project, but also to develop a greater appreciation for real world phenomena and how they work (Student 1)*

Students showed in their initial submission enthusiasm and genuine interest to the content of the course as well as the challenge-based learning process which in their perspective gave them the freedom to pursue their interests in more depth and develop useful skills for their future career.

> *When I read about the [ ] course, I felt this was THE opportunity to invest my energy solving real problems through the fields of biology and physics, my favorite natural science fields. The innovative aspect of this project, was the main reason for me to choose this project. (Student 11)*

Finally, examples of forethought phase were also found in the second submission. After students monitored their performance in week 5 and reflected on their progress, 6 students adjusted their initial goals and set new goals that were more suitable for this stage of the course, taking into consideration time constraints, personal interest, and balance with group goals.
For example, a student had initially set a goal to learn MATLAB but in week 5 re-evaluated the goal and adjusted it:

> *I have never used Matlab before, as I study mechanical engineering. I hope to gain an understanding of how the program works and how to use it (Student 8, submission week 1)*

> *Given the work-distribution that my team has adopted thus far, this is a goal I have made little progress in(…)This is something I hope to work more on in the coming weeks, especially as the algorithm (based on matlab data) is developed. My hope is that I can assume a position of assistance and aid my group members with any MATLAB work they may have. I should note that the*

> *reason they have been focusing on MATLAB whereas I have not is simply because they were already experienced in it, so it made more sense (Student 8, submission week 5).*

3.2 Performance phase

In submission 2, students had to look back at the first 5 weeks of the course and reflect on how they progressed with their self-set goals, while in the third submission they had to evaluate the overall learning experience after the end of the course.
In both submission 2 and 3, all students used monitoring as a process to assess ongoing performance and achievement of goals. Six students elaborated on the actions they performed in order to achieve their goals (self- recording). This included recording how many hours they spent on each task they had to accomplish or breaking the tasks in smaller steps or prioritizing different tasks. Self- recording helped those student to realize that certain goals needed to be prioritized according to their importance and time availability. For example, if a task was considered less important for the course and very time consuming, it was receiving a lower priority.

> *Related to the goal of learning Siemens NX, this goal has unfortunately not been achieved due to a number of reasons. First of all the main reason it has not been achieved is due to the fact that it would not add much value to our project and time could better be spent on the coded aspect of our design rather than the physical (Student 6)*

Four students mentioned self-instruction as their main strategy to achieve their goals.

> *For coding and 3D modelling I still need to watch more tutorial videos and keep practicing, as well as, learn more basics like Pandas. My plan to continue developing knowledge from the Applied Natural Science course is to often practice the exercises and hopefully maintain an average grade of at least 4 out of 5 for the quizzes (Student 1)*

> *Because of our common Signals I course, I am able to better understand how frequencies can be managed and calculated. For example how an AM signal is propagated using a carrier frequency. As well as this, I have watched multiple online lectures on the topic and read some research papers. Using these, I have managed to create an antenna suitable for a TDoA (Time Difference of Arrival) RDF system (Student 5)*

Regarding professional goals, such project management, other task strategies such as keeping notes, using calendars or using communication platforms to facilitate collaboration among team members were mentioned by 4 students.

Even though time management was an important goal for 8 students, none of the students were concrete in their planning on how to achieve them. As mentioned earlier, 6 students recorded the time spent in the accomplishment of certain tasks but they did not plan or adjust their time management for the coming weeks of the course.

Three students mentioned environmental structuring as important factor that influenced their learning. This was relevant to the fact that the course was taking place online due to COVID-19, thus students could not go to campus or meet their peers or teachers in real life. Thus, students had to do several to make studying from home productive. Help seeking was mentioned in 4 instances in the form of asking teachers or peers for support for clarifying questions, or asking additional material like articles that were relevant to their challenge.

3.3 Self-reflection phase

In submission 2, students did not engage only in monitoring of current performance, but they also engaged in self-reflection about the suitability of their goals and the need for adjustment. In submission 2, 6 students realized that the initial goals they had set were either too vague or too ambitious and thus it was hard to assess their achievement. When evaluating their progress, students realized the importance of good planning.

> *Another thing I realized next time I have to make a better plan on how I am going to achieve my goals. This was the first time I really set learning goals myself, and now while looking back, I think I could have done better if I had made a better plan on how to achieve these goals (Student 2)*

Causal attribution for their goal success or need for adjustment were found in 6 student portfolios. Students attributed the need for adjusting their goals to time constraints and project specifications that were forcing them to pursue different goals that were more relevant for the project success.

> *I need to modify my goal of developing skills needed to combine physics and maths, and instead direct it more towards improving my abilities to model mathematical-physical equations (Student 1).*

When considering adapting their goals, two aspects played an important role: how clear and attainable their personal goals were at the first place and, secondly, whether their goals were still in accordance with the group goals.

Submission 3 helped students to reflect not only on whether their goals were attained or not but also on the reasons about it and on how this learning could be useful for their professional future. In this submission, 8 students reported causal attributions about the reasons of not accomplishing their initial goals, including conflicting goals with final project characteristics, limited time and setting too many and too ambitious goals at the beginning. Nine students reported positive emotions such as satisfaction, and pride associated with the successful accomplishments of tasks and achievement of goals.

> *This course has been a pleasure to participate in. I was engaged with the topic, learnt a lot and ultimately created a final product that I'm proud of (Student 8)*

Five students appreciated the opportunity to develop reflection as a skill for the course. They realized that looking back and evaluating how things went helped them to approach new tasks in a more efficient way. These 5 students also reflected on how this learning would be useful in their future and expressed their willingness to participate again in a CBL course to develop further their disciplinary and professional goals.

What I have found in this project is that, in order to conduct research that can clearly be applied, this needs to be decided in the initial stages of the project and needs to be included in the research question[…] A good observation in the midterm report is that the application needs to be included in the tasks to be appropriately explored, which happens if the research question aims in an applied direction […]Therefore, in the future it is important to know from the start what your team members aspire to do and through that knowledge decide what directions the research can go in (Student 13)

Five students appreciated the value of reflection itself. They saw the importance of not only doing but also taking a step back and evaluate their work. For example, one student mentioned how reflection had helped him use the feedback of peers and teachers in a more constructive way.

Having practiced self-reflection before each peer review and after each meeting, I was able to reflect on the feedback for my mid-term goals and incorporate it into my final personal portfolio. Reflecting on the feedback also gave me a better understanding of how I could become a more effective team member (Student 10)

4. DISCUSSION

In this study, we aimed to assess how SRL is documented in a portfolio that students had to produce in the context of a CBL course. According to the findings of the study, students were able to identify disciplinary and professional goals that were in accordance with the course but needed additional guidance on making the goals more specific, measurable, clear and suitable for the time frame of the course. In this study, goals acted as regulatory agents for SRL. Despite the fact that students were able to set relevant and coherent goals, they did not describe a concrete planning on how to achieve them in the forethought phase. That made goal attainment and evaluation harder for students.

In the performance phase, students had to reevaluate their goals, adjust them to time constraints but also negotiate and prioritize goals taking into considerations team goals in addition to their personal goals. This suggests that individual SRL processes might interfere with group processes taking place during a CBL course.
Thus, together with the concept of SRL, in CBL also the concepts of co-regulated learning (CRL) and shared regulated learning (ShRL) are relevant [11] [12].
In the final submission, students, described clearly which goals they achieved and which they did not achieve during the course. Writing a portfolio helped students making their learning process visible and explicit both to themselves and their teachers. They used the portfolio as a tool to look back on their experience and actions during the course and make explicit what they had done, what they learned and how they have progressed during the course. This is in accordance with the study of Mansvelder-Longayroux et al. [9] where the analysis of student teachers' portfolios revealed that they focused mostly on action oriented activities. In our study, few students reported that through the use of portfolio and documentation of SRL, they appreciated the value of reflection. As reflection plays an important role in SRL, encouraging students to use the portfolio as a tool for reflection can be beneficial for

students in CBL. In this case, students need additional support when reflecting on their learning process [7].

4.1 Recommendations for practice

The study suggests that SRL is important in CBL, and portfolio can be a useful way to facilitate the documentation of students' learning process. As reflection has self-regulatory function in the learning process and students should be encouraged to use the portfolio for documenting their learning process but also reflecting about it. In our study, we saw that several aspects of SRL learning were not mentioned at all by students. In that respect, the use of portfolio can be helpful but only if students receive support in writing in depth reflections. Reflective assignments can provide opportunities to dive deep into the processes that allow students to take control of their own learning [9].

4.2 Limitations and future direction for research

The study focused on a specific course and the included sample was small, thus more general conclusions cannot be drawn. Another limitation of the study is the focus only on SRL. Learning in CBL is not only individual but also collaborative, thus other forms of regulation such co-regulation, which occurs between students and teachers and socially shared regulation which occurs with a group of students are also relevant and should be explored. Future studies should explore the influence and experiences of the aforementioned social types of regulation as well [11] [12].

5. CONCLUSIONS

SRL is one the key pedagogical principles of CBL in engineering curricula. Students in CBL have the primary responsibility for planning, implementing, and evaluating their effort and progress. Combining writing a portfolio with additional support towards reflecting would be beneficial for students' learning in CBL courses.

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ASSESSING SDGS' LEARNING OBJECTIVES IN ENGINEERING EDUCATION. CASE STUDY. ENGINEERING IN INDUSTRIAL DESIGN AND PRODUCT DEVELOPMENT AT UPC BARCELONA TECH

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Conference Key Areas: *Curriculum development, Sustainability*
Keywords: *Education for sustainable development, Sustainability in engineering degrees, Sustainability competences, Curriculum design.*

ABSTRACT

Education for the Sustainable Development Goals (ESDG) in higher education requires a methodology to diagnose its presence in the degrees as a starting phase to design a desired scenario, where graduates are qualified with the needed SDG competences. The EDINSOST2-SDG project, involving 8 Spanish universities, pursues this transition and sets the framework for this study.
This paper shows the methodology and results of diagnosing the presence of sustainability competences and the SDG at the undergraduate engineering degree in Industrial Design and Product Development at the School of Engineering of Vilanova i la Geltrú of the Universitat Politècnica de Catalunya. The methodology can be applied to any engineering degree and synthetases the results through Sustainability maps. The starting point is the Engineering Sustainability Map, from the project EDINSOST2-SDG that states the learning outcomes in relation to Sustainability and SDG that engineering students must master when graduating. From there we build assessment maps of the degree analysed. Map 1: shows the Sustainability learning outcomes. Map 2: shows the SDG based on their learning objectives. These maps allow curriculum designers to verify to what extent Sustainability and SDGs are embedded in the subjects, semesters and in the whole engineering degree.

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1 INTRODUCTION

1.1 The Agenda 2030 and higher education

In September 2015, the United Nations adopted the Agenda 2030 for Sustainable Development. The resolution announces a plan of action focused on «people, planet and prosperity» that seeks to «strengthen universal peace in larger freedom» and recognizes that «eradicating poverty in all its forms and dimensions, including extreme poverty, is the greatest global challenge and an indispensable requirement for sustainable development». The 17 Sustainable Development Goals (SDG) and their 169 associated targets are meant to «balance the three dimensions of sustainable development: the economic, social and environmental» [1]. According to UNESCO, ESDG arises as an essential instrument to achieve the SDGs that allow to face current challenges such as Climate Change and the need of a global shift regarding values, attitudes and skills. UNESCO defined 255 learning objectives (15 for each SDG) that students should master. Focusing on the role of higher education in contributing to SDGs achievement, Universities have historically been institutions aimed at creating and transmitting knowledge through research and teaching. Therefore, integrating ESDG in higher education is considered a key component to foster the emergence of agents of change in our society [2]. Mapping what a university is already doing in relation to ESDG is the first strategic step to implement it in a degree [3]. Hence, this paper is aimed at finding how to diagnose the presence of sustainability and SDGs in a higher education degree.

1.2 EDINSOST2-SDG and the Engineering Design Degree at UPC

EDINSOST2-SDG is a project aimed at integrating SDGs into sustainability training in Spanish university degrees. It is financed by the spanish Ministry of Science, Innovation and Universities (MCIU), the State Research Agency (AEI) and the European Regional Development Fund (ERDF). The project provides a set of tools that allow to diagnose the presence and learning of sustainability in a degree. The tools applied in this case study are the following:

A. Engineering Sustainability Map (ESM)

The ESM is a matrix containing a common Sustainability Map for all engineering degrees which summarizes the learning outcomes related to the 4 transversal sustainability competences proposed by the Conference of the Presidents of the Spanish Universities (CRUE) [4, 5] and the SDGs' learning objectives proposed by UNESCO [1, 2].

B. Sustainability Presence Map (SPM)

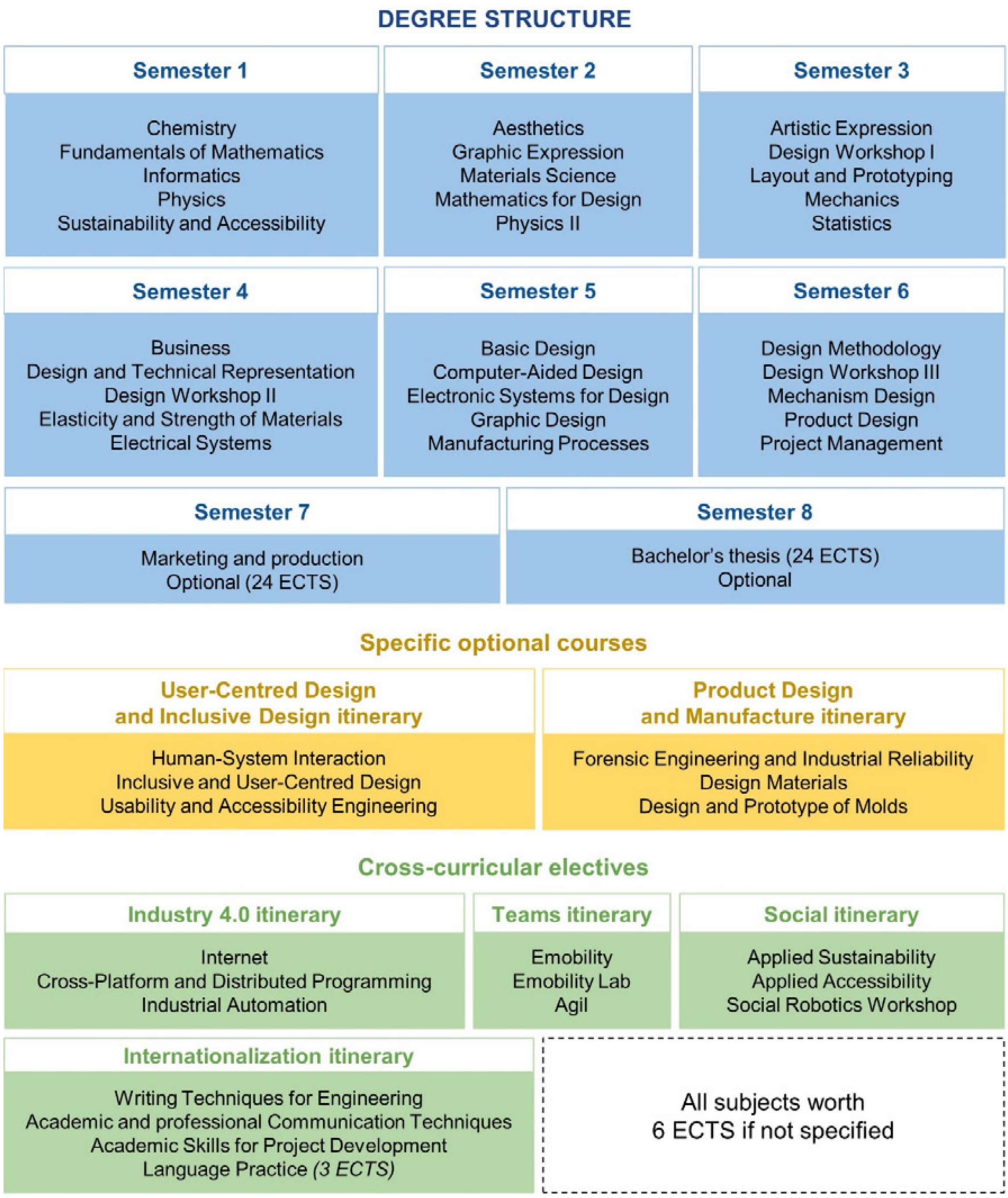
The SPM is a matrix that shows how a degree fulfils the learning outcomes of the ESM. Each cell relates each learning outcome proposed by the ESM to each subject that is being taught in the degree.

C. SDG Presence Map (SDGPM)

The SDGPM is a matrix that shows how a degree fulfils the SDGs based on the learning objectives of UNESCO [2].

The bachelor's degree in Industrial Design and Product Development Engineering is being taught at the UPC Engineering School of Vilanova i la Geltrú (EPSEVG). It is aimed at providing the student with the skills to become an industrial designer and product developer [6]. Figure 1 shows the curriculum of the degree including the specific optional subjects related to itineraries and also cross curricular electives.

Fig 1. Curriculum of the undergraduate degree in Industrial Design and Product Development Engineering.



The degree has a study load of 240 ECTS [7]. These are distributed in 60 basic education credits, 126 compulsory credits, 30 optional credits and a final degree project worth 24 credits. 49 subjects, the final degree project and optional external internships configure each student's path in order to obtain the degree.

2 METHODOLOGY

This paper presents a case study that applies a methodology to evaluate the presence of sustainability and the SDGs in Engineering Degrees, using tools provided by EDINSOST2-SDG. The methodology is piloted as a case study to the Engineering Design degree taught at EPSEVG of the Universitat Politècnica de Catalunya.

2.1 Information sources

Gathering information about the degree is the very first step. For this case study, the following information sources have been considered:

- The latest version of the application form for modification of official degrees, which provides relevant data to understand the relation between subjects, and their corresponding competences [7].
- The latest versions of the teaching guides that are available in the degrees' official website, which offer information about the content, the methodology and the evaluation of each subject [6].

2.2 How to translate the information into maps

The starting point is the Engineering Sustainability Map (ESM), which states the learning outcomes in relation to Sustainability and SDG that engineering students must master when graduating. The map disaggregates the transversal competences in 4 dimensions (environmental, social, economic and holistic) that can be assessed to facilitate its understanding and implementation. The result is a map with 7 competency units that are operationalized through learning outcomes that students need to have when graduating. The learning outcomes are categorized through a specific taxonomy based on the simplified Miller Pyramid (Level 1: Know, Level 2: Know How and Level 3: Demonstrate + Do), useful for sequencing the acquisition of learning outcomes and ending with a total set of 53 learning outcomes for the 7 competency units. The ESM facilitates analysing how sustainability is being embedded in an engineering degree [5].

To apply the ESM in the Design engineering degree, we created a matrix that compares the 81 competences of the degree (columns) with the 53 learning outcomes (raws) proposed by the ESM. To evaluate the concordance between the competencies of the degree and the learning outcomes proposed by the ESM, a scoring criteria has been developed: “A” is scored if there is a lot of concordance between the meaning of the learning objective and the meaning of the competence, as well as some words coincide; “B” if the meaning of the learning objective can be easily related to the results of the competence; “C” if the meaning of the learning objective can somehow be related to the results of the competence. and “D” otherwise. To complete the matrix, each cell needs to be scored according to the ESM scoring criteria (Table 1).

Table 1. ESM - Degree Competences matrix.

Applying the ESM to a degree		Competences of the degree		
		Competence 1	Competence …	Competence n
ESM learning outcomes	Learning outcome 1	*A, B, C or D*	*A, B, C or D*	*A, B, C or D*
	Learning outcome …	*A, B, C or D*	*A, B, C or D*	*A, B, C or D*
	Learning outcome n	*A, B, C or D*	*A, B, C or D*	*A, B, C or D*

Map 1: Sustainability Presence Map (SPM)

The first step is to relate the Sustainability learning outcomes defined in the ESM, to each subject of the degree. The result is a Sustainability Presence Map (SPM) of the degree. A complete SPM provides a visual representation of how sustainability competences are being distributed in a degree. To create the SPM of the Design engineering degree, we created a matrix that compares each subject of the degree (columns) to each learning outcome of the ESM (rows). This implies checking in advance which competences each subject is working on. Once the matrix is set, each cell can be scored 3, 2, 1 or 0 if the scoring in the ESM has been A, B, C or D, respectively. In case that a subject has competencies that coincide in scoring the same learning outcome, only the highest score will be taken into account.

Table 2. Completing the Sustainability Presence Map.

Completing the SPM		Subjects of the degree		
		Subject 1	Subject …	Subject n
ESCM learning outcomes	Learning outcome 1	*3, 2, 1 or 0*	*3, 2, 1 or 0*	*3, 2, 1 or 0*
	Learning outcome …	*3, 2, 1 or 0*	*3, 2, 1 or 0*	*3, 2, 1 or 0*
	Learning outcome n	*3, 2, 1 or 0*	*3, 2, 1 or 0*	*3, 2, 1 or 0*

To translate the SPM score into percentage, it is necessary to consider the operationalisation of the ESM. This is possible by applying the *Eq. (1)* in each cell of the SPM. The resulting percentage shows the presence of each learning outcome in each subject.

$$SPM[\%] = \frac{100*SPMscore}{nDIM*nCU*nL*nLO*nPr} \quad (1).$$

Where:

SPMscore: cell score in the SPM; ***nDIM:*** number of possible dimensions of a competence; ***nCU:*** number of competency units related to the dimension; ***nL***: number of learning levels related to the competency unit; ***nLO:*** number of learning outcomes related to the level; **n*Pr:*** amount of possible results according to the SPM scoring criteria. Scoring 0 will always mean a 0% of presence. Therefore, it is not considered as a possible result that distributes weight of the percentage.

Map 2: SDG Presence Map (SDGPM)

A SDGPM is a matrix set for each subject of the degree that shows the presence [%] of each SDG (columns) in relation to each learning outcome (rows). To obtain a SDGPM, first the EDINSOST2-SDG project identified which of the UNESCO SDG learning objectives should be mastered in any Engineering Degree and second, it related those to the learning outcomes of the ESM. Knowing both relations allows us to create a matrix that states the percentage of each learning outcome in relation to accomplishing each SDG. To calculate the presence of each SDG in a subject, the percentage of presence of each SDG related to a learning outcome has to be multiplied by the percentage of the SPM [%] of the corresponding learning outcome. Final step is taking the maximum value [%] of each SDG column, which will represent the presence of a SDG in a subject.

3 RESULTS

Results are synthesized in a graphical format to ease the communication of the diagnosis outcomes. Spider charts show which competences, learning outcomes or SDG are covered at degree, semester or subject level. Visualizing the strengths and weaknesses of sustainability and SDGs content in a degree should raise awareness of which aspects could be improved in a curriculum. A degree-level diagnose highlights which are the less (or most) aspects assessed in a degree. The results should help rethinking the distribution of the subjects to make the degree more efficient. Knowing the diangose of a specific subject provides hints on which competencies could be further developed and therefore enhancing the whole degree’s results. Figrues 2 to 4 are examples of the results that can be obtained.

Figure 2 represents the average percentage of the presence of the 4 sustainability competencies proposed by CRUE in the whole degree. Competence 1 (C1) stands out above the other 3, while competence 3 is the least developed. Figure 3 represents the average percentage of the presence of the 7 Competency Units (CU) of the ESM proposed by EDINSOST2-SDG in the 6th semester of the degree. Semesters 1 to 5 appear in grey as background to visually compare them to semester 6. Results show how Competency Unit 1 (CU1) and Competency Unit 7 (CU7) obtain the highests percentages while the rest of CU show a lower presence.

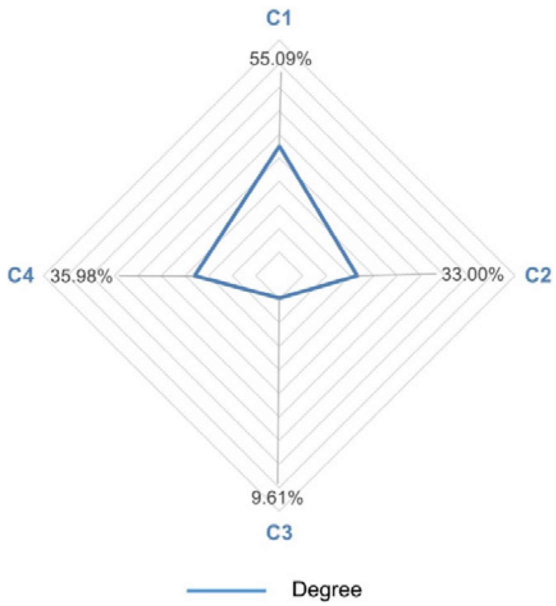


Fig. 2. Sustainability Presence Map in the whole degree in relation to the 4 sustainability competencies of CRUE [%].

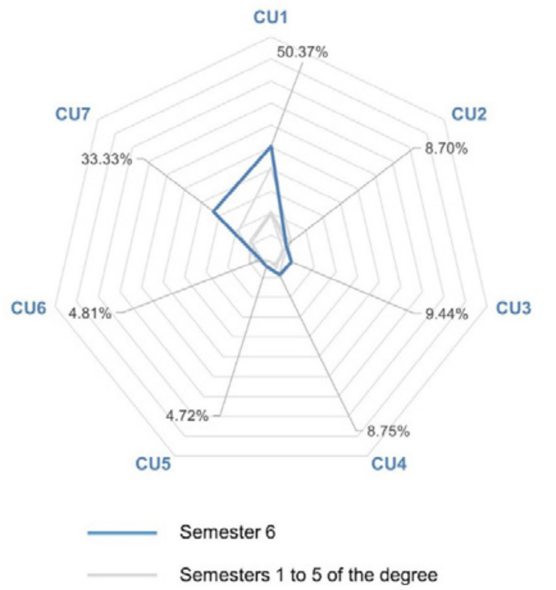


Fig. 3. Sustainability Presence Map of the 6th semester visually compared to semester 1 to 5 in relation to the 7 Competency Units (CU) of the ESM [%].

Figure 4 and 5 represent the average percentage of the presence of the SDG learning outcomes that were considered adequate to be addressed through any engineering degree, according to the EDINSOST2-SDG criteria. SDG2, SDG14 and SDG15 were not considered to be common SDG among all the engineering degrees but where included anyways bearing in mind that SDGs are indivisible and interrelated. Results show, for instance, how SDG7, SDG9 and SDG12 may have room for improvement, considering their close relation to Product engineering.

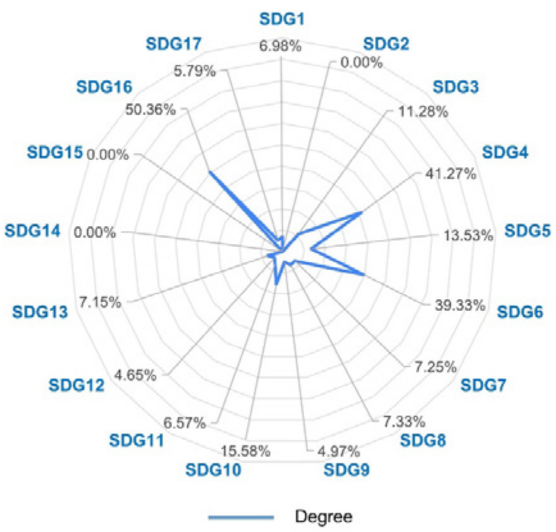


Fig. 4. SDG Presence Map of the degree in Design engineering [%].

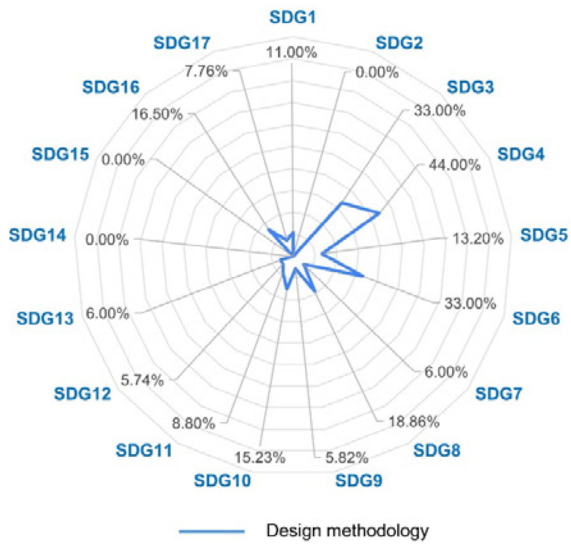


Fig. 5. SDG Presence Map of the Design methodology subject [%].

4 SUMMARY AND ACKNOWLEDGMENTS

We have introduced a methodology to analyse how sustainability and SDG are embedded in engineering degrees. Using Sustainability Presence Maps with graphical tools shows to which extent sustainability and SDGs are embedded in each course, semester and in the degree. The methodology has been applied to the Engineering Degree of Design at the EPSEVG of the UPC.

The results obtained are useful to consider which aspects of the curriculum may be sensitive to improvement and also to detect how sustainability is being approached in a degree, semester or subject.

When representing the data by degree or semester, it has been noted that it is challenging to include the optional subjects. Those should be included in diagnoses focused on assessing the different paths that the degree offers. A further limitation of the project is related to the information sources. Official documentation is not always updated and some competencies did not coincide with the information presented in the teaching guides. Further research should develop an analysis by using other information sources. The project Edinsost2-SDG is already working on this aspect and has developed a questionnaire to faculty and students which will be piloted through a similar methodology.

The concept “presence” used when considering the presence of the sustainability competencies, refers to the percentage of accomplishment of the learning outcomes of the ESM proposed by EDINSOST2-SDG. A degree would very rarely score a 100% of presence but the methodology offers results that expose which competencies are being prioritized and which not. This implies helping curriculum designers to detect gaps and opportunities. On the other hand, the concept “presence” used when analysing the presence of the SDGs is related to which SDG learning objectives are related to the ESM. In the same direction of what has been commented, the value of conducting such an analysis is creating a framework to guide further improvements in a degree.

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DIGITAL AGENCY AMONG ENGINEERING STUDENTS POST EMERGENCY REMOTE LEARNING

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Conference Key Areas: *Digital Tools; Changes beyond Covid-19*
Keywords: *digital agency, engineering students, educational technology, online learning*

ABSTRACT

The institutionalized transition to virtual classrooms for emergency remote learning caused a shift in the way in which engineering students engage with learning. Before emergency remote learning, many engineering students had limited access to digital technologies for learning. They depended primarily on traditional means of attending face-to-face physical classes and assessments with limited use of blended learning which by definition, involves some online learning. Given the opportunities that online learning provides for students, there is an expectation that post-emergency remote teaching and learning would make use of the online environment. Engineering students must develop their capacity to use and engage with digital technologies, with particular emphasis on the transformative potential of their experiences. This paper makes use of a systematic literature review to describe how engineering students develop their digital agency that is transformative in an online environment by answering the question "How do engineering students develop digital agency in an increasingly online learning environment?". Data were obtained from research studies

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over the period 2019 to 2021. The qualitative synthesis included 31 studies from the Proquest and Web of Science databases. A thematic analysis of the studies reveals that engineering students develop digital competencies during online learning by accessing key digital technologies, learning approaches, learning environments and, curricula integrated digital frameworks. Further research on the contribution of self-efficacy towards the development of digital agency in an increasingly online learning environment is recommended.

1 INTRODUCTION

1.1 Context

In response to the COVID-19 pandemic, most engineering students, with very little notice, migrated from conventional classrooms to emergency remote learning (ERL) [1]. Engineering students were required to participate in both synchronous and asynchronous learning activities that were aided by the use of various digital technologies in order to continue with academic activities. Many of the students had limited access to digital technologies prior to the emergency remote learning because they relied primarily on traditional methods of face-to-face lecture delivery and assessment. The primary application of digital technologies, such as learner management systems, was to download content for student access. Because the emergency remote learning was only temporary, engineering faculties appear to be continuing to prioritise online education over classroom learning [1]. Digital technologies that include hardware, applications, and supporting infrastructure have become a requirement for teaching and learning in engineering [2]. Engineering students are expected to study in a variety of virtual learning environments, as well as understand learning analytics and other digital learning applications. They are required to be able to effectively use and manage current and emerging technologies, as well as to adapt related pedagogies to the climate. Students benefit from assessing and managing potential technological advancements, as well as the necessary pedagogical changes, in order to achieve productivity and effectiveness. It is through these activities and responsibilities that engineering students' transformative digital agency becomes relevant for them to learn effectively.

Digital agency is best explained through its various facets. These include digital competence, digital autonomy, digital confidence, and digital accountability [3]. It is further defined as aspects of digital literacy, digital skills, and digital responsibility [3]. To describe digital agency further, a framework to define digital competence based on technological, cognitive, and ethical dimensions was developed [4]. The technological dimension entails being able to approach digital contexts in novel and adaptable ways. Students are expected to use technology primarily as creators rather than consumers to demonstrate their technological competence, seeking out novel ways to use technology to create and share new knowledge. Moreover, the students' ability to critically evaluate digital text and data as well as analyze their relevance and reliability point to their cognitive digital competence. These can carefully consider the sources of digital information and compare and contrast data to reach valid conclusions. When students demonstrate the ability to interact productively with others while using technology responsibly, they are contributing towards the ethical component of digital competence. Integrating these dimensions provide a deeper understanding of the potential offered by technologies that enable students to share information and collaboratively build knowledge [4].

In post-emergency remote learning, one would expect engineering students to acquire all these dimensions of digital competences as they solve challenges presented by interacting with digital resources for online learning. The transformative nature of digital agency is desirable as it assists the students to transfer their interactions with digital resources into an opportunity for learning and development. It avails them of an opportunity to break away from the status quo and changing the situation of the prevailing circumstances [5]. Consequently, students gain control and adapt to a digital world [3]. This study aims to investigate how engineering students develop digital agency in an increasingly online learning environment using a systematic literature review.

1.2 Review question

The qualitative review question "how do engineering students develop digital agency in an increasingly online learning environment?" was developed using the PICo (Population, Phenomenon of Interest and Context) framework. The population consists of engineering students who have abruptly shifted to online learning and are confronted with several challenges associated with the use of technology for learning. The phenomenon is digital agency, and the context is the increasingly online learning environment. Drawing from the theoretical framework on transformative digital agency and through a systematic literature review, this research paper brings an understanding of how engineering students overcome challenges and take control of the use of technology.

1.3 Theoretical Framework

This systematic literature review uses a theoretical framework as an overall orienting lens for the study of digital agency that is transformative among engineering students increasingly online learning environment. The framework is based on Cultural-Historical Activity Theory (CHAT) [6] and Vygotsky's principle of double stimulation [7]. CHAT has a cultural-historical approach and its foundation is in the work of Russian psychologists, Lev Vygotsky, Alexander Luria and Alexei Leont'ev in the 19th century. The cultural-historical approach effectively investigates how engineering students interact with technology as an activity system for online learning. The students as a group are the primary unit of analysis, while digital tools are the artifacts used for online learning mediation. The historical explanation is spoken of by the multi-voicedness of activity systems and their historicity. Tensions and challenges are used as catalysts for change and development, while the possibility of expansive transformations in activity systems indicates transformative digital agency [6]. In this learning system, digital agency is viewed as an outcome of the system rather than an object [6].

The principle of double stimulation provides a platform for students to engage in volitional actions as they address challenges presented by digital tools during their learning [8]. It contains a first stimulus that represents an issue, a conflict of motives, an obstacle, a difficulty, confusion, or another condition that requires transformative agency to overcome. These largely unknown mechanisms can be investigated by observing how engineering students respond to the second stimulus or the tools that are mobilized and used in the process of changing their practice. Thus, double stimulation is more than a one-way attempt to appropriate a cultural tool; it is a dialectic and complex activity in which circumstances and agents interact and in unexpected ways. The emerging forms of transformative digital agency can then be explained as resisting change by criticizing, questioning, opposing, or rejecting the activity; explicating new possibilities or potentials in the activity; imagining new patterns or models of the activity; committing to concrete actions aimed at changing the activity and taking consequential actions to change the activity [9].

2 METHODOLOGY

The approach of using a qualitative systematic literature review in engineering education was largely inspired by the work of Borrego [10] and Gough [11]. This approach helped the growing field of engineering education by synthesizing prior work, better informing practice, and identifying important new research directions [10]. The preliminary search, in this case, was conducted using general databases to find relevant articles, ensure the validity of the proposed concept, avoid repetition of previously discussed questions, and ensure the availability of enough articles to conduct the research. This systematic literature review is based on four methods: a systematic search to retrieve relevant articles, systematically applying criteria to code studies for inclusion or exclusion, evaluating study quality, and analyzing review results [10].

2.1 A systematic search

The primary search was conducted using two databases, Web of Science and ProQuest, which were accessed through the [institution name]'s online library between March and April 2021. ProQuest is a searchable indexed database, while Web of Science is an interconnected network of multidisciplinary databases of bibliographic material. These databases were chosen based on the review question and the disciplines that conduct similar studies. The systematic search contained a description of the search concepts, the terms that were used in the search, sources to be searched, and the search limits [11]. Through the assistance of the [Institution name] librarian, the search terms were identified using Boolean logic together with specific keywords as follows: *digital and transformat* (agency or competence or confidence or accountability or literacy or skill* or responsibility) and engineering and education*. Only peer-reviewed journal articles published between 2019 and 2021 were considered. The timeframe includes the period of emergency remote learning, which enabled learnership to continue despite the challenges posed by COVID-19. The preliminary search yielded 4 547 articles.

2.2 Inclusion and exclusion criteria

Following the systematic search, the inclusion criteria were guided by the purpose of the study and the research question for the systematic literature review [10]. As previously stated, peer-reviewed articles accessed through the ProQuest and Web of Science databases and published between 2019 and 2021 were included in the inclusion criteria [10]. However, to be fully part of the inclusion criteria, the articles had to address the research question with subject areas focusing on engineering, education, or educational technology. Furthermore, the exclusion criteria included unrelated, duplicated, inaccessible complete texts, and abstract-only articles. These exclusions were noted and reported in advance to avoid bias by the researchers.

The primary search results were filtered and screened using *engineering, education, or educational technology* subject areas on both the Web of Science and ProQuest databases to determine which papers would meet the inclusion criteria. Papers that did not cover these subject areas were automatically eliminated. As a result, Proquest and Web of Science retained 108 and 24 journal articles respectively with no duplicates. During the second screening process, the 132 articles were further evaluated for relevance to the research question and topic of study. The references were screened based on their key contribution to the use of technology for learning in engineering education, by focusing on the titles of the articles as well as their abstracts. Articles that did not address these issues were deemed unsuitable for the review and were thus omitted. The articles that were excluded focused on, but were not limited to, teachers, elementary or secondary schools, employability, children, workplace education, development or comparison of teaching methods, entrepreneurship, design of digital tools, information technology specialists, and skills other than digital. As a result, 48 journal articles remained in the pool.

3 CRITIQUE AND APPRAISAL

3.1 Appraisal of the quality of the studies

Following the selection, identification, and sorting of primary sources, the next step was to systematically assess the quality of each primary study [10]. The PICo approach, study design, and the year of publication were used to determine eligibility. The use of articles sourced from credible and reputable databases ensures that they are of high quality. The full text of each article was examined for its key contribution to the development of transformative digital agency among engineering students. As a result, articles that focussed on aspects of technology other than agency were excluded (n=15). Furthermore, articles had to be published in English in order for them to be included. This saw two full-text articles published in Russian being excluded. To avoid bias, the remaining 31 peer-reviewed articles were checked to ensure that they all had clearly defined methodologies described. This resulted in 31 articles that were used for the qualitative systematic review. The number of sources included and excluded at each point are tabulated in the Preferred Reporting Items for Systematic Reviews (PRISMA) flowchart (Fig. 1). In addition, Appendix A contains a list of the peer-reviewed papers (n=31) included in this systematic review, as well as the codes used to identify them using the respective database as a source. The full database for the systematic review can be viewed at: https://tinyurl.com/SEFIdigitalagency.

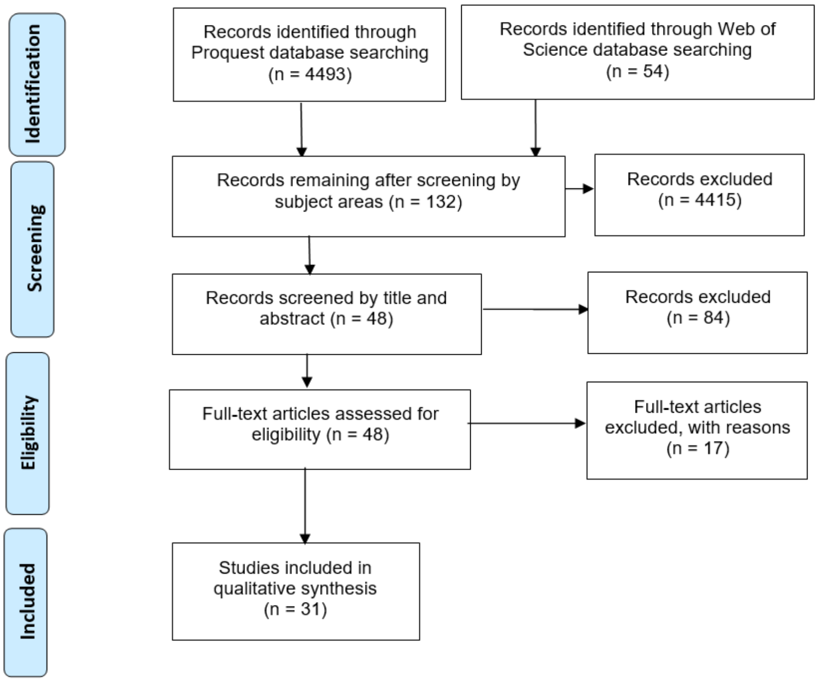

Fig. 1. Systematic search (adapted from PRISMA statement)

3.2 Analysis of the results of the review

The fourth step in conducting a systematic review is to analyze the review's findings. Information about an article's content, what is being researched, and how it is being researched was collected in a standardized format to aid in the analysis of themes and patterns across all of the studies under consideration. The codes outlined in Appendix A were used to describe the findings of the study. The research studies were published in various countries: eleven in Switzerland, seven in the United States of America, five in the United Kingdom, and two in South Africa. Each of the following countries had one publication: Belgium, Egypt, Spain, Turkey, Sweden, West Indies, Morocco, Romania, Austria, Indiana, Singapore, Mauritius and Australia. Six, eighteen, and seven of the 31 peer-reviewed articles were published in 2019, 2020, and 2021, respectively. Looking at these data, it is clear that there was a significant increase in publications on digital literacies from 2020, which can be explained by the implementation of emergency remote learning in early 2020. Table 1 depicts the distribution of journals in which the articles under consideration were published. Sustainability has the most articles (n=7), followed by Education Sciences (n=4).

Table 1. Aricles per Journal

Journal	Papers Per Journal
EAI Endorsed Transactions on Creative Technologies	1
Education & Training	1
Education Sciences	4
Higher Education, Skills and Work-Based Learning	1
Information Technology & People	1
International Journal of Education and Information Technologies	1
International Journal of Educational Technology in Higher Education	2
International Journal of Engineering Pedagogy	1
International Journal of Game-Based Learning	1
International Journal of STEM Education	1
International Journal on Interactive Design and Manufacturing	2
Journal of Engineering	1
Journal of Higher Education Theory and Practice	1
Journal of Physics: Conference Series	2
South African Journal of Industrial Engineering	1
South African Journal of Science	1
Sustainability	7
The Electronic Library	1
The Turkish Online Journal of Educational Technology	1

A variety of research designs and methods were found to have been used across the studies. The most common research design (n=13) was a literature review, with five based on a systematic literature review and one combined with a survey. There are six surveys, five evaluation studies and two case studies. The intervention method, multimethod design, phenomenography, process approach method, and a quasi-experimental study were also found. These research designs were uniformly divided into qualitative, quantitative, and mixed methods. Furthermore, data collection methods reported ranged from using the PRISMA statement in systematic literature reviews to using questionnaires and interviews in surveys.

The collected data for this research were aggregated, integrated, and interpreted to determine the evidence considered to answer the review question. Several themes emerged from an analysis of the data and are presented in the next section. The majority of the articles addressed the challenges presented by the shift in technological advancement caused by COVID-19 or Industry 4.0, and described how engineering students must adapt to the digital skills demand placed on them. Other articles highlighted the need for faculties of engineering to intervene and assist students to develop competences in digital technology as required. The study's main limitations were the low number of databases and articles used for the review.

4 RESULTS

The aggregated results of the systematic review are divided into 5 themes: results that foreground engineering students' access to educational technology (ET), results that foreground self-efficacy (SE), results that point to the need for specific learning approaches (LAs), results that foreground the learning environment (LE), and lastly, results that suggest integration of digital frameworks into the curriculum (IC). These are summarised in Table 2.

Table 2. Themes

Themes	Theme Code	Paper Code	*n*
Access to Technology	ET	1P, 6P, 7P, 8P, 10P, 13P, 14P, 17P, 18P, 19P, 22P, 23P, 27W, 28W, 30W, 31W	16
Self-efficacy	SE	6P, 10P, 19P, 30W	4
Learning Approaches	LAs	4P, 5P, 11P, 14P, 20P, 23P, 24P, 26W, 27W, 29W	10
Learning Environment	LE	8P, 9P, 13P, 14P, 16P, 17P, 18P, 19P, 25P, 31W	10
Intergration of digital frameworks into Curricula	IC	10P, 12P, 13P, 14P, 15P, 16P, 18P,	7

4.1 Access to educational technology (ET): *n = 16*

Access to key educational technology (ET) for engineering students was recommended in more than half of the articles as a way for engineering students to develop their digital agency, as shown in Table 2. Educational or collaborative robotics [1P, 2P, 7P, 18P], open-access tools, applications, software [30W], smart classrooms [17P], Artificial Intelligence (AI), 3D-printing [13P, 18P], human interfaces, augmented and virtual reality systems [27W] are examples of key and high-performing educational technology. Emerging from the analysis we suggest that for engineering students to develop their digital literacy, they require not only physical access to technology, but also technical support [8P], endogenous motivational access, skills access, actual usage of digital technologies [7P], and practical expertise [13P], among other things. We also argue that investing in these technologies will primarily benefit non-Generation Z students [28W]. These students must be able to access pedagogy remotely when necessary, using distance digital tools such as video conferencing tools [14P, 30W]. Overall, engineering students' digital competences are enhanced when they have access to guided inquiry or training [8P, 19P] and mentorship on how to creatively use the emerging and old technologies [10P, 22P]. According to Aagaard and Lund[5], digital agency that is transformative is developed when students interact with these digital resources.

4.2 Self-efficacy (SE): *n = 4*

Four articles specifically mention self-efficacy as a way for engineering students to develop their digital agency (see Table 2). Students' ability to control their use of technology can be seen when they adapt to using not only low-level technology but also high-level technology such as 3D platforms, AI applications, and mobile phones, among other things [6P]. The more engineering students utilise these technologies, the more they develop digital skills and related competences. Digital skills are further developed as students understand both hardware and software for online learning [10P], virtual collaborations [8P], training or adoption of engaging new technologies such as blogs [19P, 23P], and mastering distance tools such as video conferencing tools [30W]. Furthermore, students must be willing to embrace technological innovation in order to realize their full potential [31W].

4.3 Learning Approaches (LAs) : *n = 10*

Exposure to a variety of learning approaches can assist students to develop digital agency [4P, 5P]. Student-centred approaches, such as active learning, have been shown to provide students with hands-on experience with technology [4P, 5P]. Some of the learning approaches recommended as a result of this research are challenge-based learning [26W], game-based learning [11P, 29W], innovative approaches [14P], industry collaboration [24P], skills development approaches like high-tech labs, education 4.0 or learning factories [20P]. It is further argued that as students adopt these learning processes they, in turn, develop their digital skills [23P]. Accessing online in-game guidance that is constantly updated, as well as adequate technological support, can expedite the process.

4.4 Learning Environment (LE) : *n = 10*

Apart from the learning approaches adopted by students, the systematic literature review suggests that a supportive learning environment positively contributes to the development of students' digital agency [13P]. This includes constructivist learning environments, such as makerspaces, which provide hands-on experience with the use of technology for learning [8P]. Furthermore, the results suggest that experiential learning and integrated learning environments increase student confidence as they use educational technologies [9P]. As a result, there is a push for universities to modernize engineering programs, develop smart education, and promote active learning environments [31W], as well as facilities and infrastructure that support the acquisition of digital skills, such as the learning factory and education 4.0 [16P, 18P]. Rapid digital transformation at the institutional level has a significant impact on engineering students' acquisition of digital competencies.

However, it is also important to note that the cultural, societal and demographic aspects play a role in every learning environment. As a result, institutions must promote the use of digital technologies not only within their own circles, but also at the most elementary levels.

4.5 Integration of digital frameworks into the curricula (IC): *n = 7*

Exposing engineering students to various digital frameworks as they progress through their programmes can aid in the development of digital agencies [10P]. This is made possible by revising or modifying engineering programmes, forming partnerships with industry [13P], incorporating the internet of things into pedagogical models [15P], and incorporating digital frameworks such as education 4.0, big data, advanced simulation, learning factory 4.0, and virtual reality. Engineering students become acquainted with these digital frameworks while carrying out their daily tasks.

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APPENDIX A

Table A1. Codification of Peer-Reviewed Articles included in the Systematic Review

CODE	YEAR	TITLE	JOURNAL NAME	CITATION
1P	2021	Implementation of Educational Robotic into Teaching-Learning Process to Enhance Students Skills in the Science and Technology	Journal of Physics: Conference Series	Huda, S., Zuhrie, M. S., Buditjahjanto, I. G. P. A., & Nurlaela, L. (2021, March). Implementation of Educational Robotic into Teaching-Learning Process to Enhance Students Skills in the Science and Technology. In Journal of Physics: Conference Series (Vol. 1842, No. 1, p. 012062). IOP Publishing.
2P	2021	Self-efficacy and belonging: the impact of a university makerspace	International Journal of STEM Education	Andrews, M. E., Borrego, M., & Boklage, A. (2021). Self-efficacy and belonging: the impact of a university makerspace. International Journal of STEM Education, 8(1), 1-18.
3P	2021	Implementation of Digital Games in Advancing Students' Higher-Order Thinking Skills: A Review	Journal of Physics: Conference Series	Ahmad, M., Mansor, N. R., Rashid, R. A., Ain, N., Zakaria, C. R., & Sung, C. M. (2021, February). Implementation of Digital Games in Advancing Students' Higher-Order Thinking Skills: A Review. In Journal of Physics: Conference Series (Vol. 1793, No. 1, p. 012069). IOP Publishing.
4P	2021	Mechatronics: Experiential Learning and the Stimulation of Thinking Skills	Education Sciences	Habib, M. K., Nagata, F., & Watanabe, K. (2021). Mechatronics: Experiential Learning and the Stimulation of Thinking Skills. Education Sciences, 11(2), 46.
5P	2021	Challenges of Active Learning in a View of Integrated Engineering Education	Education Sciences	Vodovozov, V., Raud, Z., & Petlenkov, E. (2021). Challenges of Active Learning in a View of Integrated Engineering Education. Education Sciences, 11(2), 43.
6P	2021	Skills for a Working Future: How to Bring about Professional Success from the Educational Setting	Education Sciences	García-Pérez, L., García-Garnica, M., & Olmedo-Moreno, E. M. (2021). Skills for a Working Future: How to Bring about Professional Success from the Educational Setting. Education Sciences, 11(1), 27.
7P	2020	Digital divide among higher education faculty: Revista de Universidad y Sociedad del Conocimiento	International Journal of Educational Technology in Higher Education	Soomro, K. A., Kale, U., Curtis, R., Akcaoglu, M., & Bernstein, M. (2020). Digital divide among higher education faculty. International Journal of Educational Technology in Higher Education, 17, 1-16.
8P	2020	Making Future-Ready Students with Design and the Internet of Things	EAI Endorsed Transactions on Creative Technologies	Hughes, J., Robb, J. A., & Lam, M. (2020). Making Future-Ready Students with Design and the Internet of Things. EAI Endorsed Transactions on Creative Technologies, 6(21).
9P	2020	Experiential and Integrated Learning Environments - Teaching Urban Design Studio at Curtin University	Journal of Higher Education Theory and Practice	Mancini, F., & Glusac, T. (2020). Experiential and Integrated Learning Environments-Teaching Urban Design Studio at Curtin University. Journal of Higher Education Theory & Practice, 20(9).
10P	2020	Key competencies for big data analytics professions: a multimethod study	Information Technology & People	Persaud, A. (2020). Key competencies for big data analytics professions: a multimethod study. Information Technology & People.
11P	2020	The Transportability of a Game-Based Learning Approach to Undergraduate Mechanical Engineering Education: Effects on Student Conceptual Understanding, Engagement, and Experience	Sustainability	Shernoff, D. J., Ryu, J. C., Ruzek, E., Coller, B., & Prantil, V. (2020). The Transportability of a Game-Based Learning Approach to Undergraduate Mechanical Engineering Education: Effects on Student Conceptual Understanding, Engagement, and Experience. Sustainability, 12(17), 6986.
12P	2020	The Sustainable Development Goals (SDGs) as a Basis for Innovation Skills for Engineers in the Industry 4.0 Context	Sustainability	Rivera, M. L., Hermosilla, P., Delgadillo, J., & Echeverría, D. (2020). The Sustainable Development Goals (SDGs) as a Basis for Innovation Skills for Engineers in the Industry 4.0 Context. Sustainability, 12(16), 6622.

CODE	YEAR	TITLE	JOURNAL NAME	CITATION
13P	2020	Adapting Universities for Sustainability Education in Industry 4.0: Channel of Challenges and Opportunities	Sustainability	Mian, S. H., Salah, B., Ameen, W., Moiduddin, K., & Alkhalefah, H. (2020). Adapting Universities for Sustainability Education in Industry 4.0: Channel of Challenges and Opportunities. Sustainability, 12(15), 6100.
14P	2020	Graduate Employability and Competence Development in Higher Education—A Systematic Literature Review Using PRISMA	Sustainability	Abelha, M., Fernandes, S., Mesquita, D., Seabra, F., & Ferreira-Oliveira, A. T. (2020). Graduate Employability and Competence Development in Higher Education—A Systematic Literature Review Using PRISMA. Sustainability, 12(15), 5900.
15P	2020	The Technological Challenge Facing Higher Education Professors: Perceptions of ICT Tools for Developing 21st Century Skills	Sustainability	Liesa-Orús, M., Latorre-Cosculluela, C., Vázquez-Toledo, S., & Sierra-Sánchez, V. (2020). The technological challenge facing higher education professors: Perceptions of ICT tools for developing 21st century skills. Sustainability, 12(13), 5339.
16P	2020	Model Proposal for Diagnosis and Integration of Industry 4.0 Concepts in Production Engineering Courses	Sustainability	Souza, R. G. D., & Quelhas, O. L. G. (2020). Model Proposal for Diagnosis and Integration of Industry 4.0 Concepts in Production Engineering Courses. Sustainability, 12(8), 3471.
17P	2020	The Smart Classroom as a Means to the Development of ESD Methodologies	Sustainability	Cebrián, G., Palau, R., & Mogas, J. (2020). The smart classroom as a means to the development of ESD methodologies. Sustainability, 12(7), 3010.
18P	2020	Exponential Disruptive Technologies and the Required Skills of Industry 4.0	Journal of Engineering	Bongomin, O., Gilibrays Ocen, G., Oyondi Nganyi, E., Musinguzi, A., & Omara, T. (2020). Exponential disruptive technologies and the required skills of industry 4.0. Journal of Engineering, 2020.
19P	2020	Mapping research in student engagement and educational technology in higher education: a systematic evidence map: Revista de Universidad y Sociedad del Conocimiento	International Journal of Educational Technology in Higher Education	Bond, M., Buntins, K., Bedenlier, S., Zawacki-Richter, O., & Kerres, M. (2020). Mapping research in student engagement and educational technology in higher education: A systematic evidence map. International Journal of Educational Technology in Higher Education, 17(1), 2.
20P	2019	An Investigation of Industry 4.0 Skills Requirements	South African Journal of Industrial Engineering	Maisiri, W., Darwish, H., & van Dyk, L. (2019). An investigation of industry 4.0 skills requirements. South African Journal of Industrial Engineering, 30(3), 90-105.
21P	2019	Effects of digital flipped classroom teaching method integrated cooperative learning model on learning motivation and outcome	The Electronic Library	Qiang, J. (2018). Effects of digital flipped classroom teaching method integrated cooperative learning model on learning motivation and outcome. Eurasia Journal of Mathematics, Science and Technology Education, 14(6), 2213-2220
22P	2019	Creativity and Emerging Digital Educational Technologies: A Systematic Review	TOJET : The Turkish Online Journal of Educational Technology	Yalcinalp, S., & Avci, Ü. (2019). Creativity and Emerging Digital Educational Technologies: A Systematic Review. Turkish Online Journal of Educational Technology-TOJET, 18(3), 25-45.
23P	2019	The ecosystem of e-learning model for higher education	South African Journal of Science	van de Heyde, V., & Siebrits, A. (2019). The ecosystem of e-learning model for higher education. South African Journal of Science, 115(5-6), 1-6.
24P	2019	Students' learning experience in a multidisciplinary innovation project	Education & Training	Hero, L. M., & Lindfors, E. (2019). Students' learning experience in a multidisciplinary innovation project. Education+ Training.

CODE	YEAR	TITLE	JOURNAL NAME	CITATION
25P	2019	Supporting Project-Based Learning through Economical and Flexible Learning Spaces	Education Sciences	Eickholt, J., Jogiparthi, V., Seeling, P., Hinton, Q., & Johnson, M. (2019). Supporting project-based learning through economical and flexible learning spaces. Education Sciences, 9(3), 212.
26W	2020	An artificial intelligence educational strategy for the digital transformation	International Journal on Interactive Design and Manufacturing	Cantú-Ortiz, F. J., Sánchez, N. G., Garrido, L., Terashima-Marin, H., & Brena, R. F. (2020). An artificial intelligence educational strategy for the digital transformation. International Journal on Interactive Design and Manufacturing (IJIDeM), 14(4), 1195-1209.
27W	2020	Exploring technology attitudes and personal-cultural orientations as student readiness factors for digitalised work	Higher Education, Skills and Work-Based Learning	Blayone, T. J., Mykhailenko, O., Usca, S., Abuze, A., Romanets, I., & Oleksiiv, M. (2020). Exploring technology attitudes and personal–cultural orientations as student readiness factors for digitalised work. Higher Education, Skills and Work-Based Learning.
28W	2020	Educational experiences with Generation Z	International Journal on Interactive Design and Manufacturing (IJIDeM) (	Hernandez-de-Menendez, M., Díaz, C. A. E., & Morales-Menendez, R. (2020). Educational experiences with Generation Z. International Journal on Interactive Design and Manufacturing (IJIDeM), 14(3), 847-859.
29W	2020	Game Jams for Learning and Teaching: A Review	International Journal of Game-Based Learning	Meriläinen, M., Aurava, R., Kultima, A., & Stenros, J. (2020). Game jams for learning and teaching: a review. International Journal of Game-Based Learning (IJGBL), 10(2), 54-71.
30W	2020	Remote Knowledge Acquisition and Assessment During the COVID-19 Pandemic	International Journal of Engineering Pedagogy (iJEP)	Jacques, S., Ouahabi, A., & Lequeu, T. (2020). Remote Knowledge Acquisition and Assessment During the COVID-19 Pandemic. International Journal of Engineering Pedagogy (iJEP), 10.
31W	2019	Establishment of smart education system in modern universities: concept, technologies and challenges	International Journal of Education And Information Technologies	Salem, A. M., Mikhalkina, E. V. and Nikitaeva, A. Y. (2019). Establishment of smart education system in modern universities: concept, technologies and challenges. International Journal of Education and Information Technologies. (13), 180-188

BENEFIT FOR WHOM? RESEARCHING THE TEACHING AND LEARNING ETHICS WITHIN ENGINEERING IN A DIVERSE CONTEXT

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***Conference Key Areas**: Ethics and Engineering education*
***Keywords**: ethics in engineering; educational theory; research practice; emotion; transformation*

ABSTRACT

In teaching ethics within engineering, a key question is whether the learner is to be understood primarily as an individual or as part of a community. This tension is replicated in understanding the role of professional engineer where the engineer is both responsible for making autonomous decisions and for operating as part of a professional community.

Research about teaching ethics reflects a similar tension between research as an individual or collaborative activity. This raises questions about the ontology and epistemology of the researcher and the research subjects.

Learning theories address this tension in different ways, alternatively situating the learner as an individual or as part of a community. Engeström and Sannino's theory of expansive learning tackles issues of subjectivity, experience and identity in a way that usefully speaks to the challenges of researching the teaching and learning ethics within the professional space of engineering. They define learning as a *process*, where *process* is seen to be an inherently productive part of the teaching and learning relationship. Their emphasis on practice means their learning theory is inherently a research practice.

This analysis uses Sfard's distinction between language as a *tool* for communicating and as the *object of research.* Engaging critically with language around the teaching and learning of ethics as an object of research (using language as a shared tool) opens up the space to engage with policy and practice in a potentially transformative way. The paper concludes by summarising the value of practicing research as a way of engaging critically and constructively with the world.

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1 INTRODUCTION

Engeström and Sannino challenge us that the "ultimate test of learning theories is how they help practitioners to generate learning that grasps pressing issues that humankind is facing" [1]. This paper sets out to test the kind of research that might emanate from practitioners operating within the field of teaching ethics to engineers in terms three distinct learning theories. The research question thus is, "To what extent do the particular characteristics of a learning theory held by the researcher influence the kind of research that would be formulated in a specific context?"

The assumption would be that the researcher, consciously or unconsciously, selects a research strategy that relates to the epistemology encapsulated in the learning theory. Epistemology, as the theory of knowledge, relates intimately to the associated theory of learning.

Several recent SEFI special interest seminars relating to the teaching ethics within engineering have challenged participants to reconsider the way in which emotions were acknowledged and incorporated both in the teaching of ethics and in research relating to ethics within engineering. As an academic within the higher education sector in South Africa, this challenged me to consider the role of emotion in my own research.

South Africa can be positioned as a low to middle income-country with complex social challenges, including widespread youth unemployment and a perceived skills shortage. In this context, the strident political call for "radical economic transformation" has been seen to gather increasing public support in the face of wide-scale perception of public service ineptitude and corruption, polarising and simultaneously disempowering citizens where problems – and solutions – are positioned as structural rather than surmountable. Increasing cynicism and anger is accompanied by a revival of confrontation and the use of revolutionary language as a tool, or even weapon, to address service delivery failure.

In the context of these demands and challenges, questions emerge as to the use and value of research within higher education. As an academic in engineering education at a prestigious institution, I am forced to confront my own motives and vision in researching the teaching and learning of ethics relating to engineering: How do I use the tools of language to effect change? Does research engender real change? How can research contribute to transforming situations? Who benefits from the research?

This paper will examine *research* as a practice that investigates and makes visible phenomena that were previously "invisible" and that have potentially transformative effects beyond their direct environment.

This research emerged, in part, from a personal existential crisis as a result of an unexpectedly vehement emotional response to a piece of published research. The offending research appeared to be based on trivial and inconsequential data, artfully arranged and articulately argued, that gave a damning and inaccurate account of a situation that I was emotionally invested in. At the same time, the article profiled valid and pertinent issues at the cost of my hard earned peace of mind.

The result of the emotional turmoil was a critical reflection on research in general, questioning what is possible in research, what I wanted to be a part of, what is considered useful and how to justify or anticipate the potential value of the research.

Three metaphors of learning will be examined that contribute different perspectives on what learning entails. A metaphor, by definition, requires the use of a concept outside of its usual sphere of reference. The metaphor intrinsically connects the way in which we perceive and process reality with how we translate knowledge of one entity to another. By keeping the attention on the metaphor rather than the theory, it prompts us to remember that the way we talk about "things" is more a tentative grasping towards meaning than a direct representation [2].

The three metaphors of learning will be connected to specific theories and linked to relevant research practices. Some of the theories of learning explicitly make these connections but, in others, the connections may be more implicit. These metaphors of learning are not seen as competing approaches but instead highlight complementary approaches to learning that in turn draw attention to, and validate, distinct research processes. Research thus is seen to be inextricably intertwined in the learning project and with the particular theory of learning that the researcher holds.

The challenge of researching the teaching and learning of ethics within engineering will be examined as an opportunity to explore how the way in which research is formulated potentially reflects the distinctive learning theory held by the researcher.

Sfard's distinction between the use of language as a *tool* of communication and as an *object* of communication will be used to bring into focus the difficulty of reflecting on a problem using the very elements that are being questioned [3]. The consequence of this is that language is no longer the invisible net that holds a discipline together. It becomes instead the object of study: to be subject to examination, and its use negotiated within a context.

In this paper, the intention is to apply Sfard's "model" or gaze to the practice of researching the teaching of ethics within engineering in South Africa. For Sfard, the "questions one finds worth studying depend on how the phenomena under study is conceptualized" [3]. The task thus becomes to scrutinize how the phenomena relating to the area of study – that of ' teaching and learning ethics within engineering' – are conceptualized.

The application of Sfard's model can be justified in that, while her focus is the teaching of mathematics, similar imperatives operate within associated disciplines, engineering being one of these. Engineers are, in general, drawn from a cohort that has excelled in mathematics and science, where ability with language was not recognised to be central to the practice of the discipline. In this way, it may be seen that the experienced disruption to the engineering industry, as it shifts away from operating as a uniform cultural and linguistic entity to a multicultural and diverse body, focuses attention on the way in which language may be considered both a tool and an object of research within engineering, specifically as regards researching the teaching and learning of ethics.

Alongside the investigation of the way in which research and epistemology are intimately related is a personal exploration of purpose relating to practicing research within a particular context.

2 LEARNING THEORIES CHARACTERISED AS METAPHORS

At its simplest, theory may be described as making inferences from facts. Facts can be described as having little value or meaning unless they are linked through inferences and the application of metaphor so as to represent a perspective on or of reality. Sfard defines a metaphor as very much a “conceptual transplant” and so the use of conceptual theories may be seen as inherently to involve tranfer of meaning from one medium to another.

2.1 Learning as acquisition

The metaphor of learning as acquisition [3] may be seen to assume knowledge as objective and universal. This metaphor also suggests that learning might be measurable – be weighed or compared like a physical object. This understanding places the emphasis on the value and marketability of learning that can be transferred from a source to a person.

A theoretical approach that may be linked to the metaphor of learning as acquisition is that of positivism based on an understanding of the world as rational and objective, knowable through logic and deductive thinking. The emphasis on an rational world suggests that research intertwined with learning as acquisition will look to establish objective connections and comparative data about existing facts. Research will likely use experimental method and focus on quantitative method and measurable results. The assumption being that what can be measured, can be known.

An example of research to do with the teaching and learning of ethics, based in a conception of learning as transfer, would be to examine and to clarify the terms relating to ethics within a particular document so that the meaning of the words could be accessed and reproduced correctly.

2.2 Learning as participation

The metaphor of “learning as participation” [3] traces its roots to systems of apprenticeship where knowledge is passed on through the process of communities of practice.

Lave and Wenger’s [4] focus on communities of practice and the learning embedded within activity, context and culture is important for understanding the student’s “legitimate peripheral participation” in the professional space of the engineer and in the research process. While the focus of this peripheral participation may be seen to be the individual student’s learning, there is the associated contribution of peripheral participants, that keeps the system running and generates real and potential benefits. As “peripheral participants”, the students’ gaze plays a potentially significant role constituting the shared practice.

Wenger [5] distinguished four components of learning as a social theory: that of *community* - of “learning as belonging”; that of *identity* - of “learning as being”, that of *meaning* - of “learning as experience” and that of *practice* - of “learning as doing”. In this Wenger’s attention is fixed more on developing the identity of the learners that on the “how” or “what” of the skills or knowledge that accompanies the process of taking on identity. Wenger sees learning as necessary, but not the direct result of inputs or the instructor, his theory speaks more to the learning that takes place informally rather than in the formal environment.

This metaphor of learning can be associated with research seen as participation in research projects (moving from the periphery to the centre), of learning to research within a team with the support of experts within the process. The focus is on finding identity as a researcher within the team, on the experience, the learning as doing, the belonging and the meaning in the experience of the research practice. Research can be seen to be a self-perpetuating process in which people find a role and a place. Wengler’s emphasis on the confidence that is developed within the social learning situation can be usefully translated into the research process which will be seen to build the confidence and assurance of the research practitioners. Research to do with teaching and learning ethics in engineering would be built on an understanding of learning taking place as a result of participation in communities of practice. This could include research on the reflective learning that takes place when a student is involved in a community of practice, such as that of work experience. Because of the understanding of shared meaning within a community, the methodology may involve the analysis of text or speech embodying the student’s articulation of their own learning. This could be incidental, as part of an assignment, or, more overtly, as part of an interview process. The research would focus on the learning relating to the developing sense of engineering identity in the student.

2.3 Learning as transformation

Engeström and Sannino [1] critique the sufficiency of the two previous metaphors in that they see that the associated models of learning assume learning to be something already existing, that can be received or passed on, but that do not account for the creation of new knowledge. They put forward a third metaphor, that of learning as transformation.

The theory of learning that this metaphor is seen to be built on is that of “expansive learning” that forms part of the wider theoretical approach of activity theory [6]. It identifies a triangulated concept of subject, object (context) and mediated artefact. Actions are seen to have a defined beginning and end, whereas activity is conceptualized as a continuous, collective interaction of the individual subject within their context that produces a learning artefact. The introduction of the concept of a learning artefact enables the analysis of the artefact independent of either the subject or the object. This theory is intentionally creative, where learners co-create learning. Engeström and Sannino's [1] account of learning as transformation positions learning as requiring time and process, where this process is seen to be inherent in the teaching and learning relationship. They recognize the inter-related nature of teaching and learning, where the contribution of both instructors and learners is significant in the process of learning. They recognize the substantial role of instruction in the process of learning, but, in addition, identify a new space for learning to occur. This is articulated as a "gap between instruction and learning", where they identify "interesting things" to happen [1]. This opens the possibility of transformative learning beyond the intended consequences of the instruction. Engeström and Sannino's theory of expansive learning puts the attention on the collective activity of the learning community, where, together, learners learn "something that is not yet there" [1].

The most important outcome of expansive learning is seen to be *agency*: the participants' ability and will to shape their activity systems. This theory is developed further by Engeström and Sannino to tackle issues of subjectivity, experience, embodiment and identity [1] in a way that usefully speaks to the challenges of teaching and learning ethics within the professional space of engineering in complex social environments. This recognises the inter-related nature of learning and instruction, that they define as a dialectical relationship.

In research into the teaching and learning of ethics in an online context, this construct would allow the learner to be positioned as the subject, learning to be positioned as the object and the online learning management system, that contains both the instructor's intent and implementation, and the learner's engagement and response, to be positioned as the artefact.

The fact that learning is positioned as a process, angled towards transformation, gives additional impetus to connect Engeström's theory of expansive learning to its embodiment as a research practice. Here research by the participants – the ethics instructors or the learners themselves – on their own practice or context provides an example of research as transformation.

3. DISCUSSION

Engineering programmes recognize language as a *tool for communication*, where facility in communication is recognized as part of the requirements for practicing engineering. This is addressed in global accreditation programmes and, specifically, in the South African accreditation system, as graduate attribute 6, requiring proficiency in both verbal and written skills relating to technical and professional communication.

In addition, language can be approached as an *object of study* – critically engaging with the vocabulary and syntax that makes up the discourse of a discipline.

In this connection, *ethics* can be positioned as one of Meyer and Land's "threshold concepts" that operates as a "conceptual gateway to understanding" [7]. In this connection, the author's [8] analysis of the Engineering Council of South Africa's accreditation process, identified a lack of clarity in the use of specific terms relating to ethics, where meaning was assumed to be clear. This assumption of clear communication was recognized as a problem preventing the development of a deep shared understanding of key concepts, thus inhibiting effective and sustained communication about ethics within the engineering space. Ethics was seen to be invisible because of an assumption that the meaning of concepts was inherent in the words used, where meaning is passed on through transference or through diffusion within a community. The assumption of shared meaning in the use of key terms to do with ethics fails to recognize that, when communities are dynamic and represent a diversity of members or practitioners, meaning may be tentative and transient, requiring collaborative action to build meaning within the context. In situations like this, communities need to actively grapple with the meaning of key concepts to ensure their relevance and use in the discourse of the community. Without explicit engagement, talk about ethics risks being relegated to a shallow level where it does not impact the day to day discourse of the community or feature prominently in the key areas of knowledge and skill within the discipline.

Research thus has a responsibility to engage critically and constructively with student formulations of their own learning relating to ethics and with educators' reflection on their practice of teaching relating to ethics.

This process of engaging critically and reflectively with an emotional response thus enabled me to use the energy constructively to interrogate and formulate more clearly what I was aiming to achieve through my research.

4 SUMMARY

Research is action. It is advocacy. It is a bringing to light of what is not yet visible and a shaping of a space for change to occur. It is presenting a lens to see through and then walking the reader (participant) through the process of looking. It is presenting an argument that allows the reader to see differently – to categorise differently – to act differently because of the new information. Because of the vision encapsulated in the research project. It turns the reader of research – no longer the passive consumer – into an active participant in the project of transformation – of shaping reality.

Research is thus a social activity. It takes place amongst a community, those you quote (and may or may not have met) and those who read what you have written. It involves and is affected by the research subjects (whom I am not convinced should be anonymous). It involves stakeholders (both those you involve in the research process and those you do not). To me, the research subjects have a substantiveness – an authority and a dignity – that could stand scrutiny. They are an integral part of the research process and need to be acknowledged and credited for their input. Published research thus needs to affirm the contributions of the research subjects as a group if not individually.

On a personal level, what I am thus trying to do with my research – and with my practice – is to make visible the potential energy and resources for change and

transformation that already exists in the research environment, and to open a space for the varied stakeholders to contribute to making things better and to be able to measure their own progress. To change the discourse from the focus on technical activities to the purposeful action of communities. To include and profile the value that collaborative action can produce. To make space for stakeholders to participate in a common task of transformation that involves them – and others – in a project that consciously or subconsciously translates the vision and aspiration of stakeholders – and research subjects – in such a way as to enable each stakeholder to be an active part of the change process.
There is the desire to model a process that others can follow - to see research participants engage as co-collaborators in a change project: where people's vision of what is possible – of what they can do, of what public institutions can do, opens up and is transformed in a collaborative and dynamic way.

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CHANGES OF ADAPTABILITY STRATEGIES TO PROBLEM-BASED LEARNING: A LONGITUDINAL CASE STUDY OF FIRST-YEAR CHINESE ENGINEERING GRADUATE STUDENTS

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ABSTRACT

Problem- and project-based Learning (PBL) has been acknowledged and practiced as one of the widely accepted and innovative methods in engineering education over the last forty years at Aalborg University (AAU) in Denmark. However, the transition from lecture-based traditional learning to PBL represents a major challenge, especially for international students who have no prior knowledge and experience in PBL. In addition, more transition issues are raised by overseas students from China due to the differences in language, culture, learning styles etc. To remain and prosper in a new and competitive PBL learning environment, these engineering students must develop adaptability skills, which means that they must finds ways to fit into and learn through PBL. Our previous study has identified that first-year Chinese graduate engineering students' preferred adaptability strategies are integration, assimilation and separation when adapting to PBL in their first semester at AAU. In order to enrich our understanding of adaptability as a changing process, the current longitudinal research extends the focus to the changes of the students' choice of adaptability strategies to PBL over time and aims to explore the factors which influence their selection. Four Chinese engineering graduate students were followed through consecutive semi-structured interviews during their second semester at AAU. The results indicate that both integration and separation strategies are the favored adaptability strategies at this stage. Moreover, some factors relating to PBL courses, teamwork, communication

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and language proficiency impact these Chinese engineering students' preferences for different adaptability strategies.

1 INTRODUCTION

Driven by the process of internationalization and globalization, the past years have witnessed a continuously growing number of Chinese international engineering students at Danish universities as study abroad students. Due to fundamentally different cultures and educational systems, learners from China bring with them different understandings, expectations, and ways of learning to a Danish academic environment [1]. Some previous research has shown that Chinese students are inclined to be dependent learners who get accustomed to receiving the knowledge from their teachers through lectures with limited questioning and discussions [2][3][4]. Furthermore, they rely heavily on rote and individual learning, which means that they consolidate the learning contents by memorization and repetition [2][3]. However, these learning styles and dispositions are unsuitable to educational requirements at Aalborg University (AAU) where problem- and project-based learning (PBL) are adopted [1]. In engineering education, PBL is an appealing and innovative pedagogical approach built on the basis of engineering practice. The common learning principles of this approach are featured as problem-oriented, student-centered, collaborative and active learning, self-directed teamwork, teachers as facilitators and exemplary practice [5][6]. Within the PBL frames, instead of passively reading or listening to the facts and concepts that define an academic field of study during lectures, students work together in small teams on a project that engage them in exploring real-world problems and analysing ill-structured, complex questions [7].

On account of the discrepancy between Chinese learning styles and the requirements of PBL, Chinese international students are confronted with some academic and psychological challenges when adapting to a sharply distinct PBL learning environment. Our previous study found that the challenges, which first-year Chinese engineering graduate students at AAU faced, stem from collaboration in teams, communication with groupmates, heavy academic workload and different assessment systems [8]. In addition, from the psychological perspective, these students struggle with some mental challenges including loneliness, homesickness, isolation and lack of intrinsic motivation [8]. Although these students experienced the difficulties stated above in the process of adaptation, they chose different adaptability strategies to adjust to the challenges in a new environment. In PBL context, "adaptability", also termed "adaptation", is defined as the extent to which engineering students are competent to fit into the new PBL educational setting by effectively shifting their previously developed knowledge, method and theory, along with modifying their thoughts, behaviors and emotions [9][10]. Inspired by Berry's acculturation theory, "adaptability strategies" refer to the various ways of adaptation among different groups of people [11]. This concept will be elaborated in detail in the theoretical framework. There is a small but growing amount of literature focusing on adaptability strategies of Chinese overseas students. However, most of it has mainly been carried out on students integrating into traditional universities in the West [2][4][13]. Hence, it is worthwhile to enrich our understandings on Chinese first-year graduate students' adaptability strategies to PBL academic environment, particularly to investigate their changes of preferences for different strategies over time. As part of a longitudinal study, this paper seeks to address the following research questions: Compared to the first semester at AAU, what adaptability strategies do first-year Chinese engineering graduate students select during their second semester? What factors affect their selection of adaptability strategies in this stage?

2 THEORETICAL FRAMEWORK

In order to answer the research questions, this study adopts Berry's theory on acculturation strategies [11]. It should be noted that the concept "acculturation" refers to the dual process of psychological adjustment in an individual as well as cultural changes in groups while the term "adaptability" or "adaptation" is one component of acculturation that emphasizes the individual change [12]. As a result, our framework uses "adaptability strategies" to explain various strategies that first-year Chinese engineering students choose in their own adaptive process to PBL. The strategies are based on two issues: (1) the extent of maintaining one's heritage culture(s) and identity and (2) the relative preference for involvement with the host culture(s) and other cultural groups. One's inclinations to these two issues determine the adaptability attitudes or strategies. Deriving from these two dimensions, four types of strategies - integration, assimilation, separation and marginalization - are proposed at the individual level. The integration strategy means that one wishes to maintain one's own cultural identity and interacts with the new society. In contrast, marginalization appears when one accepts neither home culture(s) nor host culture(s). The assimilation strategy refers to an individual that entirely participates in the dominant culture(s) while rejecting the heritage culture(s). Finally, the separation strategy occurs when one values the culture(s) of origin, but does not integrate into the dominant culture(s).

In the next sections, we will go through the methods of data collection and further investigate how these strategies apply in a real setting.

3 RESEARCH METHOD

This study is in continuity with our previous work targeting the process of adaptation but extends the focus to the changes of adaptability strategies with time. Taking the same qualitative and sequential research design in data collection as before [8], four Chinese graduate engineering students who were enrolled in the fall of 2020 were followed through the use of consecutive semi-structured interviews at their second graduate semester at AAU. By utilizing purposeful sampling [14], they were recruited because they had no prior PBL experience in their bachelor and found it challenging to transit into a PBL learning environment. Table 1 provides some basic information of the four participants. Among them, three students consented to take a face-to-face interview whereas one student engaged in an online interview. To ensure the confidentiality, all names are pseudonyms, and the identifiable data are removed.

Table 1. Description of participants

Name	Gender	Discipline	Forms of interview
Steven	Male	Electronic Engineering	Online
Ben	Male	Electronic Engineering	In person
Yvonne	Female	Electronic Engineering	In person
Joe	Male	Energy Engineering	In person

Based on Berry's adaptation strategies and our previous findings about adaptive challenges to PBL, an interview protocol was carefully designed as a guide containing several open-ended questions. Prompts from the protocol sheet centered on participants' learning activities to PBL, experiences of collaborating and communicating with the team members in a new semester, and their attitudes towards the PBL assessment system. The questions also asked them to reflect on the benefits and challenges brought by PBL at this stage, as well as to compare their own academic performance change between the two semesters at AAU. All interviews lasted approximately one hour and were conducted in Chinese so that participants were able to fully express themselves by using their native language. The first author transcribed their narrations verbatim and partially translated them into English.

With the guidance of thematic analysis [15], the entire transcripts were read through iteratively so as to get familiar with the data. Accompanying with an open-coding process, a collection of in-vivo initial codes was then identified where the students' experience may be linked to the changes of adaptability. These coded sequences were developed as an initial codebook and continued to be refined until broader and preliminary themes emerged. By analyzing and revising the themes, we further constructed new coherent and overarching categories at a conceptual level to see if they were related to the results, as well as the theoretical framework. Finally, a report was written based on the data analysis which is represented by the finalized categories.

4 FINDINGS

From these engineering students' epistemological accounts of their experiences and changes, the degree of adapting to PBL and their preferences of adaptability strategies was found to be dependent on a number of factors related to PBL courses, teamwork, communication and language proficiency. Each factor is discussed below.

4.1 Factors pertaining to PBL courses

Despite the adaptive challenges in heavy academic workload that these students encountered in the first semester, three of them reported to gradually adjust to PBL learning activities because of appropriate pre-course reading strategies, more relevant exercises, and practical mini-projects. Although Joe still lacked time in reading piles of literature before a course, he changed his ways to read. Rather than reading all references intensively, he felt at ease by mainly looking through new and unfamiliar concepts. Ben had previously held a negative attitude towards the exercises, but this semester he thought they became more meaningful and aligned with the courses. As a result, his comprehension of what he learned got strengthened through effective application of theories. Moreover, he claimed that he valued the practical mini-projects in this term, which enhanced his interests and engagement.

> *"I firstly skimmed the slides from our course. The content that I already grasped were skipped so that I could primarily focus on the unknown parts. It reassured me through quickly developing a general overview of those unknown theories and their applications." (Joe)*

> *"We had a course where the exercises in each lecture reflected some key points of the learning content. That is to say, if I could figure out the exercise, I would totally understand what lecturers said." … "Unlike the last semester, the mini-project I am doing now is relatively practical. I enjoy doing it because it seems like working in a real laboratory, and meanwhile I am able to learn something new." (Ben)*

However, due to the change of research direction in their master, one student Yvonne still felt pressured by being exposed to a lot of new knowledge and faced difficulty in keeping up with the lectures.

> "*What I am majoring in now is quite different from my bachelor. It took me a long time to understand what I am studying."…"The challenge also derives from my unfamiliarity with the terminologies in my field. It was hard for me to follow up on our lecturers because I needed time to self-reflect and look up those concepts online." (Yvonne)*

Under the influence of the COVID-19 pandemic, all teaching and learning activities at AAU shifted to online mode. Compared with physical courses, all four students pointed out that they integrated into studying environment online because it enabled them to schedule with more flexibility. Although they struggled with some online learning problems like procrastination and lack of concentration, the live sessions could be recorded which allowed them to review learning content at their own pace. As what Ben mentioned, recording lectures benefited him from adapting the subject to his own learning style.

> "*I felt very comfortable in taking courses online. In reality, I could only concentrate on studying for an hour. Therefore, I synchronously recorded the lectures into multiple one-hour sections so as to catch up with some key points of what lecturers said after the lecture." (Ben)*

4.2 Teamwork

Since PBL involves activities that appear to be only possible in teams, students must work together to organize themselves, manage a project, make own decisions, and find solutions [16]. With more chances of collaboration, three students stated that a multicultural group, balanced team roles, clear work divisions and suitable online software increased their adaptation to PBL. Joe worked with two natives and one international student in the second graduate semester. In his opinion, this intercultural cooperation contributed to develop a certain level of openness and provide varied perspectives. Similar to Joe, in Ben's case, his group consisted of two Danish students and four PBL-entry level overseas students. From his description, flexible task arrangements and clear separation of responsibilities in his team conduced to the improvement of his collaboration skills. Steven continued to work in the same group as the previous semester. According to him, even though the project work was transferred to online this semester, the team was still managed well by using appropriate software.

> *"When collaborating on the project, my European group members preferred bottom-up approach while I got used to understanding the theories first. Therefore, a wider range of opinions from us guaranteed all possible angles, from both theory and application." (Joe)*

> *"It makes me feel more relaxed and cozier to work with some PBL beginners because we will not be constrained by a PBL framework." … "When a task was distributed, one of my group members firstly wrote down a draft, then I would add in new points and polish what we wrote." (Ben)*

> *"We selected some useful software so as to finish our distributed tasks both individually and cooperatively in different channels. We like this way to discuss our project because it would not bother the other members." (Steven)*

It is somewhat unexpected that Yvonne experienced a hard time in the teamwork. In spite of achieving a sense of belonging from her pervious group members, she was surprisingly left out by them in this semester. After negotiating with her advisors and them, she decided to work on the project alone. However, as she said, she had to deal with a great deal of difficulties by herself.

> *"Firstly, the time to finish my project is insufficient. Furthermore, I need to learn plenty of new knowledge and at the same time make a connection of what I learned in my bachelor with that of the master. Lastly, studying from home was a challenge for me because I suffered a lot from procrastination. Right now, I am still looking for a balance between life and work." (Yvonne)*

4.3 Communication and language proficiency

PBL, as an effective approach, would encourage students' communication skills during the students' learning process [17]. Based on our qualitative data, three male students reported that the communication with their groupmates become more effective after a semester at AAU. Joe noted that his shyness prevented him from asking for help from his team members before, but presently he took more initiative to share views with them. In terms of language issues, Steven declared that low English proficiency was one of his largest challenges when adapting to PBL. Immersing himself in an English-speaking environment, he ascribed his currently smooth conversation with groupmates at present to the improved language skill.

“At the beginning, I could not bring myself to ask many questions to my team members. When our relations got closer, I got more courageous to ask for more details.” (Joe)

“I feel my English is getting much better now than the last semester. I get used to using English to express my own opinions.” (Steven)

Moving on to Yvonne’s case, her experience of being excluded by the previous group members gave rise to some negative emotions such as anger, disappointment, sadness, helplessness and unfairness. These feelings further resulted in her reluctance to build any interpersonal relationships with the previous groupmates. Furthermore, in opposition to the other participants, language barriers remained a serious problem for her. Apart from issues like absorbing the lectures and preventing the free flow of information, it also intensified her stress on preparing oral examinations.

“I only talked with them [the previous groupmates] when doing assignments together in the courses. After finishing the lecture, I tried to avoid participating in their conversations and activities.” … “English is still quite a big challenge for me. In my point of view, if I divide the oral evaluation into two aspects, English skills accounts for 40% while the knowledge of what we learned takes up 60%. However, compared to those English proficient speakers who only need to worry about that 60%, I also need to prepare that 40% more.” (Yvonne)

5 DISCUSSION

From our analysis of the adaptability strategies chosen by these engineering students, in comparison to their first semester at AAU, three male students leaned towards the integration strategy whereas one female student adopted the separation strategy this semester (see Table 2).

Table 2. Changes of the participants’ preference for adaptability strategies

Name	Previous adaptability strategy [8]	Adaptability strategy at present
Steven	Assimilation	Integration
Ben	Separation	Integration
Yvonne	Integration	Separation
Joe	Integration	Integration

In regard to Steven, he shifted his adaptability strategy from assimilation to integration. In the first semester, he held optimistic attitude towards PBL but relatively negative attitude towards traditional lecture-based learning in his bachelor. At this stage, he not only perceived PBL as a valuable method for enhancing his generic competencies in problem-solving, teamwork and project management, but he also began to realize what he studied in his bachelor provided him with a solid mathematics foundation. Ben's choice of adaptability strategy was transferred into integration strategy. He was previously unwilling to build interpersonal interactions with his groupmates and acquired knowledge primarily through individual learning. This semester, nevertheless, he enjoyed both collaborative and individual learning and benefited from effective communication after working with a more multicultural group with balanced team responsibilities and concrete work division, as well as due to his successful adaptation to online courses. Joe remained committed to implementing the integration strategy. On one hand, the coordinating strategies he learned from prior learning and working experience is conducive to his cooperation with his team members. On the other hand, in this semester, he overcame more challenges in heavy academic workload, teamwork and communication. However, only Yvonne ended up with the separation strategy. The inclusive and open-minded group she worked in the first semester improved her sense of being accepted. It is worth noting that she was still looking forward to cooperating in a group, but being thrown out by her former groupmates, she now only seeks assistance from her own family and co-national peers.

6 CONCLUSION

Building upon Berry's acculturation theory, this study attempts to examine the changes in adaptability strategy choices among four first-year engineering Chinese graduate students, together with the factors that impact their selection. The qualitative data reveal that three students choose integration strategy and one select separation strategy after a period of studying in a PBL environment, which is in accordance with the results from other quantitative studies that both integration and separation are the favored adaptability strategies among overseas and first-year students [13][18]. Additionally, the outcome of the analysis shows that students' preferences for these strategies are associated with PBL courses, teamwork, communication and language proficiency. In general, the findings from this research may enrich our current understandings on transition and first-year issues towards a PBL learning context.

With empirical evidence from the engineering students, this study also highlights the needs to pay attention to the international PBL-beginners' participation in collaborative learning and their sense of belonging in an unfamiliar academic environment. We would suggest that the institutions and departments provide a more inclusive learning environment. Furthermore, it also requires school counselors and supervisors to be more concerned about the overseas students' adaptive challenges in mentality such as loneliness and isolation and provide them support in handling these problems by modelling preventive strategies and coping skills in lectures and project works. This inclusiveness in turn would lead to a greater diversity of knowledge, practice and values in the engineering field. However, only four Chinese participants are studied in this research and the small sample size makes the findings less generalizable to the larger population of Chinese international students. This limitation relates to the fact that there were only a few Chinese graduate students enrolled at AAU in the fall of 2020 due to COVID-19 pandemic. But the small number of students make it possible to have a more in-depth study of their reasons for choice of strategy. For the future work, it leaves room for exploring adaptability issues in a larger sample which include more Chinese students and more international students from different nations as well.

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THE EFFECT OF THE COVID-19 PANDEMIC ON A MOOC IN AEROSPACE STRUCTURES AND MATERIALS

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ABSTRACT

In March 2020 COVID-19 brought the world and with that aviation to a standstill. Also in March 2020, the third run of the DelftX MOOC Introduction to Aerospace Structures and Materials started on edX. This MOOC generally attracts a mixture of young aviation enthusiasts (often students) and aviation professionals. Given the large interest MOOCs have received as the pandemic hit, we investigate how the new global context affected the motivation and the way learners interact with our course material. For this project, we will use learning analytics approaches to analyse the log data available from the edX platform and the data from pre- and post-course evaluations of two runs of the same MOOC (2019 and 2020).

With the insights gathered through this analysis, we wish to better understand our learners and adjust the learning design of the course to better suit their needs. Our paper will present the first insights of this analysis.

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1 INTRODUCTION

After the first reported case of COVID-19 in December of 2019 in China, the virus quickly spread throughout the world causing travel to come to an almost complete standstill. By mid-April 2020, more than two-thirds of the 22,000 passenger airliners, had been grounded and associated staff either furloughed or made redundant, by April 2021 aviation data analysts still report 8,684 aircraft in storage [1]. Already in mid-March 2020 most higher education institutes in the world had closed their campuses [2] and switched where possible to online teaching, either creating their own or using existing online resources, a situation persisting on and off until today.

1.1 MOOC Aerospace Structures and Materials

The MOOC Introduction to Aerospace Structures and Materials (ASM MOOC) has been running on edX since August 2018 [3], and is currently in its fourth run. This MOOC is an introductory course, requiring only basic knowledge of physics, and is aimed at anyone interested in aerospace structures and materials. On 10 March 2020, the third run of the MOOC Aerospace Structures and Materials opened on edX for a 12-months run, one month after the previous run of the course, running for 10 months, had finished. The first run in 2018 was excluded from our analysis as it was not self-paced and only ran for 12 weeks. Within the MOOC, learners have a choice to try the course for free with limited access (9 weeks) or to upgrade to edX’s ‘Verified Track’ for $49 giving unrestricted access and the opportunity to earn a certificate by taking online exams and doing online assignments during the course.

1.2 MOOC learners and COVID-19

With so many people associated with the aviation industry unable to work, as well as many students and educators switching to online learning, the question arose how the new global context affected the motivation and the way learners interact with our course material compared to learners in the earlier run of the MOOC. In this paper, we used data collected in the pre- and post-course surveys carried out by our institution and learner data extracted from edX trace logs in order to understand how learners interact with the platform. Ethical permission was sought and granted by the TU Delft’s Ethics Board for this research and learners were asked for informed consent on the gathering of their data both by TU Delft and by edX.

2 METHODOLOGY

With the rise of online education, the field of learning analytics was born. Learning Analytics is “*the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs*” [4]. Learning analytics can help educators to understand and optimise learning and form an important tool in the field of online education research. Especially MOOCs, with their relatively large number of enrolments provide great data sources to better understand the behaviours of learners in online courses and are as yet often underused [5].

2.1 Research questions

Our main research question for this paper is: How does the COVID-19 pandemic affect the motivation and the way learners interact with the course material in the MOOC introduction to Aerospace Structures and Materials on edX? To answer this question, we compared the data from the 2019 (collected 9 April 2019 - 20 June 2020) and the 2020 run (collected 10 March 2020 to 21 March 2021) of the ASM MOOC in terms of (i) the number of enrolments, and the professional and educational background of enrolled learners, (ii) the completion rates of verified certificate holders, (iii) the motivation in taking the course and (iv) the level of interaction with the course material.

2.2 Data sets and data analysis

For the analysis, we used the anonymised edX learner data sets to determine the overall number of enrolments in the run and the self-reported age, gender and education level of the population and course completion. On the edX platform, formal course completion is defined as obtaining a Verified Certificate but that only applies to those learners who chose to pay to upgrade. Therefore, we defined course completion for the audit track as students who attempted all quizzes in all 7 modules. The second data set used in this paper is the answers offered by learners to the pre- and post-course survey which included detailed questions about their motivation for enrolling in the course, their background, expectations and evaluations of the course.

Table 1. Cohort and sample size.

**percentage calculated with respect to total enrolment*

***percentage calculated with respect to number of Verified Enrolments*

	Run 2019		Run 2020	
Total enrolment	11987		26329	
Verified Enrolment	663	5.5%*	2533	9.6%*
Verified Certificate	301	45.4%**	1027	40.5%**
Countries represented	151		168	
Pre-course survey				
Agreed consent	2318		5807	
Full Surveys	1944		4978	
Net Response Rate*	16%		19%	
Post-course survey				
Agreed consent	269		957	
Full Surveys	226		802	
Net Response Rate*	2%		3%	
Response Rate Verified Track**	27%		53%	

All data was analysed using JAMOVI (jamovi.org). In table 1 the description of the population of both runs is given as well as the response to the pre- and post-questionnaire. For all analyses, only complete surveys were used.

3 RESULTS

3.1 Learners

As can be seen from table 1, there was a sharp increase in learners in COVID times. The number of learners in the course more than doubled compared to 2019. Figure 1shows the normalised enrolment of both courses plotted over time, revealing a much steeper increase in growth of learners of the 2020 run in the first 6 weeks after the world-wide shutdown began (vertical grey line). This trend is confirmed in reports by other MOOC makers [6]. Also, more learners opted to purchase access to the Verified Track and the number of countries learners originated from also increased.

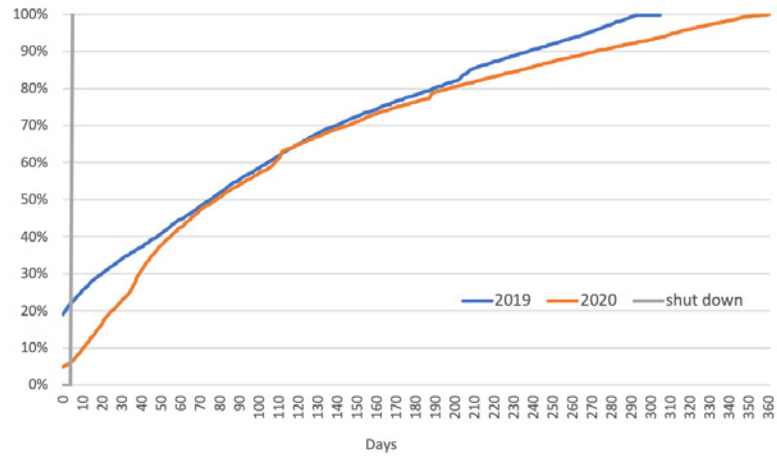

Fig. 1. Normalised Enrolment over Course Length

Using the edX learner data sets, the self-reported age of both runs was compared using an Mann-Whitney U test, U = $4.08 \cdot 10^7$ and p < .001 with a small effect size z = 0.134 showed that in the 2020 run the learners were significantly younger (Median = 23 and N = 12908) than in the 2019 run (Median = 25, N = 7301). In terms of self of self-reported gender, a X^2- analysis showed that there is a significant difference in gender distribution, with $X^2(2) = 32.6, p < .001$ with a 3.4% increase in the participation of women in the 2020 run. In 2019, 17.5% of enrolled learners were female compared to 20.9% in the following year. The overall share of women taking part in both runs is higher than the yearly influx in the BSc aerospace engineering of TU Delft. The number of enrolled learners that reported their gender as "other" did not vary across cohorts: 0.5% in 2019 and 0.4% in 2020. A X^2- analysis of the self-reported level of education of the learners in the MOOC, see table 2, also showed significant differences with $X^2(5) = 44.0, p < .001$ with increases of learners with just high school education or lower and decreases in learners holding a masters or PhD, again indicating that the major increase is among undergraduates.

Table 2. Level of education

	Run 2019 (N=6470)	**Run 2020** (N=10387)	**Total** (N=16857)

PhD	2.2%	1.7%	1.9%
Master	17.9%	14.7%	15.9%
Bachelor	36.8%	36.7%	36.7%
High School or lower	35.7%	39.2%	37.9%
Other	7.7%	7.7%	7.6%

We also looked at the differences between the self-reported employee situation of both runs in the pre-course survey. Again, significant differences were found between the 2019 and the 2020 run,$X^2(6) = 107, p < .001$. There is a sharp decrease of almost 10% in the number of people classing themselves as working, recent graduates or looking for a job and a sharp increase in students (Table 3). An investigation into the average age of these students did not indicate that the average age of this group was rising so the increase in students is not due to a return to education of people who were working. Surprisingly in COVID times, the share of parents and care-givers remains the same.

Table 3. Current job situation

	Run 2019 (N=1934)	**Run 2020** (N=4962)	**Total** (N=6896)
Working	37.0%	27.3%	30.0%
Looking for a job	7.1%	6.3%	6.6%
Retired	0.7%	0.7%	0.7%
Student	42.7%	56.2%	52.4%
Recently Graduated	9.8%	7.3%	8.0%
Parent/care-giver	0.5%	0.4%	0.4%
other	2.3%	1.8%	1.9%

For those working, we analysed what industry sector and industry branch they worked in. Significant differences were reported, $X^2(16) = 35 > 4, p = .004$, between both runs, with a 45% increase in 2020 in learners reporting to work in Transportation, indicative of the reported shutdown of aviation (full contingency table omitted due to lack of space). The top 5 represented industry branches in table 4, show that particularly in aerospace-related industry, there is an increase in the absolute number of learners in COVID times with particularly airlines/aviation standing out. This may be indicative of a culture of Lifelong Learning in the aerospace sector.

Table 4. Reported Industry

Industry (sector)	**2019 #**	**2020 #**	**Increase %**
1. Aviation & Aerospace (manufacturing)	144	229	59%

2. Airlines/Aviation (transportation)	90	255	183%
3. Mechanical or Industrial Engineering (manufacturing)	46	64	39%
4. Military (government)	33	65	97%
5. Defence & Space (High Tech)	33	53	61%

3.2 Motivation

Learners were asked for their motivation to enrol in the course. An overview of both runs is given in table 5. For both runs, the most named motivation is (prospective) career, followed by (prospective) studies and personal interest. A X^2- analysis revealed significant differences in motivation to enrol between the two runs with $X^2(4) = 14.2, p = .007$, which seems to stem from less people reporting taking the MOOC for their (prospective) career, but more people reporting taking the MOOC in view of their (prospective) studies. The explanation for this, combined with the results reported in tables 3 and 4, may be that as universities and schools were mostly shut down students were looking for alternative courses to take, were encouraged by their own schools to do so or taking these courses in lieu of being able to visit open days to help them decide on their future. Sadly, no COVID specific questions were asked in the 2020 course questionnaires.

Table 5. Motivation to enrol

	Run 2019 (N=1923)	**Run 2020** (N=4929)	**Total** (N=6852)
(Prospective) career	41.2%	37.1%	38.2%
(Prospective) studies	30.2%	34.0%	32.9%
Personal interest	25.5%	26.4%	26.1%
(Prospective) teaching	2.0%	1.6%	1.7%
Other	1.0%	1.0%	1.0%

3.3 Challenges

Learners were asked in the pre-course survey what they felt was their biggest expected challenge and in the post-course survey what they felt was the biggest challenge they faced during the course. The pre-course survey showed significant differences between the expected challenges between the two runs $X^2(5) = 51.9, p < 0.001$ and the post course survey confirms these findings with significant differences in the challenges faced: $X^2(5) = 13.4, p = 0.020$. If we take a closer look at the results as listed in table 6, it can be seen that, compared to 2019, in 2020 learners indicated that they expected time to be less of a challenge and this was confirmed in the post-course survey. This may be indicative of more people being able to make time during the pandemic as they followed the advice to stay at home as much as possible.

Table 6. Expected challenges in taking this online course

	pre course			post course		
Challenges	**2019 (n=1946)**	**2020 (n=4992)**	**total (n=6938)**	**2019 (n=199)**	**2020 (n=692)**	**total (n= 891)**
Finding sufficient time	57.2%	47.8%	50.5%	50.3%	39.9%	42.2%
Grasping the content	13.8%	18.0%	16.8%	13.6%	19.7%	18.3%
I expect no challenges	8.5%	10.8%	10.2%	18.1%	25.6%	23.9%
Meeting the deadline	12.2%	13.7%	13.3%	9.0%	6.4%	7.0%
Using the platform	6.1%	7.0%	6.8%	1.5%	2.5%	2.2%
Other	2.1%	2.6%	2.8%	7.5%	6.1%	6.4%

3.4 Interaction and engagement with course material

As can be seen from table 1, there is an almost 80% increase in the number of learners opting to buy access to the Verified Track in the course, which can be an indication of learners during COVID times wishing to engage longer with the course material. This is in part supported by the lower certificate completion rate of the 2020 learners compared to 2019. This can be an indication that they are more interested in engaging with the material for longer than in obtaining a qualification. When comparing the reported participation level in the post-course survey no significant differences between the two runs were found$X^2(4) = 3.89, p = .426$.

However, participation can also be measured in interaction and engagement using the learning activities: Video Lectures, Reading, Discussion Forum and Exercises. To do so, we first look at the reported pre-course levels of importance learners placed on these activities as well as the post-course reported levels of satisfaction and value of these activities. Using a Mann-Whitney U test to check if there were significant differences between the two runs on the importance learners placed on these learning activities, only significant differences between the 2019 run (N = 1934, Mean = 3.15) and the 2020 run (N = 4963, Mean = 3.23)) were found for the Discussion Forum (U= 4.62.106, p = 0.013 and a small effect size z = 0.038), indicating that interaction with other learners is more important to learners in the 2020 run. When looking at post-course satisfaction of learning activities, we again see significant differences between the 2019 (N = 59, Mean = 3.73) and 2020 (N = 237, Mean = 4.19) run for the Discussion Forum satisfaction: U = 5267, p = .002 and a medium effect size z = 0.25 and similarly for the value of the Discussion Forum between 2019 (N = 60, Mean = 4.27) and 2020 (N = 237, Mean = 4.38): U = 5460, p = .004 and a medium effect size z = 0.23. Learners also reported a significantly higher satisfaction of the exercises between 2019 (N = 199, Mean = 4.27) and 2020 (N = 675, Mean = 4.37) with U = 61354, p = .039 and a small effect size of z = 0.09.

In terms of hours worked per week, in the post-course survey learners reported an average of 7.14 hours/week in the 2019 run (N = 207) against 7.91 hours/week in the

2020 run. A Mann-Whitney U analysis showed a borderline significant difference: U = 69338, p = 0.05 and a small effect size, z = 0.089.

As self-reported levels can have issues [7], we also analysed the edX learner data to look at how many learners interacted with each type of activity. In table 7, the number of learners is listed that engaged at least once with videos, assignments or the forum. Significant differences were found with learners engaging in larger numbers than in the 2019 run. In table 8 we compare the extent of the engagement between the two runs and again we notice a significantly higher engagement with the course material with regard to videos watched, problems attempted and activity on the forum in 2020.

Table 7. Learners that engaged at least once with videos, assignments or the forum

Activity (N = 38316)	**2019**	**2020**	**Total**	**χ^2 (1)**	**p**
Watched at least one video	40.2%	44.1%	42.9%	52.0	<.001
Submitted at least one problem	36.2%	38.1%	37.5%	13.2	<.001
Posted in the forum at least once	10.0%	12.7%	11.9%	61.3	<.001

Table 8. Comparing the extent of engagement with videos, assignments and the forum for learners that engaged at least once with these activities

Activity	**Year**	**N**	**Mean**	**Med**	**SD**	**Mann Whitney**		
						U	**p**	**z**
# of videos watched	**2019**	4813	10.5	4	15	$2.69 \cdot 10^7$	<.001	0.04
	2020	11607	12.2	5	16.8			
# of problems attempted - audit	**2019**	3707	15.4	4	27	$1.41 \cdot 10^7$	.004	0.03
	2020	7856	18.3	4	32.3			
# of problems attempted - verified	**2019**	627	81.7	106	54.9	$6.67 \cdot 10^5$	.407	0.02
	2020	2173	80.9	98	55.2			
# of posts in the forum	**2019**	1193	1.31	1	1.5	$1.98 \cdot 10^6$	.450	0.01
	2020	3355	1.34	1	1.63			

If we look in more detail at videos, we see that in 2020, significantly more learners watched at least one video (χ^2 (1) = 52.0, p<.001) and they watched significantly more videos than in 2019: U = $2.69 \cdot 10^7$, p = <.001 (see Table 8). A similar pattern is also seen when looking at the interaction with problems of learners that are auditing the course. In 2020, more learners attempt at least one problem and these learners attempt to solve more problems on average. This trend is not visible among learners on the 'verified' track, i.e., learners who purchased access to the course. Our data does not show significant differences between 2020 and 2019 with regards to the number of problems attempted by the learners that paid for the course (U = $6.67 \cdot 10^5$, p=.407). Finally, our data shows that although a significantly higher number of learners posted on the MOOC forums in 2020 ($X^2(1) = 61.3, p = .450$), most learners did not post more than 1 message on the discussion board.

3.5 Course satisfaction levels

Looking at overall indicators of course satisfaction in the post-course evaluation in terms of overall course rating, the likelihood of recommending the course and the ratings learners gave the course for uniqueness, usefulness, being interesting and difficulty, no significant differences between the two runs were found. This may be in part that some of these ratings were already very high in the first run.

4 CONCLUSION

Our data showed significant differences between the 2020 “COVID” run of the MOOC and the 2019 run. It appears the 2020 run not only attracted a larger overall audience but it also attracted a younger audience, consisting of significantly more students and significantly more females than the year before and a decrease in the percentage of people who are working. In absolute numbers however, the aerospace sector bucks that trend, which is not surprising given the standstill in aviation due to COVID and the topic of the MOOC.

When looking at the motivation to enrol, we see here that focus in the 2020 run shifts more towards (prospective) studies than towards (prospective) careers even though this still makes up for 37% of the motivation to enrol. This is not surprising given the increase in the number of undergraduate and graduate students enrolling in this course. We also observed lower course completion rates, even though learners reported significantly less problems with allocating sufficient time. This may be indicative of less interest in obtaining a qualification and more interest in interacting with the course material.

We also see a greater need, value and satisfaction for more interactive course activities such as Discussion Forums in the MOOC, which is not strange given that most learners will have been stuck at home with less opportunities for social interaction elsewhere. Looking in more detail into the learning data of edX confirmed that during COVID times learners engaged far more with the material than learners in non-COVID times and seemed to be genuinely interested in gaining more knowledge about the topic than gaining a qualification.

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WHAT IS THE ROLE OF ETHICS IN ACCREDITATION GUIDELINES FOR ENGINEERING PROGRAMMES IN EUROPE?

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***Keywords**: Engineering Ethics, Accreditation, Document analysis*

ABSTRACT

The Washington Accord emphasises the role of ethical and societal considerations in the practice of engineering. Increasingly, national accrediting bodies are also expecting to see evidence in the delivery and assessment of ethics throughout engineering programmes. Nevertheless, there is still little known on how the process of evaluating ethics can best serve the function of accreditation ensuring quality assurance and quality improvement. The aim of this paper is to look at the top-down approach and analyse what role engineering ethics plays in national accreditation documentations in Europe. A multi-country analysis of how and where ethics appears in the systems of accreditation was carried out for the UK, Ireland, France, and Switzerland. The competencies, programme outcomes or learning outcomes were reviewed and explicit or implicit references to ethics education were identified. A quantitative and qualitative word analysis was carried out by extracting verbs and comparing verb definitions that were stated. Verbs were categorised under Doing actions, Thinking actions or both and compared to Bloom's Taxonomy of Learning. In

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all cases, ethics was explicitly mentioned however limited to 1 or 2 sections of the documents reviewed. The majority of statements linking to ethics were implicit, opening room for interpretation. A more conscious effort to engage engineering ethics in all aspects of engineering programmes as well as using higher levels of Bloom's taxonomy should be made where engineering ethics education is applied in practice.

1 INTRODUCTION

1.1 Background

Currently engineering ethics is featured in a limited capacity in engineering programmes, however it is a subject that pervades every area of engineering and therefore needs more prominence in engineering programmes. Although there are practitioners on the ground advocating this change and communities of practice in engineering ethics that are gaining critical mass, we need to also look at a top-down approach and review how policies, in particular current accreditation documents, are advocating the education of engineering ethics. The aim of this paper is to look at the top-down approach and analyse how engineering ethics is taken into account in national accreditation documentations in Europe.

In light of this aim, there is a wave of change happening at the policy level, with the inclusion of ethical and societal considerations in the Washington Accord [1], which has contributed to the inclusion of ethics in the formulation of accreditation criteria for engineering programmes in signatory countries [2]. This in turn has impacted positively on the presence of ethics education in the engineering curriculum, through an increased content of ethics [3-6] and use of active learning methods in relation to this content [7].

Understandably, Higher Education Institutes rely on their respective national accreditation documents as one of their primary resources in programme content and development. With this reliance is a dependence on the use of language, definitions and how learning outcomes are structured, which in turn become key factors on how engineering is taught. In addition to the need to be more globally relevant, the different use of language and interpretations across borders becomes even more important. To date, no critical analysis has been carried out on how engineering ethics is featured in accreditation documents with respect to use of verbs and definitions and how these compare between countries. This will be the focus of this paper with a discussion on the implications of these findings.

1.1 Context of Engineering Ethics

In order to examine how ethics is treated in the standards of the engineering education accreditation bodies, we sought to establish a reference framework from which we could diagnose the situation of the required standards. We have constructed this frame of reference from four books aimed at educating engineers in ethics: Harris et al., 2009, Martin et al., 2010, Poel & Royakkers, 2011, Fleddermann, 2012 [8-11]. To consolidate this approach, we have also taken into account a fifth book by Legault (2005) aimed at educating professionals more generally in ethics [12]. In addition to the expected concepts, this synthesis aims to bring out key words for the analysis of accreditation bodies' reference systems. Indeed, ethical know-how integrates different fields of knowledge, which can be addressed in the repositories, without appearing in a section entitled ethics.

2 METHODOLOGY

A multi-country analysis was carried out on the accreditation documents of four countries: UK [13], Ireland [14], France and Switzerland [15]. For Switzerland, only the French Swiss region was reviewed, where the France documentation was used to cover both countries. The official English translation of the CTI French accreditation document was used for the analysis. Therefore, three accreditation documents were analysed. The competencies, learning outcomes and program outcomes were reviewed and explicit or implicit references to ethics education were identified. A comparative quantitative and qualitative word analysis was carried out by extracting verbs and comparing verb definitions that were stated.

2.1 Identification of common terms used in engineering ethics

Classification of the main concepts, keywords and topics derived from the table of contents from five books specific to engineering ethics was carried out in order to identify a range of terms in current use [8-12] that were utilised in this study to carry out a word analysis of the accreditation documents as outlined below.

2.2 Ethics cited explicitly and implicitly

An analysis of the learning outcomes and programme outcomes across documents were analysed using six general categories: Dedicated Outcomes, Design, Management, General Skills, Technical and Organisational/Personal/Cultural. Under each category, it was identified wherever ethics was mentioned explicitly based on the terms “ethics” and “ethical”. Implicit association of ethics was carried out by using the common terms identified from the texts chosen (Section 2.1).

2.3 Analysis of verb usage in learning outcomes cited on ethics

Verbs were categorised under Doing actions, Thinking actions or both and compared to Bloom’s Taxonomy of Learning. A comparison was carried out on the use and frequency of these verbs according to the hierarchical learning levels.

3 RESULTS

3.1 Classification of terms in engineering ethics

The range of common terms were collected from the 5 texts on engineering ethics as shown in Table 1. These common terms were extracted from the contents page and collated to highlight the range of terms that were used in identifying subjects that implicitly relate to engineering ethics. The sub-topics also covered very broad subjects and terms that were not included for brevity such as “decision”, “cultural”, “social” and “policy”, which are not found in this list but covered under these main topics as shown in the examples.

Table 1. Terms in use from 5 textbooks on engineering ethics from contents list.

Main topics	**Examples**
Ethics global point of view	Why teach ethics to engineers, professional vs personal ethics.
Ethical values	Golden rule, universal principles such as integrity etc.
Profession and professionalism	Ethics of corporation, engineers responsibility.
Responsibility	Active or passive actions, links with standards and codes.
Charters, rules, codes, law	Characteristics, preventative measures and limits.
Understanding ethical problems, developing a critical mind and ethics reasoning: philosophy of ethics	Normative ethics, values, dilemmas and moral choices and decisions.
Solving ethical problems	Design of ethical solutions, ethical deliberation.
Engineer working in organizations	Organizational loyalty, whistleblowing, policies.
Engineer managing safety and risks	Engineer’s responsibility for safety, cost/benefit/risk analysis, Health and Safety, Risk Assessments.
Engineer and sustainable development	Environmental ethics, sustainability, circular economy.
Engineer in international context	Non-western thinking, global codes for multinational, multilingual and multiethnic considerations.
Engineer and research integrity	Research integrity, truthfulness, trustworthiness, reliability.
Engineer and digital technologies	Ownership of computer softwares, IPR, financial exploitation, data protection.
Engineer designing technology	Ethical issues during the design process, data protection.
Global justice	Technology transfer and appropriate technology, social equity vs social disparity, governance and policies.
Ethical issues, dilemmas and case studies	Extortion, bribery, many hands responsibility, systematic errors.

3.2 Ethics cited explicitly and implicitly

Ethics was explicitly cited in all documents in only 1 to 2 learning outcomes or programme outcomes, which are mentioned in 1 to 2 accreditation sections of the document. In contrast, implicitly linked words from the list of common terms used highlighted a greater presence of ethics showing a total of 56 to 92 times across documents and across all the sections on Learning outcomes and programme outcomes. However, in most of these cases, this link to engineering ethics is inferred and not obvious. A breakdown analysis of the frequency of terms according to country is shown in figure 1, showing shifts in emphasis on different aspects of engineering ethics. For example, the UK brings heavy emphasis on Safety and Risk, which is mentioned 27 times. In comparison, Ireland and France mention Profession and Professional 26 and 17 times respectively. Furthermore, none of the documents mention “global”, “Values” or “Justice” and only Ireland mentions “integrity”.

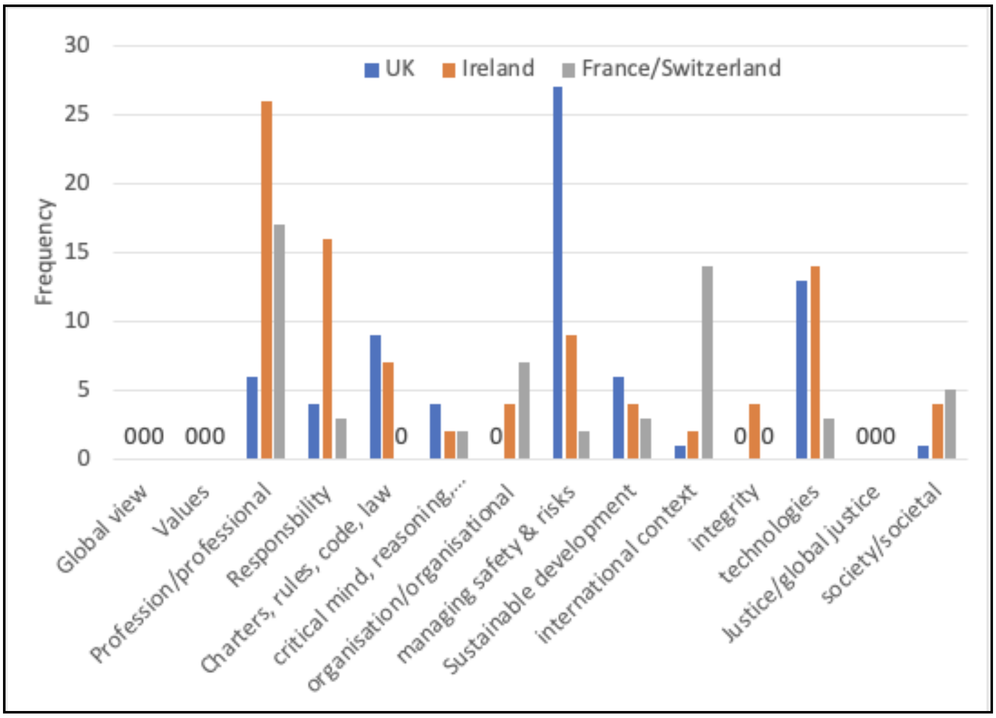

Fig. 1. Words implicitly linked to ethics found in Learning Outcomes or Programme Outcomes accreditation documents according to country

3.3 Use of verbs in learning outcomes cited on ethics

The verbs used in the accreditation documents to describe learning outcomes for ethics-related subjects were analysed and categorised according the Bloom's Taxonomy of learning, showing that most of the verbs related to the lower levels of learning, for example, “know”, “define”, “awareness” and “exercise” (Table 4). It was also noted the France/Switzerland documents had a wider spread of verbs such as “improve” and “design”, which appeals to the higher learning levels of “evaluate” and “create”. The same verbs used in the accreditation documents were also categorised into Doing actions, Thinking actions or Both (figure 2) showing a heavier emphasis on Thinking actions.

Table 4: Evaluation of verbs linking to ethics from the accreditation documents and according to Bloom's Taxonomy of learning

		Verbs used in Accreditation Documents Note: verbs colour coded according to Bloom's Taxonomy																		
		Know (knowledge)	Define	Consider (take into account)	Understand (understanding)	Awareness (aware)	Exercise (e.g. initiative)	Commit	Implement	Test	Questioning	Exploit	Identify	Evaluate	Reflect	Investigate	Self-assess	Improve	Design	Master
Accreditation body	UK: IMechE (Engineering Council)	x	x		x	x	x						x			x				
	Ireland: Engineers Ireland	x	x		x			x							x	x		x		
	France & Switzerland: CTI			x	x		x		x	x	x	x		x			x		x	x
Bloom's Taxonomy	Remember																			
	Understand																			
	Apply																			
	Analyse																			
	Evaluate																			
	Create																			

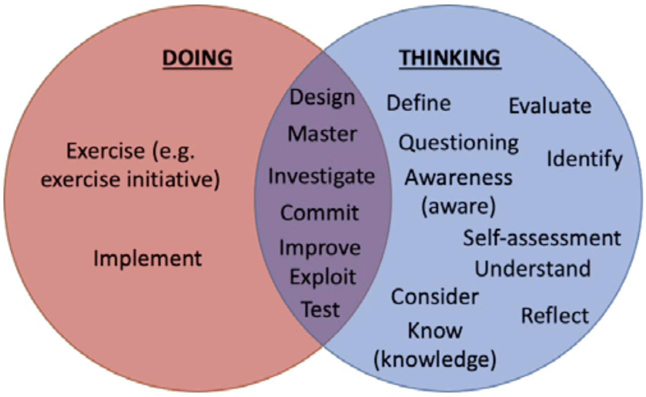

Fig. 2. Verbs from accreditation documents linking to ethics categorised according to either Doing actions, Thinking actions or both

4 DISCUSSION

The training of engineers in ethics is situated within the framework of applied ethics, participating and even guiding the decision-making process of engineers. As such, it is the field of so-called normative ethics (the study of ethical behaviour) as well as applied ethics (applying ethical theory in real life situations and decision making) that interests us here. The construction of the authors' works shows that the major challenges of such training are to enable engineers to manage the ethical implications of their work and their place in society. Three learning points were summarised from the analysis of this study.

Firstly, there is a difference in definitions across documents which will impact how these programmes and subject-specific learning outcomes are written. This might create implications in how engineering education programmes prepare their graduates for their future professions. Since the world of work has become highly globalised and international, it is important to have a stronger, and to some extent, unified understanding about ethics in engineering. Furthermore, ethics in engineering in itself brings forward an emphasis on continuous reflection around how certain engineering actions impact the local and global contexts (environments, societies, resources, et cetera), thus having varied definitions might feel a step backwards in preparing future engineers to act and think ethically.

Secondly, all documents do include engineering ethics stated in their Learning Outcomes or Programme Outcomes but most of the verbs used are generally lower in Bloom's taxonomy and referred to more thinking verbs than doing verbs. This makes inclusion of ethics in the accreditation process seem more symbolic and open for interpretation by the higher education institutions implementing engineering programmes. If ethics is more linguistically represented as a thinking than as a doing verb, it might lead to disassociating it with practical engineering knowledge, and therefore offering a more theoretical or philosophical approach to the subject. The implications of which results in no real impact to an engineer's work.

Thirdly, there are many implicitly important ethical concepts in sections of the documents that can be open to interpretation. When the common terms (table 1) were used as a frame of reference, this wider use of terms showed all sections of the accreditation documents were subject to applied ethics. This demonstrates the presence of ethics in all sections of an engineering programme. This will mean that degree programmes will have varied levels of engagement on ethics depending on the interpretation and therefore how the programme is structured and delivered in practice. Without a clear explicit "demand" for ethics at the educational institutions, there is a danger that ethics will remain on the margin, taught by (sometimes competing) humanities and/or social science faculties/teachers, and hence perceived by students to be marginal to the core of engineering education. This will also continue to impede integration of ethics in the core curriculum by teachers of engineering disciplines and make the process of moving ethics closer to the more technical disciplinary knowledge slower.

We propose a more direct mention of ethics in all sections of the programme or set an agreed definition that encompasses the depth and breadth of the engineering topics that involves the awareness of ethics in engineering. Engineers must therefore be able to situate their actions or decisions in a societal context and the ethical issues related to it. They have to develop possible solutions and then evaluate the ethical quality of these solutions in order to arbitrate and decide. Finally, they have to develop their ability to think and decide ethically. This approach is particularly emphasised by Poel and Royakkers (2011) as major axes in engineering ethics education [10].

On reflection of the use of language, there is some frustration when verbs are taken in account with little understanding of their complements, such as: understand, reflect, consider, commit, act...on what? These verbs can be applied to every domain; however, when focusing on ethics, what is it saying and what is the intended meaning? This opens up a deeper level of linguistic analysis for further exploration.

There are several limitations to the study, firstly this analysis focuses on verbs alone. The reason for this is verbs are used as the key to understanding and therefore drives our competencies and learning outcomes as reflected in the documents analysed. Since learning is driven by this, the data in this study naturally relies on evaluating the use of verbs: what we do rather than what we are. On the other hand, what we are: our identity, emotions and how we feel does indeed drive what we do, however this is less tangible and therefore very difficult to evaluate.

Secondly the documents were analysed in the English language. The original English translated glossary of the French/Swiss document was therefore used in the analysis. However this opens an important discussion on the strong link between language and culture, context and values. This in turn influences how these are understood, expressed and applied. This would need to be explored in future to include a native language assessment as part of the analysis.

Thirdly the use of common terms such as “responsibility” are too general and therefore its role in ethics education is open to interpretation or lost in translation when transitioning from understanding to application. It is hoped that this paper has highlighted this challenge, calling for a more explicit definition of terms or terms of use. It may be that a global and wider understanding of the *definition* of ethics and related terms is needed. In light of the earlier point on the impact of language, there is also a question of whether this is possible.

Finally, the use of textbooks in generating the terms are already outdated in current and future challenges our societies face. However these textbooks are in current use and commonly feature as reference text in engineering programmes. This does raise the need for a renewal of some of these books as reference text that brings more emphasis to our future challenges as a global community.

5 SUMMARY AND ACKNOWLEDGEMENTS

The aim of this paper was to take a top-down approach and carry out a word analysis on how engineering ethics is taken into account in national accreditation documentations in Europe. Although ethics is given some importance, its study and application were shown not to be directly linked to a broader treatment of ethical, social and global aspects in engineering. The authors suggest a common global working definition should be established that encompasses the broad spectrum of ethics and its application in engineering programmes. Through this top-down approach it is possible to bring a more comprehensive incorporation of ethics, taking its practice from the periphery to the heart of accreditation requirements, and therefore in engineering programmes.

The author list has been arranged in alphabetical order to reflect the equal contribution to the study design, data collection and analysis.

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A 360-VR AUTHORING TOOL FOR ENGINEERING TEACHERS

PREPARING VIRTUAL EXCURSIONS FOR MINING ENGINEERING EDUCATION COURSES

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Conference Key Areas: *Academic teachers needs and support for online teaching, Lab courses and projects blended and online*

Keywords: *Virtual Reality - Mixed Reality– Authoring Tool – Virtual Excursions – Engineering Education – 360° Video*

ABSTRACT

Fitting an excursion into a lecture plan has been always a challenge to organize [1] [2] [3] [4] – even before the global pandemic outbreak. Mixed Reality (MR) media enables teachers to invite students virtually into a remote location for a few minutes during the lecture. It enables explaining key aspects of a process or a machine in detail and finally supports aligning the practical insight with the theoretical concepts behind it. Previous publications have proofed the benefits of including MR into a teaching curricular [1] [5] [6] [7] [8]. However, the available prototypes tend to cover unique cases and barely enable teachers to adjust content to their specific needs.

This shift from on-site to virtual excursions calls for new MR authoring tools and digital skills for teachers. Aligned with the teacher 4.0 concept [9], the development of an authoring tool in context of mining engineering education is currently realized and will be presented in this paper. The tool is developed within the project MiReBooks that is funded by the EIT Raw Materials initiative.

In this paper, we introduce the concept, design and development of an authoring tool to support teachers preparing virtual excursions based on 360° video imagery. In addition to the specification of the technical design, the paper outlines the initial results of the evaluation, which is conducted in cooperation with mining engineering teachers throughout Europe. We will conclude with an outlook on follow-up development steps.

1 INTRODUCTION

Authoring tools enable teachers to prepare content themselves without programming skills [10]. Thereby, they address the current increasing need for Mixed Reality (MR) based teaching content. In terms of virtual excursions, this means that teachers would not only prepare the typical content slides for their lecture, but also add content (i.e. VR-media slides) for a short excursion into a virtual mine site on their PCs as part of their lecture preparation. Mining engineering teachers need to teach in-depth knowledge in exploration, extraction, conveying and the processing of raw materials. Often the environment influences the design of a bucket wheel excavator heavily. Conveying a better understanding of mining machines through 360° videos, would allow teachers to emphasize the understanding of processes in mining engineering more hands-on.

The current integration of MR -based classes still requires good programming skills from teachers and thus makes virtual excursions preparation not easily applicable for everyone [7]. The use cases, along with the challenges, have been previously addressed in the teacher 4.0 concept of Abdelrazeq et al. [9]. As notable in some of the previous works, the integration of MR into the class requires a close examination of didactical planning, technological skills and possible requirements from an organization standpoint [11].

User centered design (UCD) methods and agile design principles support the development and design of the authoring tool. Those methods had been applied in this research project as they can minimize the needed technical skill level for the preparation of MR based lectures. UCD is an iterative approach in software development in order to develop concepts, designs and prototypes that can be understood fast and is easily accepted by users [12]. Methods such as focus group interviews, the development of user stories as well as usability tests support better understanding of the requirements from software [13] [14].

In order to contribute into MR authoring tool concepts in education, we will first describe the aim of the MiReBooks Project and the role of an authoring tool for the teaching 4.0 concept. The following sections will introduce the main three guiding research questions for developing the authoring tool concept. First, the question regarding learning objectives for virtual excursions and their implication for the tool development will be presented. Second, the question on the workflow of the authoring tool will be addressed with the method of user stories. Third, self-explanatory software design will be applied in order to minimize the need for additional competences for the teachers. Finally, the conclusion will provide the next steps and further fields to test the authoring tool.

2 THE 360-VR AUTHORING TOOL

The aim of the MiReBooks Project is to enhance classical mining engineering teaching concepts with MR technology. As future mining engineers will need to balance more complex mining equipment with additional sustainable demands, the understanding of the actual enviroment through 360° videos becomes a key focus for current teachers.

As the contemporary 2D teaching material lacks hands-on experience from a mine site, the development of MR content such as 3D models and 360° videos are produced throughout Europe [11]. Thereby providing a textbook enhanced with MR content for teaching. Moreover, the project enables the research on teaching 4.0 skills in the context with MR based classes [1], [5], [6], [7], [11].

In addition to the technological development and infrastructure, a vital part of the MiReBooks project is to enable mining engineering teachers to plan and provide MR based lectures on their own. Therefore, the authoring tool is developed with UCD methods. The aim of this authoring tool is to support teachers with an intuitive software to prepare their own MR based lectures.

In order to define the requirements, the project-involved teachers were asked about their vision and expectations of MR in teaching. The result had been analyzed in the works of Daling et. al [5]. Learning objectives were defined with UCD methods such as contextual interviews that were carried out after testing MR in lectures. Thus, three questions arise, such as:

1. What is needed to support teachers in order to reach the learning goals of virtual excursions?
2. What kind of MR features have to be included in an authoring tool to meet the proposed learning goals?
3. How do the features need to be designed in order to be intuitively understood by teachers during their lecture preparation?

The authoring tool is developed with the Unity 3D game engine. Based on a previous requirement analysis and further iterative development, the authoring tool runs on PCs as teachers tend to prepare their lectures with this device. Hence, the Unity 3D game engine was adapted accordingly for the software development. In addition, due to the user stories method, it is optional whether teachers visit the mine in MR or navigate their students with a PC or tablet based function.

2.1 Authouring tool to support the Learning Goals for Virtual Excursions

The development of the concept required a close analysis of how teachers prepare for classes in general, how they perceive their role through the introduction of MR and how they assumed virtual excursions are supporting them in their learning objectives. Their ideas as well as the insight in lecture preparing and reflection of the test lectures supported the authoring tool concept. With contextual interviews, the teachers were asked to reflect the usefulness of different prepared MR technologies they tested with students in their lectures [5]. This first study gave a better understanding of the expectations of teachers wishing to include virtual excursions in their lecture.

As a next step, the collected use cases for teaching were sorted in two internal workshops and two additional interviews with mining engineering teachers to the learning taxonomy level of Bloom (see figure 1). The Bloom learning taxonomy addresses different level of learning, starting from higher to lower levels such as evaluate, synthesize, apply, analyze, remember and understand [15]. The use case with the highest taxonomy level addresses synthesizing and would be an application where students create their own virtual scenarios with sandbox game elements. The use case enabling students to simulate blasting in MR lets them apply knowledge through placing mining equipment and simulating how the blast would theoretically be played out in a save VR enviroment. A training scenario that lets students search for security errors such as finding the errors in a prerecorded 360° video scene addresses the analysis taxonomy level. Those first listed use cases enable students to apply theoretical knowledge, but might not need a teacher directly involved in the interaction with the MR medium.

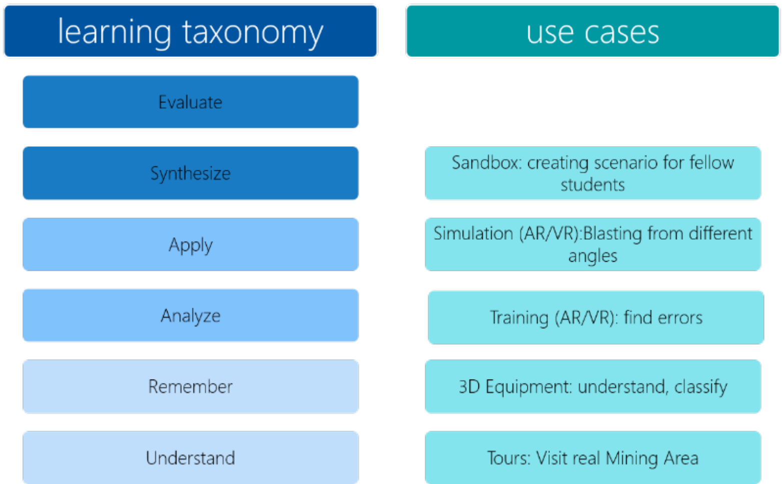

Figure 1: Aligned ideas for MR use cases in class with Blooms learning taxonomy levels.

The use cases of interacting or classifying 3D equipment as well 360° video tours in a prerecorded mining area would often need additional knowledge of the teacher to explain addiational aspects. Therefore the lower taxonomy levels such as understanding and remembering require a closer communication between teacher and student during the lecture in order to ask questions and discuss [5]. Thus, those scenarios need to be highly flexible in their design in order to address the individual teaching style of teachers. Those use cases are more likely to be used in the lectures to support the interaction in class, while security trainings or blasting try-outs are better applicable without the lectures due to the extended time that is needed. Thus, the idea of virtual tours through the mine, 3D displays of mining equipment addresses learning goals of understanding and remembering.

To address the first question of what is needed to support teachers in order to reach the learning goals of virtual excursions, the teachers were interviewed by Daling et al. in order to extract the MR use cases in teaching. The authors analyzed that teachers wished to use 360° camera footage in order to visit mine sites virtually with their students during a lecture [5]. For those virtual excursions, the questioned teachers wished to take place during class. This indicated that the learning goals, which the teachers wished to address during the virtual excursion, links to a lower taxonomy level (understand, remember).

The vital role of the teacher for the learning process in a virtual excursion calls for the design of an authoring tool instead of a finished developed MR experience. This allows the teacher to adjust the excursion at runtime and point the students attention towards specific aspects at the location. Additionally, those use cases addressing a higher learning taxonomy level are usually more complex to design and program. Due to the requirements of MR classes such as presented in the VRMine project [16], the support of software developers and game designers are needed. The transfer to an authoring tool for teachers with basic knowledge in game engines seems further challenging. The more detailed insight in learning goals of virtual excursions and their implication for the video production of 360° video content had been discussed by Khodaei et. al. previously [11].

2.2 Authoring tool Mixed Realitiy Features on the Basis of User Stories

For the second question on what features are needed to meet the proposed learning goals, three mining engineering teachers who are more familiar with MR were asked to describe their ideal workflow. In order to identify what teachers wish to include during classes and what they expect from the MR technology, the method of user stories was applied in one workshop. The workshop aim was to understand the needed features and unveil the expectation and skill level perceived by the teachers.

As authoring tools introduce a new workflow into the lecture preparation for teachers, it was needed to formulate user stories in order to understand the needed requirements and features. Those user stories were phrased in order to guide throughout the phases before lecture preparation, as well as during lecture and finally after the lecture. To formalize the user story, the teachers had a fixed structure consisting of a subject, an action with a certain content and a timeframe (see table 1).

Table 1. Formulation structure of a user story in order to understand what actions are relevant for the workflow.

Module	Meaning
As a <teacher>|<student>	<who> should be enabled to do it
Verb + <imported content>	<action/interaction> that enables the user to do things with a <content>
<before>|<during>|<after>	<when> should the action take place

The following overview shows the results of the used technique by showing the requirements consisting of 10 user stories before the lecture, 8 user stories during the lecture and two after the lecture (see table 2). Those user stories were ranked in a next step into important and nice to have.

Table 2. user stories sorted by lecture preparation phase

Phase	User stories
Before lecture	As a teacher I want to import my 360° images/videos from the mine into my lecture
	As a teacher I want to set certain view directions in my 360° videos before the lecture
	As a teacher I want to insert a break image into my 360° videos before my lecture
	As a teacher I want to know how long showing the 360° images takes before my lecture
	As a teacher I want to change and adapt my 360° videos/images before the lecture
	As a teacher I want to cut my 360° videos/images before the lecture
	As a teacher I want to place/Insert text/annotations/images into my 360° videos/images before the lecture
During lecture	As a teacher I want to switch between my 360° images/videos from the mine during my lecture
	As a teacher I want to switch between PowerPoint and 360° images during my lecture
	As a teacher I want to start and stop my 360° videos from the mine during my lecture
	As a teacher I want to track the time that shall be spent in 360° images during my lecture
	As a teacher I want to place/Insert text/annotations/images into my 360° videos/images during the lecture
	As a teacher I want to know who is watching in what direction in my 360° videos during the lecture
	As a teacher I want to jump between certain view directions in my 360° videos during the lecture
	As a teacher I want to draw attention in my 360° images/videos during the lecture
After lecture	As a teacher I want to save and restart at a certain time my 360° images/videos from the mine after my lecture
	As a teacher I want to share my 360° images/videos from the mine after my lecture

Based on the structural analysis of the user story, the following workflow for preparing the Learning Experience (LE) was conceptualized (see figure 2). LE referes to the resulting experience, the teachers wishes to convey. The tool concept consists of the phases, login and selection of different projects, preparing the lecture with self-recorded material and sharing the built LE with the class. Those steps resulted in the structure of a lobby, where the teacher selects the LE, a preparation step for the teacher to create the LE followed by a player module where students and teachers connect into one LE (see figure 2).

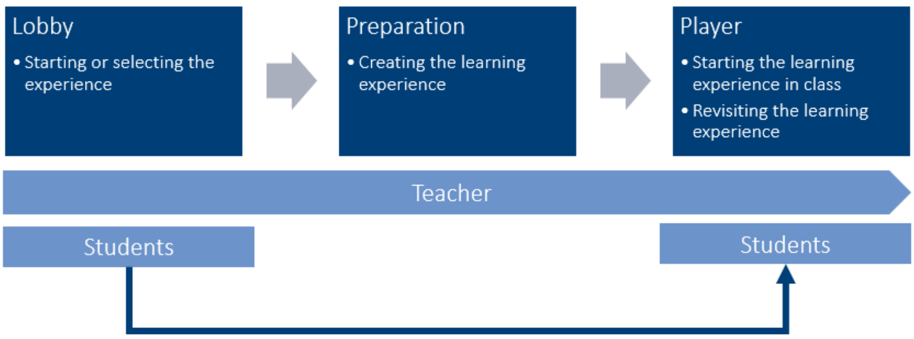

Figure 2: Overview on the three modules lobby, preparation and player.

Within the preparation phase, the following steps have been identified as important for the teacher in order to create the LE (see figure 3). The teacher needs to create the LE by opening and naming a project. Then, s/he need to load pre-stitched 360° videos into their project. Then assign their video material into slides and sort the slides into an order that fits the structure of the learning goal.

In addition, the action description in the user story give an insight in the needed features for the authoring tool development. Firstly, on each 360° video they set a viewing angle. The viewing angle defines where everyone entering the LE i tilted towards. Secondly, placing annotations on top of the 360° image such as texts, arrows and icons in order to highlight or explain certain points in the experience. Thirdly and finally being able to save the project into a LE format. Those features are needed to be predefined in the preparation phase by the teacher, as those were described in the user stories as part of the preparation process.

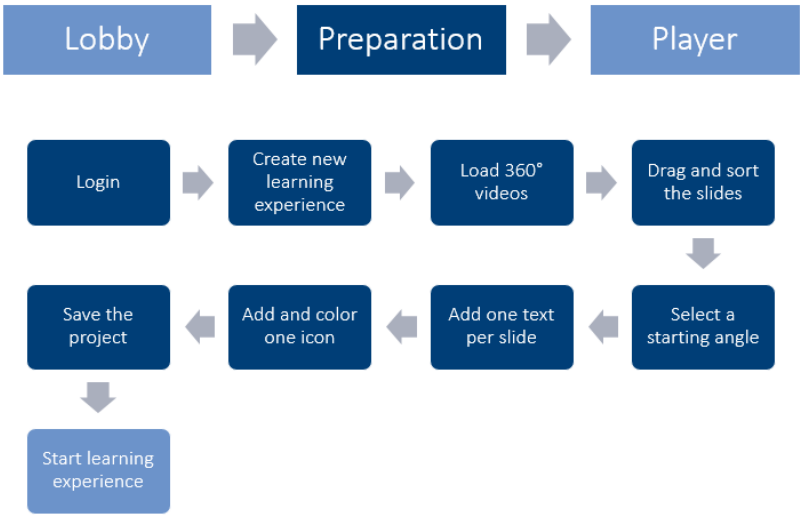

Figure 3. A detailed workflow on the steps that the teachers wished to do based on user development

2.3 Slides as key design element for MR based authoring tools

After the concept and features of the authoring tool is understood, the third question on how to design the features in an intuitive way are addressed. Thus, the first step is to make the interaction as intuitive and self-explanatory for teachers as possible in order to minimize the need for learning additional technical skills. The initial step alignes the design to familiar tools in order to apply the UCD principle of context understanding principles [17]. For part of the user story development, it is needed to understand what tools the teachers usually prepare their lectures with. As most of the teachers use tools like PowerPoint, the design elements of slides have been selected from PowerPoint both visually and terminologically.

The editor consists of three areas (see figure 4). The first and main area is a preview/working space area which takes 2/3 of the screen in the middle. The second is a slide area that gives an overview of the selected video material on the bottom. The third is on the right side and allows to select tools and edit the size and color of text fields. This area is changing in regard whether the teacher is in editing or in playing mode. One key design decision to support the flexible and more floating switch between editing and playing is the factor, that the overview of the teacher is the same for editing and playing with regard to the overview area. Otherwise, a fundamental design change between preparation and teaching might cause confusion through the course and consequently neglecting the tool. In the area of the preview is a set of icons and annotation texts as well as the ability to select a starting angle. Apart from preparing annotations before the lecture, it is also possible to spontaneously add texts and arrows in play mode. The preparation and player mode were designed to have the similar preview and slides. The right side represents the needed tools for the editing or player more.

Figure 4. The overview of the authoring tool in preparation mode.

The first user interface study in may 2021 aimed to test how self-explainatory the used icons and concepts are. As the minig engineering teachers were already heavily involved in the design process, in this study seven students prepared the virtual excursion. In the selection of students a mix between male and female students is considered as well as different scientific fields and nationalities.

The study concept has a mixed approach of qualitative oberservation and a questionnaire with quantitative scales such as the System Usability Scale (SUS)[18]. The participant gets the autoring tool software along with 360° example videos. The participant is asked to perform a set of 12 tasks. The tasks are formulated along the workflow in figure 3. During the task completion the participant is asked to think aloud and is observed by both male and female developers and designers. Afterwards a quenstionnaire asks to reflect on how well they fulfilled each task.

The observation and questionnaire revealed that that the slide concept and preview field was intuitively understood. The SUS Score of 73,5 indicates that the usability of the tool is good, but there is still improvement for the tool needed. The qualitative observation with the thinking aloud method revealed that the general impression of the tool feels overwhelming and the display of the duration of an annotation is not directly understood and the viewing angle concept was not grasped. Addiationally, more features in the design of the text annotations (e.g. text alingements) were requested. Thus, additional further iterations and following a detailed study on the usability of the authoring tool are the next steps.

3 CONCLUSION AND OUTLOOK

In summary, we introduced the concept, design and development of an authoring tool to support teachers preparing virtual excursions based on 360° video imagery. Several steps in UCD methods such as contextual interviews, user stories and usability tests were applied through this process. Through the contextual interviews, it became clear that virtual excursions are mostly seen as a support during a lecture and thus would address learning goals that apply to lower taxonomy levels. Through the phrasing of user stories in workshops, the expectations towards an authoring tool and the steps in preparing the lecture were made visual for development. For minimizing the needed additional skills from the teacher, the tool design was built on software that is already used for lecture preparation such as Power Point. Moreover, the first User interface focused study indicate that the tool is intuitively designed and requires few prior knowledge in order to prepare a virtual excursion.

As next steps, additional user experience studies are needed and planned in order to further design the authoring tool into an intuitive support for preparing MR based lectures. Moreover, studies that analyze further interaction between teacher(s) and students during the virtual excursions are needed. Additional studies within other research fields such as construction sites, city planning or environmental classes would further support into creating more virtual excursions and testing best practices for MR based teaching.

In general, the development of supportive authoring software for teachers to prepare MR technologies continues to have great international relevance. Due to the growing need for new blended learning methods and the high variety of use cases further research applying the principles and methods of UCD support this current approach.

4 ACKNOWLEDGEMENTS

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Further references regarding the discussed project can be found under MiReBooks.com.

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PEDAGOGIES OF INTEGRATION IN CHALLENGE BASED OR INTERDISCIPLINARY EDUCATION

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ABSTRACT

Integration is key characteristic of Interdisciplinary learning and often also of Challenge based Education. The definition and operationalisation in Engineering Education is, however debated widely. In this study we explored the tacit knowledge of Engineering Lecturers in HE education by doing semi-structured interviews. It yields suggestions for operationalising integration, boundary conditions and a peak insight into the beliefs and matches with theoretical literature.

1. INTRODUCTION

Grand challenges such as the Sustainable Development Goals (SDG"s) are used in Higher Engineering Education to shape challenge-based education. The idea of incorporation of the SDG's is often based on the necessity for students to acquire professional skills, such as learning to deal with complexity, collaboration in teams and across disciplinary boundaries [1]. Often these SDG topics are addressed in inter, trans or cross-disciplinary settings, meaning an integration of disciplinary knowledge (inter) or even lay-men knowledge (trans) is used to realise a solution [5]. The challenges adapt authentic contexts as a potential learning environment beyond formal academic education [2]. Exploit temporal available wisdom and power of diverse communities in vital coalitions of stakeholders [3] and add to different knowledge systems [4].

In this paper, we have focused on exploring the pedagogies of integration used in interdisciplinary or transdisciplinary approaches in challenge-based education. A key feature of interdisciplinary education, while engaging with challenges, is the integration of different disciplinary knowledge fields, which are used to solve societal challenges [4][5]. Arguably, interdisciplinary education is positioned by some as the next step to a post-disciplinary stage of Education [6] requiring a synthesising mind [7]. Arguably, students with a robust understanding between different disciplinary conceptualisations of vital themes, are likely to enhance integration, to help develop more coherent conceptual frameworks and increase productivity in the problem-solving process [8].

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Yet integration alone, as one means to this robust understanding is unravelled in numerous different ways. It needs to be realised through boundary-crossing [10], overcoming epistemological differences by clarifying the purpose of the outcome. It needs to be realised through disciplinary grounding, leveraging integration and taking a critical stance [11] or overcoming power differences [12]. Others discuss the integration in terms of education, such as the need for teamwork [13] or problem-based education [14] [6]. Therefore, the teaching of integration as an inter or -transdisciplinary competence can be difficult to operationalise in educational design [9] [12]. We noted very few authors, have come up with a description of the tacit knowledge available to Lecturers in Higher Education to tackle and address integration as a part of interdisciplinary competences to be acquired in challenge-based learning. It is an educational design challenge to be explored.

Tacit knowledge is knowledge acquired through practice and exercise in the performance of some tasks [16]. The idea is that the externalisation of tacit knowledge may provide insights into a range of integration beliefs and practices that may help theory formation of "Pedagogies of Integration" for teachers. The main research question in this paper is therefore: **What can we learn from the tacit knowledge of lecturers on “pedagogies of integration” in interdisciplinary learning contexts?**

2. METHODOLOGY

In this qualitative study, we interviewed 18 lecturers at our Technical University responsible for a minor or master course comprising interdisciplinary education. To find these lecturers, we consulted the course guide to identify which courses have been indicated as being interdisciplinary. The interview protocol has been based on the literature literature review model of van den Beemt [17], addressing the vision, education and support structures. The semi structured interviews have been transcribed and coded descriptively resulting in 11 emerging and principal codes, namely: vision, working methods, assessment, skills and knowledge, interdisciplinary problems, level of integration, objectives, involvement, reflection and evaluation. This paper focuses on the code level of integration. The code integration has been accorded to 220 excerpts across the 18 transcriptions by three coders. Interrater reliability (IRR) is used to establish if the information is collected in a consistent manner and show the identification of the 1st level coding is more than mere chance. The inter-rater reliability (IRR) was calculated, and is 0.71 showing a substantial degree of agreement among several raters, with a Fleiss ‘ Kappa (K).

Second level coding consisted of axial coding to get to grips with the data set and uncover the general patterns discerned and their interrelationships. This coding is done by using the headers in table 1 (results section) as a theme. Theme 1 is the phase of the action taken, while realising the educational design, such as programme design, and a refinement in the next column. Theme 2 is the mediating activities or the proposed intervention, and theme 3 is the outcomes or the anticipated integration of some sort if discussed. The themes and patterns will be discussed in the results section.

3. Results

The interviews show that when we talk about the "Pedagogy of Integration", each lecturer thinks of different moments in the design or performance phase of an interdisciplinary course—varying from programme design, instructional design at the course level to content methods, evaluation and integration methods (column 1). Column 2 is a refinement focused on what the function is of the tacit knowledge in the design of education. These results emerged from the tacit knowledge of education from the interviewee's and was influenced by their background knowledge in different disciplinary fields. The table below is a summary of the 2nd level axial coding of the interviews. Below table 1 the rows will be further explained.

Table 1. Pedagogies of Integration

DESIGN PHASE		MEDIATING VARIABLES	OUTCOMES (ANTICIPATED OR EXPECTED OR EXPERIENCED)
PROGRAMME DESIGN (3.1)	Structure resources	Support courses /mini lecture series/micro-lectures 3- pillared approach Cascading minor Retrospective design Disciplinary Pre-study	Integration of materials by students
INSTRUCTIONAL DESIGN (3.2)	Boundary conditions	Interdisciplinary topic (different disciplines) Mixed groups (disciplines, nationality, culture, gender) Entry profile of students Real life Cases Higher order knowledge Team-based teaching/facilitation Homologation	Stimulating Integration
CONTENT METHODS (3.3)	Content methods	Integrated design method Systems Engineering	
EVALUATION (3.4)	Assessment	Integrated final report /essay/diary writing	Higher order thinking skills (application, collaboration, discussion, presenting, synthesis) Impact and relevance in the field Writing & cohesiveness
INTEGRATION METHODS(3.5)	Working methods	Awareness activity House of the Future Cartographic Drawing Scoping Tohoku (Charette) Making a wiki Reflection	Connecting the dots Innovation Building interpersonal trust & empathy Testing assumptions Evaluation and adaptation

	Harris profile	Discovering values of disciplines Getting used to different jargon

3.1 Programme design

Structuring resources for students is mentioned as one of the approaches for integration of different disciplines. The mediating actions (table 2) are the three pillars approach, the cascading model and the retrospective design set up or a study in context. In the first three pillars approach topics from different major disciplines are offered in a programme– hence the "three pillars of a programme" comprising for example the topics environment, social aspects and economic aspects. These pillars are embedded in the curriculum at different levels and can consist of (1) entire courses (electives/mandatory), (2) support courses in projects in the format of mini-lectures to all the students and to a situation where (3) micro-lectures are given to a subgroup of students, who are required to share this knowledge within their project- team.

Another approach that was shared is the cascading model, in which in the

- 1st phase of a minor, the theoretical foundation is given,
- 2nd phase of a minor, a group assignment for the research analysis is given,
- 3rd phase of a minor, the involvement of an internal/external client is orchestrated.

In yet another “retrospective design set up”, a case is presented by multiple experts of different disciplines, local stakeholders are interviewed, and successively, a redesign is realised of the current situation or a situation that occurred in the past.

Finally, a last format is discussed where a problem is studied in a disciplinary context. After the problem definition, data collection and analysis are realised, groups are redistributed across interdisciplinary groups to realise an integration of disciplines into the solution. In each design the students are expected to realise the integration with the knowledge on offer at the beginning of a programme.

3.2 Instructional Design

When we consider the typical characteristics of an interdisciplinary learning context, all the interviewee's described boundary conditions, which might be necessary to trigger integration of disciplines. These boundary conditions are linked to the topic, teamwork vs individual, the backgrounds of students and the collaborative attitude of the lecturers themselves.

There needs to be a content topic that can be addressed in an interdisciplinary way – meaning it should be open, have sufficient scope and involves different types of knowledge.

In most interdisciplinary contexts, students work in interdisciplinary teams of 3-5 students per group. It means the students are mixed, consisting of different disciplinary backgrounds, different international and cultural backgrounds, and gender balanced. The group composition is of crucial importance one of the interviewee's said:

"different disciplines bring crucial skills to the table to come to an innovative solution."

Sometimes, however, the interviewees indicate that interdisciplinary learning occurs at an individual level.

The boundary condition background is determined by the entry-level profile of a student. They are, for example, asked for a motivation letter, and different background criteria. The criteria are used as selection mechanism such as explicit knowledge of particular disciplines for admission e.g. 1 designer in the group. Enthusiasm goes a long way, however, as admission criterium, it is cited by all.

The boundary condition collaboration between teachers elicits the following observation. It is suggested that real-life cases stimulate interdisciplinary collaboration between students, especially when these cases involve the use of higher-order thinking skills. Intuitively, these courses should involve teachers with different disciplinary background. The impact thereof on integration becomes tangible when there is close collaboration and matching of content matter across the different content topics provided by the teachers. This matching of activities is not always taking place. Often the teachers do their content/activity (provide lecture/group work) and return to their home base after teaching the students and do not talk to other staff. Therefore, team-teaching and continuous adaptation to what is going on in the course tend to be more critical than in regular courses.

"*Making schema's which show how content is connected, methods and techniques to fill the toolbox connected to the backgrounds and the formulation of final qualifications of a sub-specialisation are necessary to make things work." At teacher and student level.*

It requires a specific profile of Interdisciplinary teachers to make interdisciplinary integration work [21].

3.3. Problem definition and Content Methods

Topics or problem definitions should be interdisciplinary by nature and allow for a multiplicity of solutions. Interdisciplinary problems can be characterised as open problem definitions of real life, societal and complex situations. The solutions space typically involves consultation with multiple stakeholders, involving multiple perspectives and different scientific paradigms. Sometimes the programme offers an overarching methodology for solving interdisciplinary problems, such as socio-technical systems, systems engineering, design methodology, design thinking or other problem-solving techniques stimulating integration. These characteristics overlap with many CBE courses [19].

3.4 Evaluation

The realisation of integration is one of the most difficult as no clear criteria for assessing the success of the integration in the final results exist. The assessment methods tend to be essay writing or final report/presentation in which content of different disciplines is integrated. Although this integration is nowhere explicated, general agreement amongst the interviewees seems to imply that it should demonstrate higher-order thinking skills. Higher-order thinking skills are skills such as application, collaboration, discussion, presenting and synthesis. Another measure is the impact, relevance and cohesion of a report/presentation. However, none of these three parameters is per se a measure of integration. The best idea was the daily/weekly journal/log writing in which teams have to explicit (1) how things were done, (2) what was going well, (3) what needs to be completed.

3.5 Integration Methods

There was a range of different working methods used for integration at different phases in the courses of the interviewees.

Starting up

Awareness activity, the house of the future and scoping are used at the beginning of an interdisciplinary course/challenge.

Awareness activity

One lecturer had a workshop in which students are grouped in their discipline, solved the problem and presented to other groups from different disciplines. They became aware of the differences. The next step, in the same workshop, was to mix the groups and come up with approaches/solutions for the same problem that showed the realisation of integration.

House of the Future

In the house of the future, students from different disciplines make a house together they would like to inhabit. Different disciplines integrate their knowledge, ideas and values to make the house. It is a warming-up exercise in which students get to know each other. The exercise creates empathy and trust between the different participants hopefully stimulating integration of other solutions proposed by a team.

Scoping

Scoping can be a part of the Tohoku method but can also be realised independently. It entails students sharing their disciplinary values and how they would like to see activities done with a number of guiding questions.

- What information do you need from the other participants and stakeholders?
- How can other peers/stakeholders provide that information to you?,
- What do you need to give to others?
- How can participants define different solution routes?
- "How do disciplines relate to each other?

Finally, they draw diagrams of what they need from each other and the participating stakeholders.

Continuous design working methods for integration

The next set of working methods for integration are used to critically question the process during the entire problem-solving process.

Tohoku (Charette)- The Tohoku method – was named after the project case, which happened in Tohoku, Japan. The basis of this method is the Charette method and entails a reflection onto solutions for a problem by making the choices explicit for solutions x and y. For example, by using the People, Profit, Planet, Project concepts. An iterative confrontation with other disciplines to reconsider these 4 P's choices is an essential part of the activity. Successively, of course, to adapt solutions to dilemma's that get more weight during the process. The language of the group members and the matching of different disciplines such as thinking at different scale levels or systems is an integral part of the realisation of an integrative (design) problem solution. The innovation is connecting the dots between a variety of topics that are typically not considered. Continuous presentations to make each other's perspectives insightful is a necessity. The methods are described expertly in the article by Hooijmeijer [20].

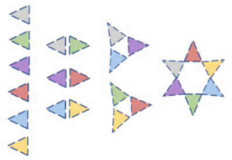

Figure 4 Schematic representation of the charette approach, each colour is a participating discipline with their scope, set of concepts and measures.

Cartographic drawing
This is a method where local stakeholders share their values and ideas. These values and ideas are made tangible in student design solutions drawn on geographic maps. Including red structures students do not want in the design and green structures students do want in their design. After each round of stakeholder consultation, students redraw their map and get longitudinal insights into the design process [19].

Making a forum or wiki
In which they do activities together and jointly write towards the solution of the problem. To make it acceptable, they need to iteratively make their co-writers understand and explain what they found in theory and practice.

Reflection
This is more generic involving the listed questions in the table but can relate to any **questions triggering reflective activities.**

- How do disciplines relate?
- What are the boundary conditions of a discipline?
- What Inputs do they need from each other?
- What information do they need from other people?
- What do you need to give to other people?
- Understand what each one is doing?
- What needs to be adapted?
- What are the values embedded in your group?
- How would you like the design done?

Harris profile
In evaluating their solution, students identify criteria based on business aspects, business criteria, and technological criteria. The students give each of these criteria a score and make a mathematical decision matrix based on their scores to come to a solution/concept [25].

Anticipated and observed outcomes of Integration Methods

Outcomes can best be illustrated with a quote:

"They learn how to give up their assumptions or abandon their preconceptions of the way people work and communicate and reconstruct it together with the others. Because, again, just with the word of what a design means, between an architect and an engineer being much different on that, we can no longer keep our preconceived ideas of what a design is and still produce a useful end product with these other people who have a much different idea."

3.6 Outcomes

Finally, there are, of course, also some obstacles, pitfall mainly related to integration.

Exploring different scientific perspectives is the critical activity to capture different knowledge-bases and have a group come to results. The latter can only be achieved according to some of the interviewees, at the master level. Preconditions for effective integration according to the interviewees is that students minimally need to master the following skills:

- awareness of different problem perspectives which includes an understanding of different scientific paradigms.
- Reflection and integration by means of stimulating discussions.
- Communication skills to overcome communicative obstacles, such as different jargon, opinions, and paradigmatic differences.
- Creativity skills are another key element to deal with the uncertain situation.
- working methods typically used to garner integration are design assignments, integrative project work on challenges, individual research.

Drawbacks and obstacles for integration in interdisciplinary settings are, for example, that students divide their tasks based on their disciplinary knowledge. Each student tends to pay attention to one particular part of the group work and forgets the remainder. The reasons might be that students lack the skills to search for interdisciplinary solutions as there are no books available! They need much support to make this integration happen.

Interpersonal and communication skills may become top-heavy in the process of disciplinary integration. Time spent on communication cannot be spent on design and in-depth work. Consequently, lower content standards, such as a lack of depth and focus in work, may be accepted by the teachers, as the purpose of this type of solution finding is different from disciplinary work.

Finally, the lack of availability of teachers with an interdisciplinary background and funding structures may result in the obstruction of the integration of multiple disciplines.

4. Conclusions and Discussion

In this overview of “pedagogies of integration” used in practice, the view emerges that the list of interdisciplinary competencies mentioned by Boix Mansilla: (1) purpose of integration in interdisciplinary education, (2) disciplinary grounding, (3) integration and (4) critical awareness of what the others bring to the table, are tacit values of interdisciplinary education at investigated institution [12], [11]). The tacit knowledge is in line with the literature, where integration is described as "the leverage of different knowledge and methods from different disciplines to understand a phenomenon or the advancement of knowledge" [11]. Typically, this separates interdisciplinary learning activities from other types of education. We further noticed that the programme/course design/integration exercises are well articulated and even researched. In line with other literature, however, assessing integration seems to be following the traditional assessment lines, meaning there is no suitable method yet to assess integration [17]. Finally, the research provides several tangible exercises to operationalise integration at different levels of course design.

Some limitations may have influenced the final results. The number of lecturers involved was limited and particularly represented the sustainability and design engineering fields. From the social sciences, business students were involved. It is recommended to do another study, which includes data triangulation of the (perceived) student results. confirming the intentions of the lecturers on the programme design, working methods and additional findings. Equally, these results are from the engineering sciences. It would be of interest to find out if different disciplinary domains would provide additional insights into what works and does not work for integration of disciplinary knowledge in interdisciplinary higher education.

Further research will focus on the impact on student learning and societal change.

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PARTICIPATION OF MATHEMATICS AND PHYSICS STUDENTS IN MULTIDISCIPLINARY CHALLENGE-BASED EDUCATION AT THE END OF A BACHELOR PROGRAM

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ABSTRACT

Many universities introduced Challenge-Based Education (CBE) as a way to innovate engineering education. Typically, in CBE students develop and use their knowledge in order to solve real-world problems in society, in multi-disciplinary groups and often in collaboration with external stakeholders. For departments of mathematics and physics innovations such as CBE are often not straightforward. In their strive for depth, they struggle for example with the multi-disciplinary nature of CBE. This study focused on the Bachelor Final Project in an innovation lab (IBFP) at a university of technology in the Netherlands. We have investigated the affordances and constraints for mathematics and physics students to participate in such IBFPs, and how these can be understood in terms of successful innovations in engineering education. Students from all departments can participate in IBFP, but mathematics and physics students have been practically absent. We investigated the reasons for this absence by studying university documents and interviewing stakeholders (N=13). We identified themes emerging from this data, which show that organizational issues played a role, but also factors related to educational innovations and the particular nature of mathematics

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and physics education. The study helps to understand innovation efforts towards CBE, involving mathematics and physics students.

1 INTRODUCTION

1.1 Section 1

Many universities have introduced Challenge-Based Education (CBE) as a strategy to innovate engineering education. Typically, in CBE students develop and use their knowledge in order to solve real-world problems in society, in multi-disciplinary teams and often in cooperation with external stakeholders [1]. It is expected that CBE fosters student motivation and that they will develop skills, important for future engineering work: working with stakeholders, collaborating in multidisciplinary teams, identifying and analysing relevant problems, and designing (prototype) solutions [2].

The introduction of CBE to a university or a department implies a curriculum innovation. However, it is complex and demanding to create successful and lasting innovations in engineering education [3]. Graham [4] identified key characteristics of successful change in undergraduate engineering education, based on interviews and selected case studies. Effective innovations have tended to focus on connecting learning with authentic professional engineering contexts and a student-centred pedagogy, such as problem-based or project-based learning, and arguably CBE, due to its connection with these approaches [5].

Departments of mathematics and physics, typically have a special position in universities of technology, because these two disciplines are of a more fundamental nature than the traditional engineering disciplines, such as mechanical and electrical engineering [6]. Essentially, mathematics is an abstract and pure science, and not just a service subject to help engineers carry out their calculations. Also questions in physics are often indirectly rather than directly connected to problems experienced in society. Hence, for departments of mathematics and physics the introduction of innovations such as CBE is not straightforward.

The study described in this paper focuses on the participation of mathematics and physics students in an innovative CBE experience at a university of technology in the Netherlands. In this university's educational vision, CBE plays an important role. One CBE opportunity created for students is the Bachelor Final Project at an innovation lab at the university (IBFP). In the IBFPs, students work together in multi-disciplinary teams (e.g. industrial design, mechanical engineering, innovation sciences) on a challenge, set by a stakeholder from outside the university. The one-semester projects take place at the end of the students' three year bachelor programmes.

At this technical university it was noted that students from the mathematics and physics bachelor programmes had been practically absent from the IBFPs. The goal of this study was to investigate the reasons for this absence.

We pose the following research questions:

1. What are the affordances and constraints that stakeholders perceive for mathematics and physics students to choose and participate in an IBFP?

2. How can these affordances and constraints be understood from the perspective of success factors regarding innovation in engineering education?

After this introduction, we first outline the theoretical frames used: Challenge-Based Education, and innovation in engineering education. Second, we describe in more detail the context in which the study took place and the research methods we used. Third, we present the results, and fourth, our conclusions.

2 THEORETICAL FRAMES

In this section the theoretical frames used in this paper are explained: Challenge-Based Education (CBE), and successful change in engineering education.

2.1 Challenge-Based Education

In CBE “grand challenges” are offered to students, from which they themselves identify a particular problem they will address. Students typically design and create a prototype solution to the problem in multidisciplinary groups [1]. CBE is considered a student-centered learning (and teaching) approach, where students are actively involved in choosing and developing their own learning trajectory. The challenges are often connected to big issues that need to be addressed to ensure the sustainability of human societies. During their work on the project, participants realize the value of different perspectives, critical thinking and reflection. In this way, CBE experiences can engage students in ways of thinking and learning authentic to the engineering profession, which is said to contribute to deeper learning and meaning making than traditional lecture-based courses [7].

CBE changes the roles of both the teacher and the student. Students need to become more self-regulated learners. Their work is guided by tutors, process and academic coaches and often by external *challenge owners*, who adopt the role of a coach and co-experimenter, instead of a knowledge provider. The challenge owners are people from industry or from within the university who have proposed the grand challenge, and they are stakeholders in the solution. With different parties involved, collaboration in the team of educators and stakeholders becomes important.

CBE in mathematics or physics at university level is scarcely reported in the research literature. Mathematics and physics can be considered fundamental subjects that study particular phenomena in depth. However, in the practice-oriented CBE projects, mathematics (and to a lesser extent physics) are often seen as tools for the engineering sciences. Dahl [6] claims that the knowledge created in mathematics contributes to the society of researchers in other fields, as it facilitates new developments in those fields. The literature contains some examples of multi-disciplinary work in which physics students participated, on open-ended problems towards the end of engineering bachelor programs (so-called Capstone projects [8]). This indicates that there are likely to be opportunities to define challenges relevant to society, which are suitable for mathematics and physics students, if the specific nature of these subjects is taken into account.

However, the introduction of CBE in mathematics and physics is not only a matter of identifying suitable challenges. It also constitutes a curriculum change in the departments, in which several factors play a role.

2.2 Successful change in engineering education

Lattuca and Pollard [9] have identified different influences relative to curricular change: external influences (e.g. quality assurance systems, workforce needs), internal influences (at the institution and department level), and individual influences (e.g. experiences, knowledge, attitude and beliefs; see also [10]). They contend that these influences motivate decisions to engage in curricular change. They have also noted that disciplinary cultures (at the departmental level) often influence faculty commitment to change and decision-making practices.

Actors associated with curricular change are in particular (1) the *stakeholders* – those individuals or groups who have vested interest and/or involvement in or are impacted by curricular change; and (2) the *change agents* – those individuals or groups who are charged with the implementation of the change. These include department chairs, curriculum committees, individual faculty members, and groups of individuals.

The context and actors, it is said, ultimately shape the success of curricular change. Features that support successful curricular change can be termed as success factors, and those that account for unsuccessful curricular change as barriers. In her extensive international study of educational change in engineering education, Graham [4] identified common success factors and barriers, divided into four categories: (1) the context for change (e.g. upcoming institutional/sector-wide change); (2) leadership and faculty engagement (e.g. explicit support from university management); (3) educational design and implementation (e.g. a “unique” educational approach); (4) sustaining change (e.g. improvement in student intake quality and motivation). Graham also identified barriers to successful change, such as: insufficient resources to sustain the reforms; over-reliance on a small number of individuals; strong student or faculty dissatisfaction. We have used these factors as an analytic frame for the analysis of our data (see below).

3 CONTEXT

The university where this study took place has a educational vision in which CBE plays an important role. Several university departments have been creating opportunities for student learning based on the principles of CBE. A university-wide task force has been established to oversee the CBE-related education and research efforts, to identify promising educational practices for a curriculum based on CBE, and to facilitate integrating CBE in the departmental curricula.

One of the CBE initiatives has been the opportunity for students to conduct their obligatory Bachelor Final Project in an innovation lab at the university (the IBFP). In the IBFP groups of 4-5 bachelor students work together in multi-disciplinary teams (e.g. industrial design, mechanical engineering, innovation sciences and physics) on a challenge, set by an external stakeholder. This setup provides students with opportunities to investigate an authentic situation, identify and select a particular problem to work on, and develop a (prototype) solution.The educational directors of the university departments decide which challenges are suitable for their students. The students have to fulfill the Bachelor Final Project requirements set by their respective disciplines and departments. Communication with the students about IBFP takes place both by the departments and by the innovation lab. Each student group has a coach and a tutor from the innovation lab, as well as the outside stakeholder, who support the collaboration process and guide the projects. Moreover, each student has an academic coach from his/her department, who supports the student regarding disciplinary content. After it had become clear that (practically) no students from the physics and mathematics departments had participated in IBFP, a study was commenced to investigate why this was the case and how IBFPs could be made more attractive for these students. In this paper we report on the first part of the project: to understand the absence of physics and mathematics students in IBFP.

4 METHODOLOGY

4.1 Participants and data collection strategies

Using a qualitative approach, we conducted an exploratory study, involving semi-structured interviews and content analysis of university documents to answer the research questions. We individually interviewed 13 respondents involved with IBFP: the CBE task force leader, coordinators and educational directors from the mathematics and physics departments, an academic supervisor from the department of mechanical engineering, and managers, coordinators and a researcher from the innovation lab. We also interviewed a physics student doing the IBFP and his academic supervisor.

The topics addressed in the interviews concerned the following: the content of the challenges and their suitability and attractiveness for physics and mathematics students; supervision and coaching; the context, views and policies around CBE, Bachelor Final Projects and IBFP; organizational issues (e.g. communication, alignment).

In terms of university documents, we studied the relevant study guides and assessment documents, and university websites containing communication to students, including challenge descriptions.

4.2 Analysis

Following a grounded theory approach [11], the interviews were transcribed and we, (the first and second author) independently coded the complete set of interviews. We used the interview topics as sensitizing concepts, and adding codes based on our interpretation of the data. We then compared our results and discussed all discrepancies until an agreement was found. This resulted in a total of 248 interview quotes connected to 14 codes. For each code, the quotes were identified as affordances or constraints to IBFP participation. Subsequently we compared the codes and their quotations and found we could group them into three themes, related to: (a) the content of the challenges and the CBE approach, (b) the students and university faculty, and (c) the departments and the university as a whole. We then wrote summary descriptions of the affordances and constraints for each theme, which we verified against the interview data.

In the second part of the analysis we used the summary descriptions to connect each of the affordances and constraints with the success factors and barriers from Graham's framework [4] in order to answer the second research question.

5 RESULTS

5.1 Affordances and constraints

We present a summary of the affordances and constraints we identified for each of the three themes (Table 1). Space does not allow for a full elaboration of the results.

Table 1. Affordances and constraints for the participation of mathematics and physics students in IBFP

A/C[1]	Description
Theme 1: the content of the challenges and the CBE approach	
A1	Respondents had experienced that the challenges allowed students from different departments to show their disciplinary knowledge and skills.
A2	In some challenges, respondents from the physics department saw "sufficient physics" for successful participation of physics students.
A3	Respondents from the physics and mathematics departments saw potential benefits for students in the CBE approach (e.g. "to see mathematics at work", "to work in multidisciplinary groups").
C1	Respondents from the mathematics department found it difficult to see how the challenges could lead to a mathematics project of sufficient depth.
C2	Given the broad challenge descriptions, respondents from the physics and mathematics departments expected that students (and coaches) might not be able to recognize how they could contribute using disciplinary knowledge.
Theme 2: the students and university faculty	
A4	Respondents expected that IBFP would appeal to those mathematics and physics students interested in engineering, design, and collaborative work.
A5	Respondents expected that coaching IBFP students would appeal to part of the mathematics and physics faculty.
C3	Respondents expected that lack of earlier (positive) collaborative group work experiences could discourage mathematics and physics students to apply to IBFP.

C4	Respondents expected some faculty to feel uncomfortable coaching IBFP, for reasons of workload, perceived lack of required expertise, and difficulties to apply the departmental assessment criteria.
Theme 3: the departments and the university as a whole	
A6	Mathematics and physics educational directors indicated that they supported the participation of their students in IBFP, provided certain conditions were fulfilled.
A7	The innovation lab emphasized communication with the departments in order to (a) define suitable challenges, and (b) attract students.
A8	At senior management level, the university, supported the introduction of CBE, including the multidisciplinary IBFP.
C5	The organization and communication within the departments and between the departments and their students had not been aligned with IBFP requirements.
C6	There had been few collaboration experiences between the mathematics and physics departments and the innovation lab. As a results, the innovation lab hardly had any “ambassadors” in the departments to foster CBE opportunities such as IBFP.

Notes: [1]: A: Affordance; C: Constraint

5.2 Factors affecting curriculum change

We compared the affordances and constraints from Table 1 to the framework of factors associated with successful (and unsuccessful) curriculum change [4]. The results show that some success factors could clearly be identified in the IBFP developments for physics and mathematics. However, the constraints implied that several success factors were present only to a limited extent, or not at all (Table 2).

Table 2. Affordances and constraints for the participation of mathematics and physics students in IBFP

Framework description	A/C[1]	Interview data
Factors positively related to successful curriculum change		
Faculty agree change is necessary, due to issues “in the market”.	A3	Students could develop relevant engineering skills in IBFP, not generally offered by the departments.
Support from senior management; balance of top-down and bottom-up pressures.	A3, A6, A8	IBFP was in line with university policies regarding CBE. The attitudes of the task force leader, the departments (with reservations) and the innovation lab were positive.

The changes are a core and integrated element of a coherent curriculum structure.	A2, C1, C3, C4, C5, C6	IBFP was not yet in line with the core mathematics and physics curricula. Students had had relatively few CBE experiences. Departmental procedures and communication were not in line with IBFP participation.
High proportion of faculty involved in the (design of) the curriculum change.	C2, C6	Mathematics and physics faculty not had not been involved in the process of formulating IBFP challenges. Absence of “ambassadors”.
There is no pressure on reluctant faculty to participate in the change.	A5	Directors and coordinators showed awareness that interest to coach IBFP would be with part of the faculty only.
The change leads to an improvement in student intake and motivation.	A1, C2, A4, A7	A number of physics and mathematics students were expected to benefit from IBFP. The innovation lab’s activities aimed at increasing student intake from different departments.
Factor negatively related to successful curriculum change		
Faculty “revolt” against the change, e.g. because they fear a “dumbing down” of the curriculum.	A1, C1,	The physics department did *not* expect that IBFP would lead to a lower level of student work (no “dumbing down“). For mathematics there was a concern that their students would be used for “doing calculations”.

Notes: [1]: A: Affordance; C: Constraint

6 SUMMARY

Based on our interviews and document analysis, we found affordances and constraints that stakeholders perceived for mathematics and physics students to choose and participate in IBFP. We argue that important conditions for participation of these students have been fulfilled at the university: there is top-down and bottom-up support and it is likely that the IBFP will appeal to part of the students and faculty.

We also found important short term and long term constraints. There is a need for challenges with sufficient mathematical (and to a lesser extent physical) depth, or even: a need for design principles regarding such challenges. To this end, involving mathematicians and physicists in the process of defining challenges may prove helpful. There are practical communication and organizational issues that would need to be solved. The limited opportunities physics and mathematics students have had in the bachelor programme to engage in open-ended collaborative projects might be a constraint to their participation in IBFP.

The introduction of CBE and IBFP has signified a still ongoing change in the curriculum of the physics and mathematics departments. In terms of Graham’s framework [4], the support IBFP has received at various levels in the university is promising for its success. However, to ensure its success for mathematics and physics students, challenges need to be designed in line with the disciplinary demands of these subjects. Moreover, in the long term, the integration of more CBE into the departmental curricula might foster IBFP as a feasible option for interested students, similar to the departmental Bachelor final Projects. Finally, collaboration between departments in the light of a curriculum change can be demanding for those involved. It is expected that an increased sense of ownership for the development towards CBE will develop, when more mathematics and physics faculty and students become involved in the innovation lab, the creation of challenges, and IBFP [10].

7 ACKNOWLEDGMENTS

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IDENTIFYING INDUSTRY NEEDS FOR INNOVATION SKILLS IN ENGINEERING EDUCATION: A THEMATIC ANALYSIS OF CASES FROM DANISH INDUSTRY

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ABSTRACT

Providing students with knowledge, skills, and competencies in innovation has become a central focus in engineering education. However, there is limited knowledge on which innovation skills need to be supported and how well engineering education meets current knowledge gaps in the industry. As a first step towards addressing this research question, our paper presents findings from examining 49 innovation cases provided by Danish industries for the Applied Innovation in Engineering (AIE) course at Aarhus University. A thematic analysis was conducted to identify dominant trends from the case descriptions and to assess areas of interest and demands from different industry sectors. Results identify areas of interest from the cases that correspond to desired innovation skills in three primary aspects (i) technology/product, (ii) digitalization, and (ii) sustainability, and five secondary aspects: (a) future trends, (b) customer behaviour, (c) business, (d) regulations, and (e) training. This study provides valuable insights on needs from the Danish industry and the areas of interest to which innovation skills are required, therefore supporting EE in integrating industry-oriented competencies for engineering students.

1 INTRODUCTION

Today's engineers are required to cope with the demands of a multifaceted professional world marked by rapid changes, associate information and computer technologies to traditional practices, consider ethical- and sustainability-related implications of their decisions, and address complex multidisciplinary issues. Moueddene et al. (2019) emphasize the need for improving university education among the priorities on policies for the future of the labor market [1]. Thus, higher education institutes (HEIs) have the responsibility of providing students with the necessary means to develop such knowledge and skills before they enter the job market. In order to do so, HEIs need to go beyond standard engineering curricula by bringing industry actors closer to their education setup and further understanding market needs [2].

Understanding the knowledge, skills, and competencies required from future engineers has become an important focus in engineering education (EE) research [3]. The diversification in required competencies has led to an increase in the number (and type) of courses and educational activities offered in engineering curricula. New interest areas such as sustainability, ethics, digitalization, and innovation have become integral to several engineering programs. Such courses can provide students with innovation skills that help engineering students contextualize their technical skills, and solve multi-faceted challenges and needs faced by industry. In this paper, innovation skills are considered as technical or professional skills that are complementary to primary technical skills. For example, assessing relevant sustainability regulations and recognizing the potential for digitalization, are innovation skills that complement primary technical skills in engineering education. However, there is limited knowledge on what innovation skills should be emphasized to meet current industry needs.

This study evaluates **the areas of interest demanded by local industry** and **the need for innovation skills to be reflected in EE.** To identify the need for innovation skills, we analyze the contents of case descriptions proposed by a range of Danish companies to students in an MSc. course at Aarhus University. The industry cases expose the needs of the involved companies for future engineering practices. Furthermore, the cases reveal local industry needs and trends to be considered in EE for better preparing students for upcoming industry demands. Based on our results, we provide a broad set of recommendations to help engineering educators better align curricula with innovation skills demanded by industry.

2 METHODOLOGY

The methodological approach of this study aims to analyze industry-provided cases to evaluate demands from Danish industry and further propose insights in relation to industry trends and required engineers' innovation skills. An open call for cases was announced to both large firms and small & medium enterprises (SMEs) in Denmark for the Fall 2020 semester of the Applied Innovation in Engineering (AIE) course at Aarhus University. A total of 23 companies from different sectors answered this call.

The sample of 23 companies included five sectors: (i) computer programming & information technology, (ii) engineering & construction, (iii) manufacturing, (iv) public sector & foundations, and (v) other (research, wholesale, geology, and food). Furthermore, the selection also accounts for a broad spectrum of company sizes as illustrated in Table 1.

Table 1. Sample of companies involved in this study

Company Size	Nr. of Companies	Nr. of cases	Generic Category
Micro (<10 employees)	3	7	SMEs =12
Small (<50 employees)	6	10	
Medium-sized (<250 employees)	3	12	
Large Enterprises (<5.000 employees)	9	17	Large = 11
Corporations (>5.000 employees)	2	3	
Total	**23**	**49**	

The companies involved provided a total of 49 cases. The cases had a primary technical focus since it was oriented to a diverse group of engineering students. Each case was composed of two blocks of text: (i) a case description, and (i) a challenge, which we analysed together. Figure 1 illustrates an industry-case analysed in this paper.

Case Description	The Challenge
Unnecessary consumption of electricity, heating, water and gas in buildings leads to high recurring costs and unnecessary CO2 emissions. Municipalities own and rent several thousand square meters of buildings and have an energy management team who are focused on analyzing and maintaining the energy consumption. Their analysis is time-consuming and does not always result in optimal reductions, since local technical staff are required to manually adjust equipment/infrastructure and the users of the building must change their behavior. A method or equipment to analyze or automate building infrastructure and change the consumption behavior of the users of the building if necessary.	We want to provide a way for municipalities to effectively reduce their spend on energy and CO2. The tool also should help the energy management team to communicate actionable data to the local technical staff and convey the importance of changing their behaviour to the users.

Fig. 1. Example of an industry case (description and challenge)

A thematic analysis was carried out based on the description and challenge specified in each case. The analysis followed an iterative coding process between three authors (2 senior & 1 junior researchers). The qualitative data from each case were systematically analysed via inductive coding and iterative coding cycles, until a final set of codes had been developed [4]. Finally, these codes were further refined into dominant themes to identify areas of interest for the innovation skills. The areas of interest convey current industry demands identified in the descriptions from the assessed cases. In our analysis, innovation skills are defined as the understanding and use of engineering knowledge to create new ways of thinking in order to develop solutions to new industry needs, and to create new products/services [5]. The qualitative data was further evaluated using NodeXL, an open-source plug-in for MS Excel 2010[1]. We used network analysis for illustrating the relations between the themes, companies, and areas of interest [6].

3 RESULTS AND DISCUSSION

The analysis of the 49 industry cases reveal three main areas of interest: (i) technology/product, (ii) digitalization, and (ii) sustainability, along with five secondary aspects: (a) future trends, (b) customer behaviour, (c) business, (d) regulations, and (e) training. Figure 2 presents the distribution of these areas of interest against the individual cases (C01-C49).

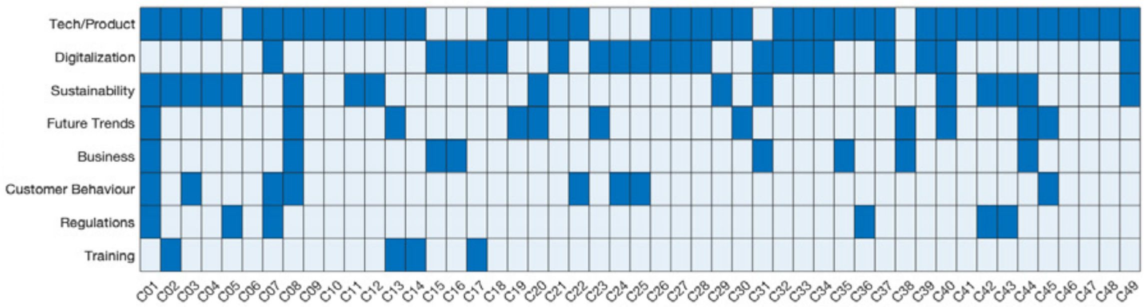
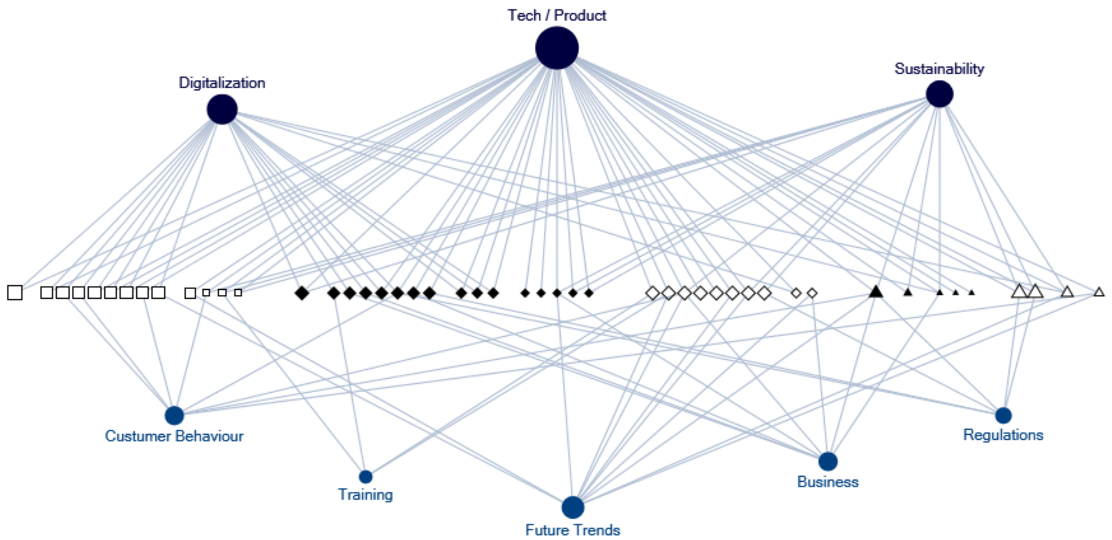


Fig. 2. Distribution of expressed areas of interest per case



Company Sector (Vertex Shape)

☐ Computer programming & IT
◆ Manufacturing
◇ Engineering & Construction
▲ Other
△ Public Sector & Foundations

Company Size (Vertex Size)

corporation >5.000 employees
large <5.000 employees
medium-sized <250 employees
small <50 employees
micro <10 employees

Nr. of cases (n=49)

corporation = 3 cases
large = 17 cases
medium = 12 cases
small = 10 cases
micro = 7 cases

[1] https://nodexl.com/

Fig. 3. Network analysis of company cases by areas of interest and industry clusters

Figure 3 illustrates results from the network analysis. The three main areas of interest are shown at the top and the secondary aspects are at the bottom. The cases are arranged horizontally in clusters determined by the industry sector (vertex shape) of the proponent company, and ordered by company size (vertex size) ranging from the largest to the smallest (left-to-right). The following section expands on the areas of interest identified from the above analyses.

[a] 3.1 Areas of Interest for Innovation Skills

Tech / Product refers to the explicit interest of new technology or product development assigned to the proposed challenge. This is the primary area of interest for the companies enrolled in this exercise. This area of interest is explicit in 82% of the cases (n=40) and is well distributed along companies of all sectors and sizes. This results from an increasing demand for creating new products and services that differentiate a company from their competitors.

Digitalization refers to the integration of digital solutions to existing practices or the need for developing digital tools and artifacts. Cases that requested use/development of sensors, data collection, LiDAR, VR/AR, simulations, digital twins, mobile applications, digital platforms, and data processing technologies are included in this category. This is also a primary area of interest for the companies and is present in 41% (n=20) of the cases. While digitalization was seen as an important aspect by all sectors, it was more predominant in large and medium-sized companies. Additionally, this aspect was commonly observed in relation to optimizing business strategy or product development.

Sustainability refers to the explicit aim for solutions that can help minimize environmental impact such as CO_2 emission reduction, use of resources, issues related to air and water pollution, and so on. This is the third primary area of interest accounting for 33% (n=16) cases from all companies. However, within our sample this aspect is mainly present in cases from the public sector and in cases from micro or small companies.

Expressed concerns of adequacy or need for preparedness in relation to **Future Trends** are observed in 22% (n=11) of the cases, primarily in large companies in the engineering & construction sector, and are nearly absent in the manufacturing sector. These concerns are mainly related to the potential long-term impact of a developed solution and ensuring the positioning of these companies in the market.

Business and **Customer Behaviour** areas are each observed in 16% (n=8) of the cases. The first interest area mainly indicates the need for business strategies in relation to market penetration, time to market, or market positioning, and is more common in cases from large companies in the manufacturing and engineering sectors. The second mainly relates to nudging and understanding customer behaviour which is notably represented in the computer programming & information technology sectors as well as large companies from other sectors.

Concerns related to upcoming **Regulations** and compliance is observed in 12% (n=6) of the cases exclusively provided by large companies. The most common factors influencing the case challenges are in product category certifications, General Data Protection Regulation (GDPR), safety and privacy, and legal environmental compliance.

Finally, aspects related to **Training** were noted in 8% (n=4) of the challenges and specifically address the need for optimizing training and employee performance, and the need for behavioural change within industries. Case descriptions tap into the need for increasing knowledge transfer in multidisciplinary firms and across international operations. The cases highlight aspects related to educating or training citizens for behavioural change, and new methods for training employees in relation to both machinery and product simulations. In addition, companies are seeking digital solutions to support their workers with machinery maintenance.

[b] 3.2 Lessons learned and recommendations to engineering education

The above results reveal the areas of interest from Danish industry and point to avenues for improving the teaching of innovation skills in EE. Emphasizing such innovation skills throughout the curriculum can help students better apply their engineering knowledge towards solving real-world challenges [5]. Therefore, a broad set of recommendations are suggested in Table 2 for integrating results from Section 3.1 as innovation skills into EE.

Table 2. Innovations Skills and Recommendations to EE

Areas of Interest from Industry	Innovations Skills and Recommendations to EE
Tech / Product	Future engineers must be able to assess and develop new technologies and products. Therefore, EE curricula must reflect this need by providing students' with a dedicated space for practical learning [7]. This recommendation can be achieved by incorporating active learning and case-oriented pedagogical approaches into the best practices of EE, and by increasing collaboration between HEIs and innovation-oriented technology and product companies.
Digitalization	Future engineering practices will require a broad understanding of digital technologies in relation to both the development and implementation. EE should consider integrating digitalization aspects across all engineering disciplines, which can be implemented by using a variety of educational components such as new study modules in the curriculum, hands-on laboratory work, and extracurricular activities [2].
Sustainability	The development of an instrumental understanding of sustainability and the capability for implementation of its concepts into engineering practices is acknowledged due to the increasing demands from the job market. However, Lönngren (2017) observed that there is still a lack of integration of overall sustainability knowledge in foundational engineering courses [8]. Ramanujan et al. (2019) explores guided discovery learning as an approach to teach environmental sustainability in undergraduate engineering courses, and highlights the benefits of promoting students' understanding of complex relationships between domain-specific design parameters and environmental sustainability [9]. Sustainability aspects should be presented very early in the

	engineering curriculum for supporting students with learning opportunities and internalization time that along with personal commitment facilitate a long-term sustainable mindset that guides impact-driving engineering practices [10].
Future Trends	Engineers should be able to use tools that help to foresee market trends that can promote or hinder the development or implementation of technologies, products and services. Prior research shows that methods such as a trend analysis can be easily integrated as part of innovation courses in EE, and that it requires a rigorous step-wise process where the choice of tools and techniques is given in relation to the characteristics of a case [11].
Business	Future engineers are expected to hold a broader range of capabilities that allows them to understand concurrent aspects of technology and product development such as business strategies and market assessment. These areas of knowledge are traditionally disconnected from the technical aspects of EE and require a different approach to problem-solving. According to Lönngren (2017), engineering students are less likely to be able to adequately address wicked problems - such as those occurring in socially complex contexts [12], without operationalized innovation skills provided by extensive training [8]. This aspect of cognition development requires greater attention from HEIs to develop professionals that are able to also tackle non-engineering problems.
Customer Behaviour	Future engineers must be able to relate technical solutions to customer behavior. In EE such skills are discussed under human centered design (HCD). HCD is viewed as an essential engineering skill but prior research shows that students have significant misconceptions about the process and the terminology of HCD [13]. EE should increase the emphasis on HCD and its relationship to innovation and help future engineers become more competent at leveraging technology to address unmet customer needs.
Regulations	De Graaff and Ravesteijn (2010) outline the knowledge and skills in the field of “science, technology and society” as a broader category of competences with high relevance to engineering education [14]. In such a skill set, working with regulations and rules are to be considered as part of the job as an engineer. It provides the ability to make decisions and balance the pros and cons from a standards and normative perspective.
Training	Operator training is a significant concern for industry as insufficient training can result in damages and injury to both machinery and staff, impacting operational efficiency and costs [15]. Traditionally, engineering students had a limited perspective on the implications of the technologies they developed on operator training. A significant barrier for this was the time and expenses entailed for conducting such studies. The recent rise of digital technologies such as virtual reality (VR) have the potential to reduce these barriers [16] and they should be further used in the context of EE.

4 DISCUSSIONS & CONCLUSIONS

Technological developments lead to new industry demands that creates a need for EE to adapt its pedagogical approaches and redefine engineering curricula [1,2]. Today’s newly trained engineers are required to develop a number of innovation skills that support their technical practices, become socially and culturally aware, as well as entrepreneurial [7]. Therefore, there is a need for future interventions in EE to consolidate these capabilities demanded from industry.

This paper analysed 49 industry-provided innovation cases expressing the challenges and concerns of 23 Danish companies across five industry sectors. A qualitative analysis was conducted to identify dominant trends from the case descriptions. As a first step, our analysis identified the areas of interest for which innovation skills are required in the Danish industry based on the exposed needs and problems from the representative companies in the study. The analysis also provided insights into the synergy between the industry sectors and EE. We plan to conduct further studies that assess the degree to which current EE approaches enable students to acquire the required innovation skills, and identify innovation skills developed in the current setting that are not recognized by industry as yet.

In the innovation process taught in the current AIE course, we encourage engineering students to work with strategic and technological foresight across their cases, and to systematically look for opportunities into the future. In this way, we aim to equip students with the necessary skills for the job market by advancing their understanding of innovation, new product development, and business processes as a holistic approach related to the companies' contexts. Results from this study will help us focus the pedagogical practices and curriculum in the AIE course with respect to the needs expressed by Danish industries.

The results from our study are limited to the context of one university and the cases provided by selected Danish companies that volunteered for this study. Companies which opted out, or that were out of the scope of our study, could potentially provide different insights. Therefore, further work is required to generalize the findings from this study.

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STUDENTS' LEARNING STRATEGIES, MOTIVATION AND PROJECT-MANAGEMENT SKILLS DURING INTERDISCIPLINARY PROJECTS IN COVID TIMES

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ABSTRACT

In this study, we investigated an interdisciplinary project-based learning program. Students were confronted with interdisciplinary challenges in the form of complex and authentic problems, like building a racing car or making a mobile laboratory for genetic analysis. These hands-on educational formats had a clear aim to develop skills required in students' future careers, as well as bridge the gap between theory and practice. In this paper, we show preliminary results of an on-going mixed-method study where the students' learning strategies, motivation, and project-management skills were measured through a survey using a pre and post-test approach. Quantitative results were contrasted with qualitative input from interviews

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with projects' coaches and students' focus groups. The results provided evidence of gains regarding professional skills (e.g. risk assessment in projects), but also shed light on difficulties and needs to implement meaningful experiential learning content within engineering education (e.g. collaboration). On top of this, the research took place during COVID-19 lockdown, hence both students' and coaches' reflections accounted for ways in which this situation did impact the projects.

1 INTRODUCTION

The challenges that students will be confronted with once they graduate are becoming increasingly complex. Besides requiring solid background in a core discipline, they demand an ability to work at the intersection among many fields. At Ecole Polytechnique Fédérale de Lausanne (EPFL), there is a program of interdisciplinary projects called "MAKE" that aims to close this gap in its students' education. The goal of this Project-Based Learning (PBL) initiative we studied was to give students an opportunity to confront themselves with the challenges posed by interdisciplinarity during their training, giving them a head start in developing the necessary skills they will need in their professional future. By participating in one of these projects, students were expected to acquire solid team-working and project management skills and get a first hands-on experience in a real-world project at the same time. Students engaged in one interdisciplinary project either enrolling formally (i.e., earning some credits to their Bachelor's or Master's degree), or engaging on a voluntary, *ad-honorem* basis. Each project involved one or more teams where interdisciplinarity could be seen within one team (it included students from different faculties) or across teams (each team typically included students from one area of expertise). Students and coaches all worked together towards the creation of products through prototyping cycles (designing, prototyping and testing) that required the input of all the team members.

The aim of this research was to inform curriculum development about student's engagement and learning not only in terms of disciplinary learning but also transversal competences. To this end, this study investigated the evolution of student motivation, learning strategies, and transversal competences like project-management skills in the course of PBL. Both student and teacher perspectives were considered. As a consequence, feedback and results were provided to the teachers and managing staff at the end of the experience.

To achieve the research objectives, the study was guided by the following questions:

- Are there any significant changes from pre to post-test in terms of student motivation, student learning strategies (i.e., critical thinking, peer learning, metacognitive self-regulation, effort regulation), or project-management skills (i.e., project planning, risk assessment, ethical sensitivity, team communication, interdisciplinary competence)?
- Are there any contextual factors that are associated with such changes according to students and coaches (e.g., instructional design of projects,

learning activities, coaches' and teachers' feedback, COVID-related restrictions, use of technology)?

2. Literature

Experiential learning is the base of project-based educational models and their potential advantage is projected through narrowing the gap between academia and the "real world" (Condliffe et al., 2017). PBL has reported positive results in mathematics, natural sciences and technology, with a medium positive effect size on average (Chen & Yang, 2019). The 2018 MIT Engineering Education Report suggested that "a move towards socially-relevant and outward thinking engineering curricula" is a strongly anticipated trend, which quite directly connects to rethinking higher education and its pedagogical approaches (Graham, 2018, p. iii).

Interdisciplinary learning is seen as another potential advantage in the overall higher education curriculum. Interdisciplinarity offers the so-called boundary-crossing skills which enhance "the ability to change perspectives, to synthesize knowledge of different disciplines, and to cope with complexity" (Spelt et al., 2009, p. 366). This educational approach is in contrast with traditional academic pedagogy which often focuses on subject and domain-specific knowledge. Spelt et al. (2009) pointed out that, unlike multidisciplinarity, interdisciplinary education is integrative, hence it creates the capacity to synthesize and integrate different knowledge and modes of thinking from a variety of disciplines.

There is a great variety of aspects and approaches when dealing with PBL, and this is oftentimes difficult to synthesize. Thomas (2000) defined PBL according to these five criteria:

1. Centrality: PBL projects are central, not peripheral to the curriculum.
2. Driving questions: PBL projects are focused on questions or problems that drive students to encounter (and struggle with) the central concepts and principles of a discipline.
3. Constructive investigations: projects involve students in a constructive investigation.
4. Autonomy: projects are student-driven to a significant degree.
5. Realism: projects are realistic, not school-like.

However, transferring from traditional learning methods into PBL methods is quite a challenge, both for institutions, teachers and students (Chen, Kolmos & Du, 2021). Despite the high expectations created over interdisciplinary PBL, at this stage we've had few rigorous studies on its impact on student learning (Lafuente, 2019) which showed only a small positive effect size on student's academic achievement (i.e., content-based learning) on average. This points to the difficulty of achieving highly effective environments where teachers from different disciplines get to coordinate their designs, teach, and assess student's learning, which requires a great deal of effort and time. Although the scientific community holds high expectations on PBL's impact on student engagement and motivation, meta-analyses have shown a very weak positive effect size (Lafuente, 2019). So far, we have seen that PBL is very likely to produce a very positive and appreciative opinion in students (i.e., they often prefer PBL over traditional lecturing); however, studies produced thus far showed that this does not translate into a significant increase of their intrinsic motivation towards learning. In the same vein, we lack rigorous studies to document the impact of project-based scenarios on student's transversal competences (Condliffe et al., 2017; Lafuente, 2019) like collaborative learning skills, critical thinking, metacognitive self-regulation, or project-management skills.

3. Methodology

In this study we used a mixed-methods approach, gathering data both from a quantitative and qualitative approach. The sample included all five PBL projects starting in the autumn semester 2020/2021 in which 85 students (74 males and 11 females) and five coaches were involved:

- *Genorobotics*: students develop a miniaturized tool to automatically extract and sequence DNA samples from expeditions with the objective of identifying and protecting biodiversity.
- *Procam*: students build a low-cost camera that combines infrared and visible light sensors to track individuals with a fever while preserving their privacy on all captured footage.
- *Lab in a tube*: students design and experimentally validate flexible microsensors via manufacturing, electronics and modelling to finally have a smart catheter equipped with temperature and liquid flow sensing.
- *Racing Team*: distributed in different teams (e.g. chassis, aerodynamics, electronics, business), students design and build a single-seater and electric car.
- *Student Kreativity and Innovation Laboratory*: without any predefined topic or assignment, students work together in small and interdisciplinary groups on their own ideas, with access to a wide range of tools, materials, software, etc. and assisted by specialized coaches.

On the quantitative side, we developed a pre-post-test design to measure student motivation, learning strategies and project-management skills. The pre-test was launched at the start of their project (September/October 2020), and the post-test at the end of it (January/February 2021). A total of 36 answers from students to both the pre and post-test (33 male and three female students) were collected and analysed running a paired t-test of students' scores and calculating effect sizes through Cohen's d estimator.

Two main questionnaires were used for this purpose:

1. Motivation Strategies for Learning Questionnaire (MSLQ) (Pintrich, Smith, Garcia & McKeachie, 1993, 1991). We used a 5 point-Likert scale and an abridged and adapted form of this questionnaire selecting four or five items per each subscale, namely:
    a. Intrinsic goal orientation (i.e., intrinsic motivation)
    b. Extrinsic goal orientation (i.e., extrinsic motivation)
    c. Critical thinking

   d. Effort regulation
   e. Metacognition for self-regulation of learning
   f. Peer learning
2. Interdisciplinary Project Management Questionnaire (IPMQ) (Tormey and Laperrouza, forthcoming). We used a 5 point-Likert scale and the following subscales were included in this questionnaire:
   g. Team communication
   h. Ethical sensitivity
   i. Interdisciplinary competence
   j. Project planning
   k. Risk assessment

Items were answered on a Likert scale: 0: strongly disagree, 1: disagree, 2: neither agree nor disagree, 3: agree, 4: strongly agree.

Furthermore, one question to gauge student's satisfaction with the project was included in the study. Also, the survey included an open-ended question where students had to mention their main challenges in the project.

The qualitative part of the research gathered data from coaches and from students. With coaches we used a semi-structured interview to explore their experiences with curriculum design, organisation of resources, implementation difficulties and interventions, and learning outcomes for students. A total of eight coaches were interviewed, representing all projects (three coaches were involved in more than one project simultaneously). As for the students, we had individual and group interviews (with six students) exploring the themes emerging from the pre-test survey at a deeper level. Specifically, the interviews had four main blocks of questions, including:

- Why students joined the project: the motivation behind student participation.
- Experience of PBL: the specific learning strategies, time-management, collaboration, and difficulties.
- Impact on future choices: the learning outcomes, benefits and dimensions of project management.
- What works: the elements that are important for students engaged in PBL.

4. Main findings

We first present an overview of the quantitative data (pre and post-test), followed by the survey outcomes and qualitative results which we structured in three sections: (1) motivation, (2) learning strategies, and (3) interdisciplinary project-management skills.

Differences between the pre and post-test are explored in Table 1. Qualitative data were analysed using a targeted thematic approach in order to distil deeper understanding of some trends in the survey charts.

Table 1. Pre and post-test scores of all dependent variables (mean and standard deviation) , t statistic and p-value from a paired t-test (two-tailed), and effect sizes calculated through Cohen's d estimator. Values in bold are statistically significant at CI=95%.

	Mean pre-test	SD pre-test	Mean post-test	SD post-test	T stat.	P value	Effect size

Intrinsic mot.	3.35	0.45	3.23	0.44	-1.95	0.06	-0.32
Extrinsic mot.	2.48	0.60	2.18	0.80	-3.16	**0.00**	**-0.53**
Critical thinking	3.07	0.39	3.12	0.45	0.91	0.37	0.15
Effort regulation	3.46	0.41	3.17	0.48	-3.03	**0.00**	**-0.50**
Metacognition	3.32	0.34	3.23	0.40	-1.12	0.27	-0.19
Peer learning	3.49	0.49	3.27	0.50	-2.87	**0.01**	**-0.48**
Satisfaction	3.75	0.44	3.47	0.61	-2.94	**0.01**	**-0.49**
Team communic.	3.05	0.48	2.97	0.50	-1.07	0.29	-0.18
Ethical sensitivity	2.51	0.83	2.59	0.83	0.77	0.45	0.13
Interdisciplinary comp.	2.97	0.52	3.04	0.43	1.06	0.30	0.18
Project planning	3.04	0.63	3.06	0.62	0.31	0.76	0.05
Risk assessment	2.63	0.63	2.84	0.53	2.61	**0.01**	**0.44**

4.1 Motivation

Intrinsic motivation, which reflects the degree to which students perceive themselves to be participating in the project for reasons such as challenge, curiosity, mastery, decreased from pre to post-test, t(35)=-1.95, p=.06, d=-.32 (see Figure 1). Extrinsic motivation, which reflects the degree to which students perceive themselves to be participating in the project for reasons such as grades, performance, evaluation by others, competition, or job-related goals, also decreased with a moderate effect size, t(35)=-3.16, p=.003, d=-.53. In both the pre-test and the post-test, intrinsic motivation scores were significantly higher than extrinsic motivation scores. The responses on the question on student satisfaction with the project also evolved negatively, t(35)=-.2.94, p=.01, d=-.49.

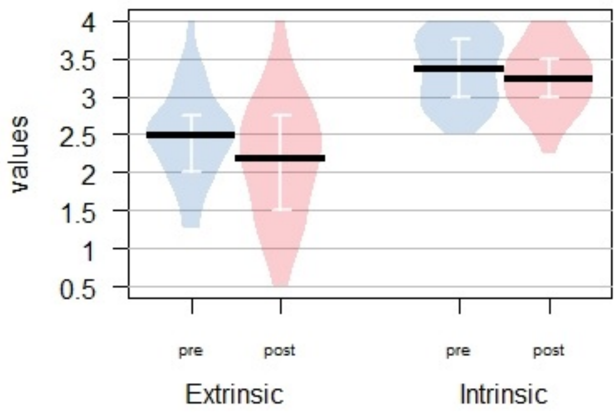

Fig 2. Pre and post-test scores of intrinsic and extrinsic motivational orientations.

Student qualitative input confirmed high levels of motivation, and they were willing to engage for long hours in order to work on their projects.

Coaches reported in the interviews that students were aware about the potential benefits of their engagement in the project, especially on the level of preparedness for future jobs as well as a more complete CV.

> *"Too much work, but they are happy because the work is exciting" (C1)*

Motivation was potentially connected to the fact that students gained practical skills which complemented the theoretical knowledge the school provides.

> *"One good thing is you can try out what you want" (S03)*

> *"This kind of project allows us to get practice. The school is very theoretical and we don't get much practice in our courses (…) this kind of projects really helps us to put into motion the theory we get in the courses" (S05)*

> *"The benefit is that you should work on a topic that is so wide that no one is an expert and we need to know where you are relevant on this topic and also know when you need to seek help. And this is really something that is not learnt [through classes]" (S07)*

4.2 Learning strategies

Two of four learning strategies decreased significantly (see Figure 2). First, peer learning, which means to what extent students see themselves as engaged in collaborative endeavours in the project, $t(35)= -2.87$, $p= .01$, $d=-.48$. There was also a decrease in effort regulation, which reflects the student's perceived ability to control their effort and attention in the face of distractions, difficulties and uninteresting tasks, $t(35)= -3.03$, $p=.004$, $d=-.5$. Critical thinking and metacognition did not change significantly between pre and post-test.

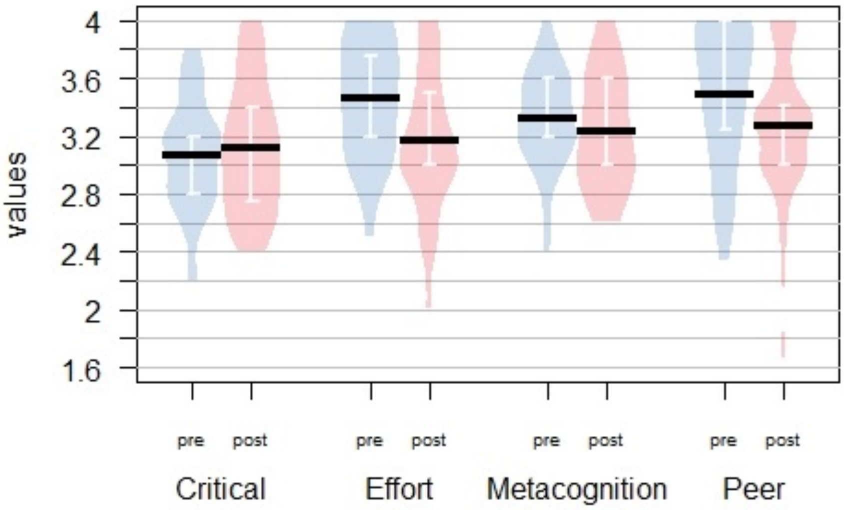

Fig 2. Pre and post-test scores of the learning strategies critical thinking, effort regulation, metacognition for self-regulation of learning, and peer learning.

From the open-ended questions in the surveys, students did anticipate difficulties connected with learning new skills as well as using their generated knowledge in project-related tasks. The answers included: learning new skills, learning engineering software, learning from transversal teams, not understanding other fields of expertise, catching up with the lacking theoretical background, as well as working in French. Coaches noticed a steep learning curve for the students, and they pointed out that hands-on, experiential learning on the project helped students to use their theoretical knowledge. Furthermore, three out of seven interviewed coaches also mentioned that PBL complements theoretical acquisition and that students involved in the projects were more capable to identify gaps in their theoretical knowledge and hence returned to the classes more attentive and prepared to learn.

4.3 Interdisciplinary project management skills

Only one project-management skill showed relevant change from pre to post-test (see Figure 3). After the project, students saw themselves as more capable of assessing risks in their projects (i.e., managing uncertainty when carrying out a project), compared to before, $t(35)= 2.61$, $p=.01$, $d=.44$. No significant changes were observed for team communication, ethical sensitivity, interdisciplinary competence, and project planning.

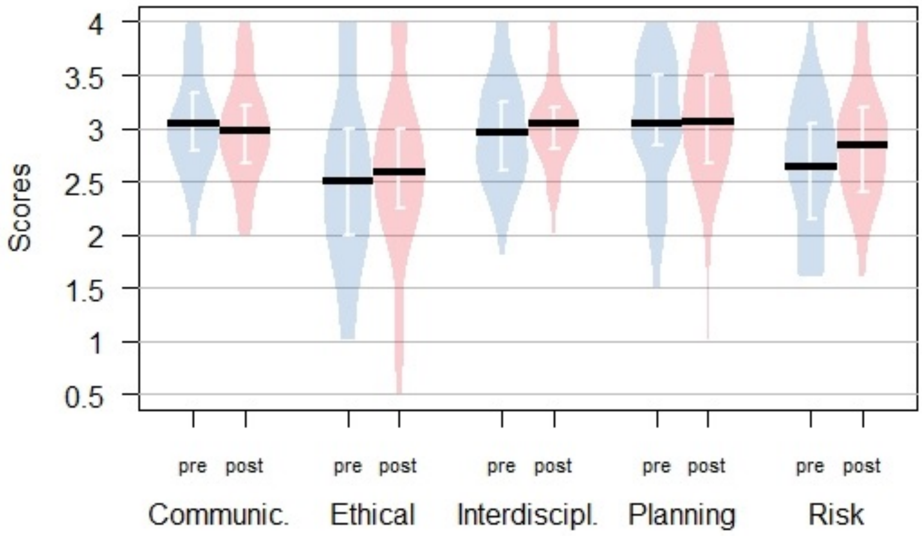

Figure 3. Pre and post-test scores of interdisciplinary project-management skills: team communication, ethical sensitivity, interdisciplinary competence, project planning, and risk assessment.

In the interviews, students expressed difficulties with project coordination, communication and planning, and most profoundly time management. Indeed, this confirms the perspective of coaches who agreed that time management is a difficulty for students; in their opinions, students tend to like investing time in projects and this is sometimes costly in terms of their course work. Furthermore, this confirms also the larger intrinsic motivation, since if students were only motivated to get the credits, they would have other options (i.e., semester projects) that are way less costly in terms of time and energy invested. With regards to the communication skills, all coaches shared their observations that students have difficulties in communicating or coordinating within the teams.

On the other hand, the interviewed students recognized the difficulty of acquiring professional skills, including team management, internal and external communication and resource allocation, but throughout the course of their engagement with the projects they realized how important these skills are for the engineering profession.

> *"What I learned from these projects is that technical barrier is not the toughest barrier. Yes, you need to find the engineering solution, but usually what needs to work is not engineering but all the rest, it is the fundraising, management, dealing with the people in the team, resource allocation" (S06)*

The problematic issue raised by students is that project-management skills are not frequently part of the regular curriculum.

In some teams, COVID-19 impact was felt particularly with the newcomers, as it was a bit difficult to motivate the new members. Team building lacked the element of physical contact, as the teams would regularly meet between the classes which was not possible during the lockdown. Interviewed students reported few positive sides, for instance the fact that the lessons are recorded meant that the students could more flexibly navigate through their project work.

> *"Especially during COVID-19, it is great to be part of a team. [...] during lockdown, I would not see anyone and they (the team) are the ones I can see now and I'm very happy and always talking about the team and it is very rewarding" (S04)*

As students have confirmed in their interviews, being part of the team that works on something was emotionally rewarding, despite COVID-19 limitations for working and meeting face to face on a daily basis.

5. DISCUSSION AND CONCLUSIONS

Throughout the projects, the students' intrinsic motivational scores were always above those of extrinsic motivation. This highlights that students valued the interdisciplinary project-based learning program for the learning opportunities it provided. Students aimed to achieve learning outcomes that they can't achieve through other ordinary courses like the mastery of practical skills, and working in interdisciplinary teams where they can try new things. However, extrinsic motivation was also an important ingredient of their goals, as students appreciated the importance of having these interdisciplinary projects in their CVs, and contacting stakeholders from private corporations that may give them an opportunity to be hired in the future, highlighting the fact the PBL may be also a way for them of narrowing the gap between the 'real world' and academia (Condliffe et al., 2017).

Motivation decreased throughout the projects. It is possible that, given that the pre-test was run at the very beginning of their projects, this captured their prior expectations on the project, which went up in the pre-test due to hyper excitement about the project. The decrease was especially true for extrinsic motivation. We speculate that while the students may have strong learning-unrelated reasons for joining the project, once they develop the project, they realize that these may not be the most important goals. Another reason for decreasing motivation may be that the students realize that working in interdisciplinary projects is harder than they thought it would be, experiencing difficulties that range from coordination and collaboration, to time-management, to resource allocation. Overall, our results confirm the difficulty of improving students' intrinsic motivation suggested by previous reviews of the literature (Lafuente, 2019).

As the projects unfolded, students perceived that collaboration was not as required and frequent as they thought it would be. While students generally realize the importance of learning soft-skills like collaboration and communication, they also acknowledged that this was one of the major challenges they had to face in their projects: students struggled to learn in interdisciplinary teams and to understand other fields of expertise. While PBL presents a tremendous opportunity for encouraging such skills, in the literature we find scarce examples as to how to do that (Condliffe et al., 2017).

The reported decrease in collaboration may also be related to the fact that students find it harder to keep focused and productive despite having obstacles in their projects. This is what the variable 'effort regulation' seems to reflect, and we cannot rule out that some of these obstacles they encounter (e.g., not being able to work and coordinate appropriately) are directly related with limitations due to COVID-19 restrictions in the school that impede face-to-face working in large teams.
Regarding interdisciplinary project-management skills, we saw that the only significant change is an increase in risk-assessment skills. Students perceived themselves as more capable of assessing the risks involved in the project and dealing with the uncertainty of it. While coaches assert that project-management skills are not part of the common engineering curriculum, it seems that escaping the well-defined environment of regular theoretical classes and directly participating in these kinds of projects, students feel more comfortable over time to deal with the unpredictability arising from many factors, from misunderstandings in the team, to lack of resources and funds.
As for the main take-aways and recommendations for the future, we propose the following:

- Make sure the students have an operational working environment at all times. Operational and organizational issues are not to be underestimated and they can erode students' motivation if all their energies are focused on overcoming issues related to, say, infrastructures, IT, resources, legal and financial needs, administrative support, etc.
- It is important to more tightly follow students' endeavours and provide support to remediate difficulties encountered throughout the project, which may help to better sustain high levels of intrinsic motivation and effort regulation.
- Students don't learn collaborative and communicative skills spontaneously: it is important to have explicit practices to promote these skills and save some time for scaffolding them and to give some feedback on them.
- As metacognition did not improve throughout the projects and students convey issues with time management, we suggest to model project schedules for students and to provide explicit opportunities for them to write their own plans and schedules to prepare working sessions and distribute roles.
- As critical thinking skills seem to stagnate over time, it is important to provide better opportunities for the students to criticize the ideas and proposals presented in the projects and come up with their own solutions. Coaches should engage in critical conversation with students so they can identify potential drawbacks and areas of improvement.
- As only one of the five project management skills improved, it seems relevant to implement explicit programs to promote the conscious acquisition of those skills (Picard et al., 2021).

This study has some important limitations. First, the survey response rate (36 out of 85) poses a threat to generalization of these results to all students and we cannot deny that the results may be biased in relation to the whole population of students. We hope to have more responses as the rest of the projects finish. Second, we lack a control group with which to compare our results, so without a counterfactual our evidence is purely correlational and far from the realm of causality. We recommend future studies where evidence goes beyond self-reported data. Likewise, future studies could explore more in detail the evolution of the students' motivation and learning strategies. This study puts forward the need to unravel how much of those changes in students' motivation and learning strategies are due to their prior expectations, and how much of them are due to adaptive reactions to succeeding or struggling with their projects.

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COLLABORATIVE DESIGN PROJECTS PROMOTING WORK-RELATED LEARNING IN ENGINEERING CURRICULA: FEEDBACKS FROM THE FIELD

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ABSTRACT

ISAE-Supmeca, a French engineering school, has chosen since decades to engage in work-related learning. In the framework of this orientation and as a part of a reflection on the enhancement of hybridization of teaching methods before and during the covid-19 era, our paper presents how collaborative design projects are used to promote work-related learning among students. This study aims to propose a critical analysis and a feedback of the use of Problem- and Project-Based Learning (PBL) and Collaborative Project-Based Learning (CPBL) in the engineer curriculum of ISAE-Supmeca students. Several educational research projects, carried out with partner institutions, have been providing frameworks for many students' projects, especially

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CPBL, for years. The originality of our study lies on the nature of the CPBL students' projects analyzed. Indeed, they involve students' teams from two different academic partners with different levels and backgrounds and can run during several semesters. The projects are collaborative, multi-partner and involve the need of a proper transmission from teams to other teams. The general framework is analyzed and three projects are observed in depth in order to highlight good practices. Our study identified six good practices in three topics: collaboration between the groups forming the whole project team, project management and digital chain management. The first goal of these good practices is to enable students to have an optimized learning experience in an environment as close as possible to real professional conditions. The second goal is to help practitioners (teachers, industrial partners) to improve their working methods.

1 INTRODUCTION

ISAE-Supmeca has been involved in educational research for a decade through concrete students' projects involving several stakeholders. We will here quote two of these projects: PLACIS (Collaborative Platform for Systems Engineering) and EXAPP_3D (Experiment Learning by Problems and Projects via 3D Design).

PLACIS was a large-scale project coordinated by ISAE-Supmeca and co-funded by the French National Agency for Research under "Investments for the future" program from 2012 to 2017. The project aimed at promoting active learning and teaching through industrial, international and at-a-distance collaborative projects, carried out by engineer students. PLACIS led to several theoretical questions and to the development of an Erasmus+ project (called EPICES) more dedicated to the role of teachers in Problem- and Project-Based Learning (PBL) and to assessment issues.

EXAPP_3D (Experiment Learning by Problems and Projects via 3D Design) is an ongoing so-called e-FRAN project coordinated by ISAE-Supmeca and co-funded by the French Fund Deposits, from September 2016 to December 2022. The project aims to promote active learning involving on common dedicated projects students from secondary school and/or high school and/or Bachelor's degree and/or engineering school. These projects focus on collaboration, conception, 3D design and lead to concrete deliverables.

Through these projects ISAE-Supmeca has gained experience on international and industrial multisemester collaborative projects (PLACIS) and on regional translevel multisemester collaborative projects (EXAPP_3D). PLACIS and EXAPP_3D allowed multisemester and even multiyear projects, some of these projects are still expanding through both frameworks. In this paper, we will focus on both of them.

Our study focuses on the feedback from ISAE-Supmeca's educational practices to implement and improve students' experience of learning through work. More specifically, the aim is to perform a critical study of the existing situation and capitalize on in order to draw good practices from the learning experience in the context of multi-stakeholder collaborative projects.

Our paper is organized as following. Section 2 provides insights into work-related learning practices through a literature review and outlines the context of their application at ISAE-Supmeca. Section 3 presents the specific projects analyzed in-depth in order to provide the feedback. Section 4 exposes the feedbacks and findings from the field. Finally, section 5 concludes and opens to a possible wider study.

2 WORK-RELATED LEARNING AT ISAE-SUPMECA, FROM PROJECTS TO COLLABORATIVE PROJECTS

According to Smith and Betts [1], there are three different ways to connect learning and work. We have learning about work, learning at work and learning through work. The use of business-based case studies is an example of learning about work. Learning through work is experiential, but not necessarily in the workplace [1]. Our paper focuses on learning through work according to this previous taxonomy. Also, for this study, we adopt the work-related learning definition presented by Kyndt and Baert [2] « as the engagement in formal and informal learning activities … to acquire and/or improve competences (integrated knowledge, skills, and attitudes) that change individuals' present and future professional achievement (and eventually also their career) and organizational performance. »

The next section will present key literature elements related to our study and detail the ISAE-Supmeca students' projects context and frameworks.

2.1 Literature review: learning processes in collaborative students projects

The first step to optimize learning is to understand how it occurs. Understanding the way in which people acquire new knowledge and skills, understanding how these knowledge and skills can be changed, updated or enhanced are both fundamental issues. Shuell [3] claims that "…learning is an active, constructive, and goal-oriented process…". The second step is to design a supportive learning framework. In the learning process three criteria are unavoidable [3]. The first criterion is the change in an individual's behavior or ability. The second is practice or experience that produces the change. The third criterion is that the change is a lasting one.

Formal and informal learning are important components of the learning process [2]. Indeed, there is a continuum between both of them with greater purity at either end [4][2]. Despite being often presented in contrast [5] [6] [2], they should not be separated and can be complementary [2].

Formal learning is typically institutionally sponsored, classroom-based, and highly structured [6]. Informal learning is characterized by a low degree of planning [2]. It includes incidental learning [6]. Its outcomes are not defined in advance. They depend on the learning context, learning support, learning time and learning opportunities. The opportunities of learning are not restricted to intentionally created learning environments but can occur during several on- and off-work-related activities. Informal learning presents many benefits at work as flexibility, rapid transfer to practice and resolution of work-related problems [5]. During the informal learning process, students gain knowledge and skills through their own self-engagement. They learn on their own and through interaction with others [7].

PBL approaches are perfect frame for both formal and informal learning. PBL approaches have been used for many decades [8]. These approaches place students at the center of the learning process [9][10]. Indeed, students are actively involved through prepared situations (problem-based learning) or real situations (project-based learning) [11]. They work to identify what they need to learn in order to solve a problem. To do so, they continually re-evaluate their approach in response to outcomes of their efforts. As a consequence, during the learning journey, students can acquire both content and thinking strategies [8]. In this journey, the teacher acts to facilitate the learning process rather than to provide knowledge.

PBL is familiar in engineering education with growing use in first-year engineering courses [11]. This popularity in engineering schools can be partially explained by the fact that PBL involves engineering students in a dynamics close to challenges and environments they are likely to encounter as professionals. Additionally, PBL fosters self-regulated learning, develops effective problem-solving skills [10], helps students become effective collaborators and enhances their motivation [8].

In a collaborative problem- and project-based learning (CPBL), the learning is fulfilled by the involvement of students in a collaborative group project. CPBL uses a production model [12]. The entire process is meant to mirror real world production activities. During the collaborative project, students' own ideas and approaches are used to accomplish different tasks.

At the beginning, the learners define the purpose for creating the end product and create a plan to the project management. As there is less centralization than in a pure PBL, management and share of information is a key element. During different steps of the project, students not only resolve problems and issues encountered, but they also really learn how to deal with a multiactors environment and how different kinds of stakeholders react. They go beyond the traditional soft skills and have to deal with the management of the information and of the engineering tools.

2.2 ISAE-Supmeca context

ISAE-Supmeca aims to train students not only to become classic engineers, but also to be able to understand multidisciplinary and industrial issues, to work in teams, with people from different cultures. More generally, ISAE-Supmeca prepares them to be actors of their curricula and to move easily in today's and tomorrow's work world. To achieve this goal, it is needed to establish a bond between education and work.

The approach adopted at ISAE-Supmeca aims to use its strong relationships with industrial companies in order to make the experience of students as close as possible to the future environment they will face in their work. So, one of the challenges is to have as much time as possible under conditions close to a professional context to create a real work-related experience. PBL is one of the most efficient learning approaches to create work-related experience. It allows to develop skills and competencies linked to teamwork. Through interactions, formal and informal learning, students develop the ability to create, present and argue propositions.

ISAE-Supmeca, through PLACIS and EXAPP_3D frameworks, developed projects involving many stakeholders and reflecting the industrial reality. These projects create a framework allowing students to interact with counterparts working on different parts of the projects with different backgrounds in order to respond to a challenge.

Many student projects have been developed with several partners. Most of them included at least one professional partner and one academic partner (international at a Master level, or local at a Bachelor or lower level). Some of partners were far away geographically. Remote collaboration became then the normality.

The covid-19 pandemic added another challenge: the projects were carried out entirely remotely instead of partly remotely, due to health constraints. In our case, it is an evolution, making these projects more difficult, but this is not a full-scale revolution.

PLACIS and EXAPP_3D include the following types of projects:

- Basic projects: sometimes one-shot study, involving several partners but not planned to last several semesters with a heavy project management work,
- Complex projects: multi-semester project, with two academic partners having each a group of students working at least partly at the same period during a semester. A professional partner provides a real subject of study. The main features are: remote work, use of professional tools and everything being done in the way that can be defined as "the students change, the tutors stay, the institutions stay, the project runs". Some projects were active during five years.

In our study, we are focusing on three complex projects, which are full CPBL projects as presented in section 2.1. Within them, students from ISAE-Supmeca and its partners work in groups and are involved in a greater team made of the groups of each institution plus the tutors (academic and professional), as shown in figure 1 hereafter.

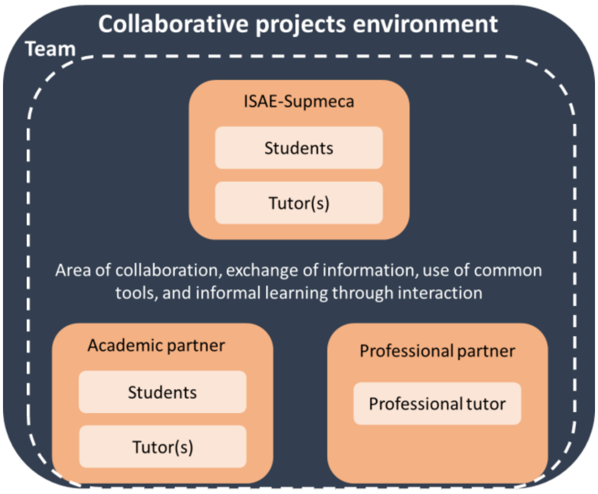

Fig. 1. ISAE-Supmeca collaborative projects model

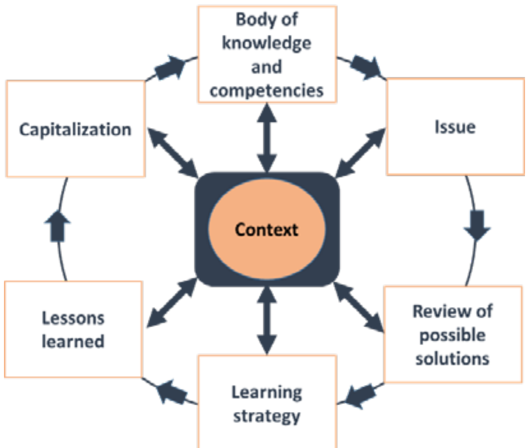

Fig. 2. ISAE-Supmeca collaborative learning process model

Figure 2 shows the steps of the learning process implemented in the projects. The students start with an initial body of knowledge and competencies. While facing issues in the project, students are led to develop strategies to make this body of knowledge grow. These strategies are often developed through formal and informal exchanges and pooling of expertise of different partners of the project. The implementation of these strategies triggers a learning-by-doing mechanism making it possible to capitalize on the experience.

3 PROJECTS DESCRIPTION AND OVERVIEW

In this section, we present an overview of the studied projects and their integration in in the ISAE-Supmeca curriculum.

In our study, the students involved in the three considered projects are the 3rd year engineers (equivalent to Master 2) from ISAE-Supmeca and senior technician (equivalent to the 2nd year of bachelor) from Lycee Louis Armand (LLA). These projects took place in 2019-2020 (Mini-Bee) and 2020-2021 (all three projects).

More precisely, the Mini-Bee project consists of designing and prototyping a Vertical Take Off and Landing (VTOL) aircraft (an example of design of the Mini-Bee in TRL2 is presented in figure 3), launched in January 2015 by Technoplane. The vehicle has hybrid propulsion that uses electric motors with a thermal engine for urban air mobility. Having VTOL features, this allows the vehicle to have high mobility as a helicopter, but also a high cruising speed, with maximum weight and maximum budget specifications to be respected.

Fig. 3. Mini-Bee collaborative project: example of design in a taxi version (TRL2)

Eurlab's goal is to collaboratively create innovative robotic systems. RovDrone is one of its projects. It is a robotic system made up of a rover and a drone that can assist rescue teams in a disaster area or explore hard-to-reach sites. The rover must be able to move independently in an unfamiliar environment and provide video information, photos and terrain analysis to the user.

For the past two years, the introduction of foils (composed of a front wing, a stabilizer, a fuselage and a mast) on surfboards has opened up new development prospects for manufacturers. Several had the idea of using an electric thruster in order to be able to feel the sensations of flying over water without needing a wave to generate the necessary take-off speed. The challenge of the project is therefore to design the foil of the efoil system to reduce energy consumption in the given operating range.

What these three projects have in common is that they are carried out by a team made up of a mixture of groups of senior technical students and groups of engineering students. They also all have a third partner providing the subject, one (Eurlab) being a small lab created by European teachers and two being start-up companies. Another difference is that two projects are recent and involve only two academic actors, while one project (Mini-Bee) is a highly collaborative R&D project involving many academic actors (Lycee Louis Armand and ISAE-Supmeca are only two of them) lasting for years and coordinated by the start-up Technoplane SAS (which collaborative with ISAE-Supmeca since with agile methodology and an open share of technical information. The main features of these CPBL are presented in the table 1 hereafter.

Table 1. Main features of the projects studied

Project name	*Frameworks*	*Partners*
Mini-Bee	PLACIS & EXAPP_3D	Technoplane SAS, LLA, ISAE-Supmeca, among many other partners
RovDrone	EXAPP_3D	Eurlab project, LLA, ISAE-Supmeca
Efoil	EXAPP_3D	Company (confidential), LLA, ISAE-Supmeca

4 LESSONS LEARNED FROM THE FIELD

In this section, we presents the best practices identified in our study. They are based on the feedback on the projects performance collected through observation and interviews with both closed and open questions with academic supervisors coaching the projects (for all three projects, one tutor per institution), students and the industrial tutor from Technoplane SAS. The following qualitative in depth analysis has been adopted: study of the findings from the feedback, their nature and convergences into statements and ultimately the extraction of good practices related to the statements.

4.1 A rich feedback with clear statements

In our everyday lives, Information Technologies (IT) became more common and present in almost every part of our doings [13]. IT artifacts such as computers, software applications, and smartphones are everywhere [14]. Due to the covid-19 pandemic situation, the flow of projects that were already largely done remotely has witnessed heavy use of these digital artifacts.

The first statement is that the use of digital tools is more extended than never before. For example, nine tools (3DExperience, Catia V6, Teams, Wikimedia, file server on a private cloud, Zoom, Google Hangout, Dropbox, TeamViewer) are used in the Mini-Bee project because of its very complex nature and numerous actors. In projects, some tools were proposed by the students for convenience. Others were imposed by the institution or the company. As a consequence, the information may not be up-to-date in several digital spaces and/or at some moments and/or for some actors of the project. The industrial tutor from Technoplane highlighted that the use of the email also worsens the situation in some cases. Here comes the second statement, linked to the first one: there is a dispersion of the information.

But, as noticed by several respondents, even when there are many tools, there are reference tools, and sharing them is mandatory and should be respected. When it is, as noticed one of the academic tutors, no problem of file version or file format happens. He points out the need of “a computer-aided design tool integrated to a platform” in the case of these kinds of complex CPBL. Nevertheless, as noticed by an experienced 3DExperience user, collaborative engineering tools require a change in the behavior of new users (students therefore). They have to get acquainted with the existing information generated by other collaborators, work, produce documents related to this work, publish this work and share the information. To achieve this result, users must be trained in this process and in the tools (collaborative platforms) to facilitate this process. The training of these tools can be done remotely in interaction with a trainer but it is then necessary that the users force themselves in the collaboration process on a regular basis so that it becomes a habit. The context of the pandemic does not facilitate this because the training interactions were (and still are) limited and less rich. One tutor confirmed this difficulty for students with limited experience to “access (and use) the working areas in 3DExperience: 3DSpace, 3DDashboard, 3DDrive”. Consequently, some students prefer to use a non-integrated tool instead of an integrated tool, for example using “Dymola standalone instead of using Dymola within 3DExperience” because it is “faster, easier to use and does not require a lot of resources.” Acting in that way, they break the team work (only a small group is made of insiders, others become outsiders). This confirms and reinforces the second statement about the information dispersion stated above. On the other hand, when it is well done, “centralizing data for remote work teams makes it possible to better synchronize tasks and work on the right versions”. So, we are facing a behavior issue here and it is the third statement: it is hard to convince users to adapt their behavior to a degraded context, especially when the users are hundred percent online.

Before the pandemic, people met, at least in two ways during a CPBL: between groups during a kick-off meeting or a final presentation and among a group during all the project period. During the pandemic period, people do not meet between groups, but sometimes, do not even meet within the same group. It impacts negatively the interpersonal relations and creates communication problems. Our fourth statement is: people are more dispersed physically than never before.

Linked to the dispersion is the problem of common time to collaborate directly, i.e. working remotely but not fully in the asynchronic mode. As explained by one of the academic tutors, the solution was found without the tutors: “The major problem was to find time slots for both technician students with their supervisors on the one hand, and ISAE-Supmeca students with their supervisors on the other hand. However, the students were able to talk to each other when their supervisors were not available.” Here is our fifth statement: CPBL context urges students to work in autonomy.

So, the multiplicity of actors, tools and locations makes the project management and the centralization of results more difficult. Indeed, the project “runs faster than its formalization”, as claimed by one of the academic actors. As a consequence, the project management is at risk and harder. But, when well-organized and formalized since the beginning of a semester for all its actors, apart from the problem of finding common time slots, using new tools like Teams makes it easy to organize meetings with students, especially unplanned ones. Several respondents affirm that it is “sometimes easier to plan remotely than face-to-face”. Also, “access to exchanges between students makes it possible to better supervise the work and to intervene as soon as possible”. Finally, “coaching and collaborative learning (peer coaching) help students in developing their skills”. These last remarks by a teacher make us conclude with our sixth statement, on project management: being agile is a must in order to fit with the evolution of tools and behaviors of students, but the autonomy has to be controlled to prevent overactivity and loss of control, very short regural meetings help.

4.2 A set of best practices

From the previously established statements and from the feedback of the PLACIS experience (kick-off meeting, formalization with industrial partners, clear requests for confidentiality…), we suggest hereafter a set of best practices (BP) composed of six good practices dealing with collaboration between groups, project management and digitalchain management:

- BP 1: Make the rules clear from the beginning! (tools, data management, way to work…)
- BP 2: Keep it lean: rationalize the number of collaborative tools!
- BP 3: Collaborate digitally, but stay human! (meet in-person if possible, and at least online at the beginning of the project and at specific milestones, especially when meeting within a group is not physically possible),
- BP 4: Take time to learn and improve the use of tools! (Go in-depth, especially for the complex tools, improve informal learning as much as possible, in a peer-to-peer fashion, which is a fair complement to a formal way done in person or online),
- BP 5: Manage the share of data! (from the beginning to the end of the project period, spell properly file names, integrate and contextualize data),
- BP 6: Empower students to make them autonomous! (keep the frame as large as possible, but maintain a frame requiring short and regular exchanges).

5 CONCLUSION

Our study led us to draw up six best practices. Their confluence point is project management, which tends to be the key in CPBL. Understanding who is who and who does what in this kind of project is difficult but needed. Defining a project manager and maybe an assistant is an interesting way to deal with the complexity of CPBL.

As summarized by an academic tutor, “collaborative work brings meaning and involvement to the complex and evolving issues faced by students” allowing awareness of their future professional environment. The covid-19 pandemic allowed “an acceleration of collaborative remote work”. The good practices identified in our study will be disseminated to enforce work-related learning for ISAE-Supmeca students. It will be done as part of a broader Initiative launched by the Educational Innovation Unit (EIU) of ISAE-Supmeca to capitalize on the pandemic experience.

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SPECIAL RISK CHARACTERISTICS OF DROPOUTS REGARDING THE DROPOUT INTENTION OF BACHELOR STUDENTS IN MECHANICAL ENGINEERING

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ABSTRACT

Mechanical engineering programs in Germany are characterized by high dropout rates of 34% in the study entry phase [1]. These persistently high dropout rates can be attributed to a number of performance-related problems of students in the study entry phase [2]. Other reasons for dropout include unsatisfactory entry qualifications in mathematics and physics [3], and lack of motivation to study [4]. Based on the dropout model of Heublein (2017) [5], this paper identifies subject-specific reasons for academic success and dropout in the bachelor's program in mechanical engineering in order to improve the study conditions in an evidence-based manner depending on the specific characteristics of the students and the specific qualification goals.

1 INTRODUCTION

In Heublein's (2017) dropout model (Fig. 1), dropout is depicted as a complex multicausal process that can be divided into the phases of preliminary phase of the study programme, current study situation, and decision. In the preliminary phase of the study programme, individuals are socialized in such a way that they acquire the higher education entrance qualification (HZB) and subsequently decide on a course of study and on a university. Matriculation marks the beginning of the individual study process, which is characterized by the interaction of internal factors (study behavior, study motivation, psychological and physical resources, and performance in the studies) and external factors (type of university with its respective study conditions). If discrepancies between the internal and external factors do not resolve, the decision to drop out becomes more likely. Educational origin and migration background as well as personality influence socialization in the education process, study decisions and the individual study process.

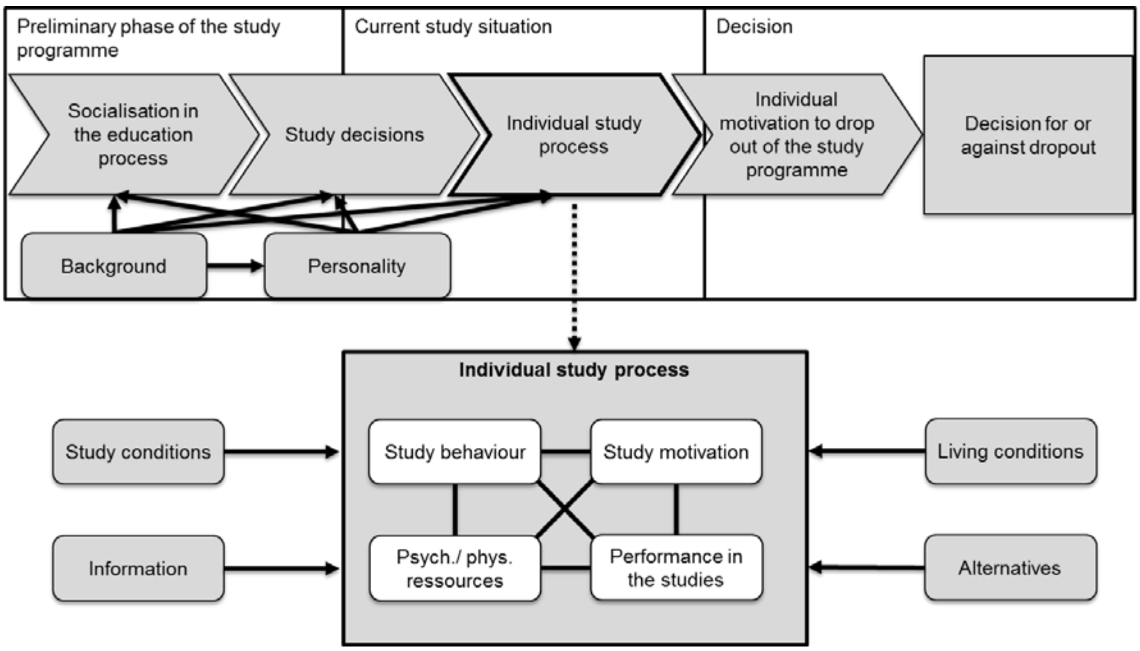

Fig. 1. dropout model according to Heublein (2017) [5].

2 METHODOLOGY

2.1 Instruments

In addition to the educational origin and the migration background as operationalization of the origin from the dropout model according to Heublein (2017), the educational socialization at the beginning of the first semester was recorded with the help of a questionnaire on the sociodemographic background [6]. For this purpose, the type of HZB incl. grade as well as information on vocational training were asked. In addition, the students indicated whether they had taken a basic or advanced course or no course in physics or mathematics in the upper secondary

school. The subject-related study prerequisites associated with educational socialization were surveyed using written performance tests to record previous knowledge in mathematics and engineering mechanics [7]. Additional performance tests in mathematics and engineering mechanics [7] were used at the end of first and second semester to survey special knowledge acquisition as a component of study performance. The tests were scaled using the 1-PL IRT model (Rasch model).
The cognitive abilities (subscale Figural Reasoning) [8] were also surveyed. Furthermore, online surveys were repeatedly administered in the middle of the first subject semester (MZP2), end of the first subject semester (MZP3), beginning of the second subject semester (MZP4), end of the second subject semester (MZP5), beginning of the third subject semester (MZP6), end of the third semester (MZP7) and beginning of the fourth semester (MZP8). In the online surveys were the individual motivation to drop out [9, 10], study behavior through resource management [11], psychological and physical resources [12], and study motivation [13, 14, 15] surveyed. The choice of study program or type of university results directly from the sample and was therefore not asked separately.
Since this paper focuses on the analysis of students with academic success (active students) and dropouts (inactive students), the surveyed sample is divided into two groups based on the response options of the item "Are you still studying the subject in which you are participating in this study?". The item could be answered as follows: 1: "Yes, I am still actively studying this subject.", 2: "No, I am no longer actively studying this subject, but I am still enrolled.", 3: "No, I am studying another subject.", 4: "No, I have exmatriculated." It was used within the online survey at the above measurement time points. Active students answered the item with answer choice 1 at least until the beginning of the third semester of study. Inactive students answered the item with answer choice 2, 3, or 4 during the survey period from the middle of the first semester to the beginning of the fourth semester.

3 RESULTS

The presentation of results first shows to what extent active students and inactive students differ with regard to the characteristics that shape the preliminary study phase. Furthermore, results on the relevant characteristics of the individual study process and the individual intention to drop out are presented.
The sample (N_{total} = 145, N_{active} = 100, $N_{inactive}$ = 45) consists of students who started studying mechanical engineering at two universities and two universities of applied sciences in Germany in the winter semester 2018/2019. From a χ^2 homogeneity test, the proportions of active students (69.0%) and inactive students (31.0%) are the same at universities as well as at universities of applied sciences. Due to low case numbers, no analyses were performed separately by type of higher education institution (university and university of applied sciences).

3.1 Preliminary phase of the study programme

From a χ^2-homogeneity test, active students (N_{active} = 100, 25.0% female and 75.0% male) and inactive students ($N_{inactive}$ = 32, 31.3% female and 68.8% male) do not differ in gender distribution ($\chi^2(1)$ = 0.491, p = .483). Descriptive examination of the data reveals an age average of 19.0 years for active students (N_{active} = 100) and an age average of 20.3 years for inactive students ($N_{inactive}$ = 44); both groups of students do not differ significantly from each other in age average (t(142) = 0.993, p = .322).

The factors belonging to socialization in the education process are presented below. In the type of acquisition of the HZB, no significant differences in the distribution between the active students and inactive students can be observed (N_{active} = 93/$N_{inactive}$ = 42, $\chi^2(2)$ = 2.905, p = .234). While 72.0% of the active students acquired their HZB at a Gymnasium, 59.5% of the inactive students' HZB acquisition falls on at a Gymnasium. Their HZB at a comprehensive school has 16.1% among active students and 28.6% among inactive students. The remaining students of both groups of students have the HZB from a vocational college, the HZB as a second educational pathway, or other. No significant differences become apparent in the taking of physics as a school subject in the upper school. For the active students, there is almost a 40/30 distribution with respect to the choice of a basic course or an advanced course, and for the inactive students a 50/10 distribution. Another part of both groups of students did not take physics at all in high school. In contrast, significant differences can be found in the use of mathematics as a subject. Active students take this subject 20.8% as a basic course and 79.2% as an advanced course. Inactive students, on the other hand, take this subject 51.2% as a basic course and 48.8% as an advanced course (N_{active} = 96/$N_{inactive}$ = 41, $\chi^2(1)$ = 12.649, p = .000, Cramer V = .304). From the total cohort of active students, 17.3% students have completed education prior to entering the program, and among inactive students, 13.3% have completed education prior to entering the program; both student groups do not differ significantly with respect to having completed education prior to entering the program (N_{active} = 98/$N_{inactive}$ = 44, $\chi^2(1)$ = .368, p = .544). The active students surveyed achieved a 2.11 as their average HZB grade. Inactive students achieved a significantly worse average HZB grade of 2.44 (N_{active} = 100/$N_{inactive}$ = 43, t(141) = 3.160, p = .002, Cohen's d = .581). Active students and inactive students also enter the mechanical engineering program with strongly different mean person abilities in prior knowledge (total) (N_{active} = 95/$N_{inactive}$ = 43, t(136) = -5.903, p = .000, Cohen'd = .613) (Fig. 3). A detailed examination of the person ability of prior knowledge of both groups of students shows lower prior knowledge for the inactive students than for the active students in both mathematics and engineering mechanics. The reported differences are statistically significant in mathematical prior knowledge (N_{active} = 95/$N_{inactive}$ = 43, t(136) = -4.599, p = .000, Cohen'd = .985) and in prior knowledge in engineering mechanics (N_{active} = 95/$N_{inactive}$ = 43, t(136) = -5.129, p = .000, Cohen'd = .598), so that one can speak of different subject-specific study prerequisites for active students and inactive students.

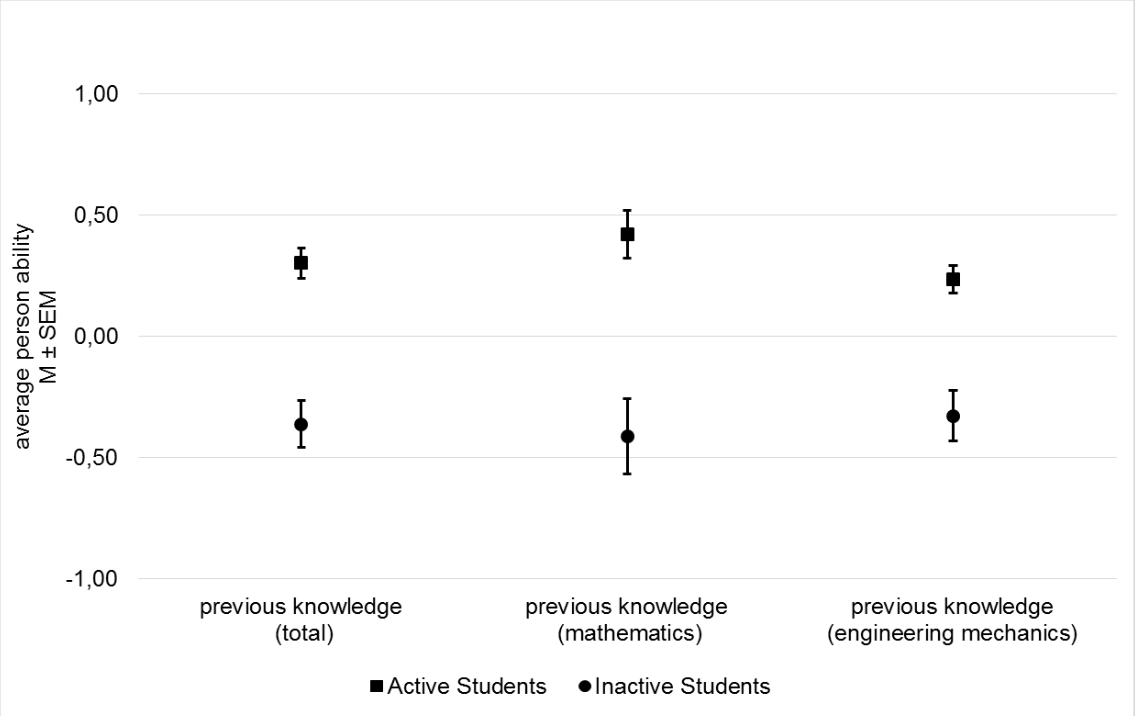

Fig. 2. error bars of average person ability for the performance test of previous knowledge (total, mathematics, engineering mechanics) at the beginning of the first semester of study for active students and inactive students.

The characterization of the educational origin is done by a five-level classification according to the concept of educational origin of the DZHW [16]. Here, the characteristics of the professional education of the father and mother of the students are divided into the following gradations: very low (neither parent has a professional - non-academic - degree), low (one parent has a professional - non-academic - degree), medium (both parents have a professional - non-academic - degree), high (one parent has an academic degree) and very high (both parents have an academic degree). The breakdown by educational origin shows significant differences in the distribution of active students and inactive students ($N_{active} = 100/N_{inactive} = 45$, $\chi^2(4) = 13.588$, $p = .009$, Cramer-V = .306). The active students show a split of 2.0%, 6.0%, 44.0%, 23.0%, and 25.0% in the different categories (very low/low/medium/high). Inactive students show a breakdown of 11.1%, 20.0%, 37.8%, 15.6%, and 15.6% in the different categories. Active students are significantly more likely than inactive students to come from academic families.
Migration background is also considered as an operationalization of origin. The breakdown by migration background also shows significant differences in the distribution of active students and inactive students ($N_{active} = 97/N_{inactive} = 40$, $\chi^2(1) = 15.826$, $p = .000$, Cramer-V = .340). Of active students, 3.1% have an immigrant

background. Among inactive students, the proportion of students with a migration background (25.0%) is significantly higher.

3.2 Decision

In the following, the average intention of active and inactive students to drop out of the study program from the middle of the first semester to the beginning of the fourth semester is examined in more detail (Fig. 3). During the survey period under consideration, there are significant differences in the average intention to drop out between active and inactive students (MZP2: $N_{active} = 90/N_{inactive} = 35$, $t(123) = 8.418$, $p = .000$, MZP3: $N_{active} = 94/N_{inactive} = 32$, $t(124) = 10.185$, $p = .000$, MZP4: $N_{active} = 94/N_{inactive} = 31$, $t(123) = 9.313$, $p = .000$, MZP6: $N_{active} = 75/N_{inactive} = 20$, $t(93) = 9.367$, $p = .000$, MZP7: $N_{active} = 84/N_{inactive} = 8$, $t(90) = 5.448$, $p = .000$, MZP9: $N_{active} = 73/N_{inactive} = 9$, $t(80) = 4.733$, $p = .000$, MZP10: $N_{active} = 72/N_{inactive} = 12$, $t(82) = 5.438$, $p = .000$). It can be seen that active students tend to report a low average intention to drop out over the entire survey period, which increases slightly over the course of their studies. The average intention to drop out among inactive students is more than twice as high as among active students over the entire survey period. Among inactive students, the mean intention to drop out of the study program increases more strongly until the end of the second semester, after which the average intention to drop out of the study program decreases slightly.

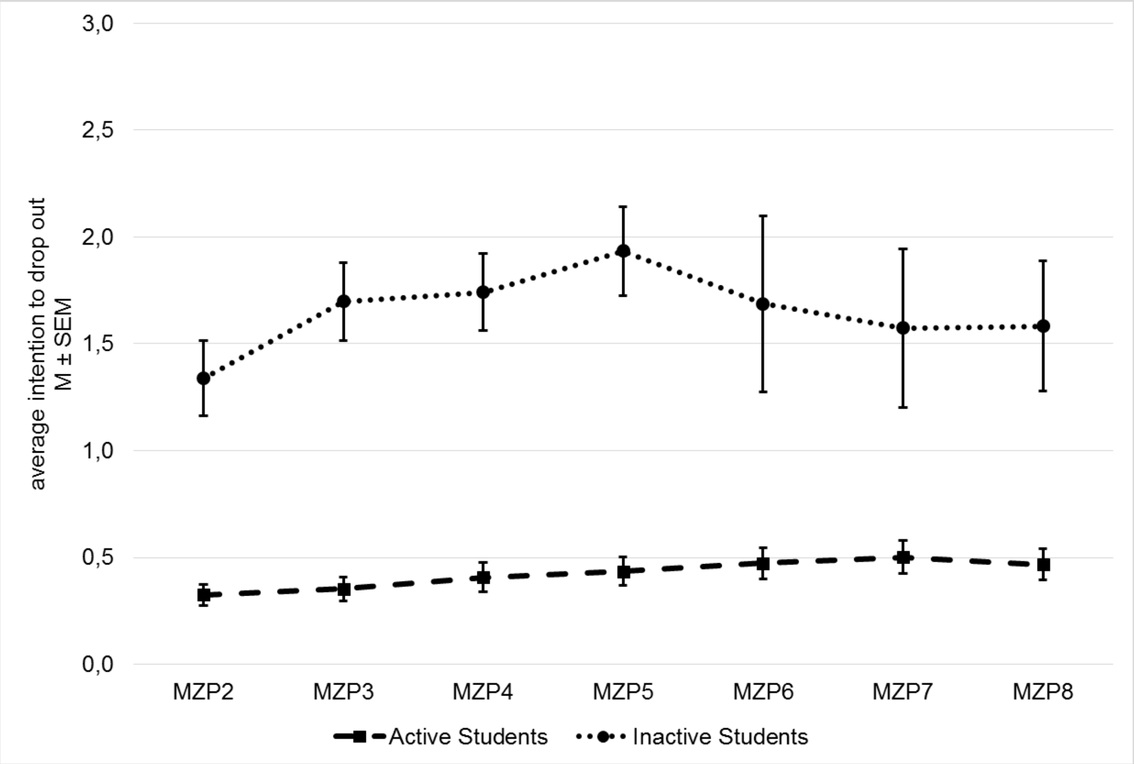

Fig. 3. error bars of average intention to drop out of active students and inactive students at different measurement time points.

3.3 Current study situation

In a further step, a regression analysis is calculated for active students and inactive students respectively in order to investigate the influence of the factors of the individual study process on individual dropout intention at the beginning of the second semester (Fig. 4). The regression analyses show that there is no significant influence of study behavior or psych./phys. resources on individual dropout intention at the beginning of the second semester. For active students, high study motivation causes low individual dropout intention (β_{active} = -.194*). Inactive students show no influence of study motivation on individual dropout intention. In this group of students, however, study performance shows an influence on individual dropout intention ($\beta_{inactive}$ = -.382*). The factor study performance in the regression model includes prior knowledge in mathematics, because for analyses of the influence of the factor expertise on the individual intention to drop out of the study, the number of subjects of the inactive students is not sufficient.

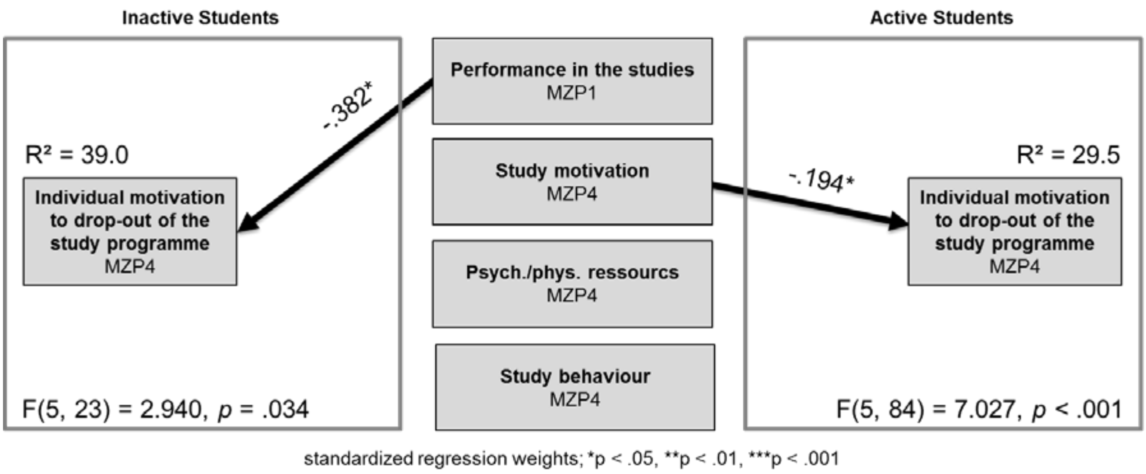

Fig. 4. regression model for the influence of the factors of the individual study process on the intention to drop out at the beginning of the second semester.

4 SUMMARY AND ACKNOWLEDGMENTS

Several differences between inactive students and active students can already be identified in preliminary phase of the study programme. In addition to a lower HZB grade, inactive students have less prior knowledge of mathematics and engineering mechanics. There are also differences between the two groups of students in terms of their educational background and migration background. Inactive students have a lower educational background than active students and are more likely to have a migration background. During the individual study process, inactive students show a correlation between prior mathematical knowledge and individual intention to drop out. For this group of students, a low level of prior mathematical knowledge leads to a high individual intention to drop out.

For active students, there is no correlation between performance-related factors and the individual intention to drop out. However, for this group of students, a low motivation to study causes an increased individual intention to drop out.The reduction of individual dropout intentions can be achieved by supporting first-year students in compensating for deficits in prior knowledge in mathematics, ideally before they start their studies.

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PERFORMING ETHICS OF TECHNOLOGY. USING IMPROVISATIONAL PERFORMANCE-BASED TECHNIQUES IN ENGINEERING ETHICS EDUCATION

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Conference Key Areas: *Sustainability and ethics*
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ABSTRACT

The paper explores the potential for improvisational techniques used in ethics tutorials with the aim of fostering moral sensitivity. Recently there has been an increased interest in researching how performance-based techniques can foster certain ethical competencies. In ethics education for engineering, role-playing games have been an example of performance-based technique successfully employed to help students understand the complexities of ethical decision-making. However, role-playing games have several limitations because of the rigid structure of the roles and of choices in the script, which may lead students to act detached from the situation. Based on the idea that we need to foster also practice-based skills in engineering ethics education, not solely analytic skills, we have encountered in the previous literature the hypothesis that improvisation games can help students rehearse what it is like to act morally in an engineering situation. To clarify what is the potential of improvisation in engineering ethics education, we observed and helped with designing a course centred entirely on improvisational techniques for engineering and science students. Drawing from this pedagogical experiment, we noticed that improvisational performance-based techniques managed to stimulate the student's moral sensitivity. This happened by two effects that we named the spectator effect and the shared space of vulnerability effect that we describe in detail. While role-playing has acquired the status of a "classical" exercise in engineering ethics education, improvisation still needs to be adopted by ethics teachers. Through our experiment, we hope to have shown that there is definitely an untapped potential in

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this kind of exercise for increasing student's moral sensitivity and engagement, thus making possible an increased moral agency.

1 INTRODUCTION. MORAL AGENCY AS A META-COMPETENCY FOR ENGINEERING ETHICS EDUCATION

A central question for researchers in engineering ethics education (EEE) is what learning objectives should form the basis of their courses towards developing the necessary competencies for future engineers. There are lists of such aspirational competencies to be found in various charters of engineering worldwide (such as ENAEE2 or ABET3 as most visible). However, what is actually taught in the EEE classroom is shaped by what teachers see as achievable in a limited time-frame and with a fixed repertoire of pedagogical methods. Thus, while ethical competencies for engineers are aspirational and ambitious [1], their translation into educational goals is done more concretely by breaking down the competencies into "behavioural" goals. For the competency of being a responsible engineer (which we would call a virtue), one needs to translate it into something measurable, such as "the student will act responsibly in situations X,Y, Z." However, since we cannot enact situations X, Y, Z in classroom to test the student's behaviour, we take as a proxy the explanation of how one would act if one were to be found in such a situation. From this, we test knowledge or understanding of how one should behave in certain situations and take it as sufficient knowledge to evaluate if specified learning objectives have been met. The mystery remains if our students - once out in the real world – will act in a way that measures up to their understanding of moral concepts and theories learned in class. What we seek to achieve in EEE – and probably in any other form of professional ethics education – is primarily instilling a sense of moral agency in a professional context: our students should feel called to act when they sense a moral wrong happening in their professional environment. However, teaching moral agency in a professional context is not a simple matter of describing it as a stand-alone competency and devising exercises for it. Rather, moral agency is a meta-competency, relying on the other competencies included in EEE [2] such as moral imagination, moral sensitivity, moral knowledge, and the disposition to act. We frame the specifics of this meta-competency as demanding both analytical skills as well as practice-based skills. In pedagogical practice, there seems to be a tension between teaching analytic or practice-based skills. For this distinction, we take our inspiration from Freiman's [3] work on ethics education for legal practitioners which, we argue, holds for most other professional ethics fields, including engineering ethics.

Analytic skills are those skills of manipulating information in complex ways such as understanding said information, using it to create new solutions, looking for missing information, performing logical operations on the premises and conclusions. In the context of EEE, analytic skills entail how to use correctly the moral vocabulary for describing the moral situation in the appropriate terms, and how to argue logically

[2] https://www.enaee.eu/
[3] https://ethics.iit.edu/ecodes/node/5693

about a moral issue [4]. What matters for our purpose is that analytic skills can be entirely learned in the classroom, since the intellectual operations entailed do not require the student to go out in the field. By contrast, the practice-oriented skills are not fostered by intellectual exercises alone, hence the classroom setting has difficulty in fostering these. The difficulty in teaching any form of professional ethics is that, as Freiman argues [3], we do not aim to teach students merely analytical skills but also action-oriented skills. Simply put, we do not want students to merely recognise that a moral situation is at stake, but to also to feel called to act upon it (Callahan calls this a feeling of moral obligation [4]) and to try to act even in conditions of adversity. However, in the EEE classes, we overwhelmingly teach analytic skills while hoping that these will somehow entail that our students act responsibly in the world as engineers. The overwhelming analytic skills focus in EEE is demonstrated by how, pedagogically, we favour assignments such as argumentative essays, discussing case-based exercises [5], or debating about moral dilemmas in a classroom. Analytic skills are great for structuring the student's thinking about open-ended problems, but in ethics education these skills are not enough by themselves. In an engineering context, analytic skills are a tool one uses "to solve unstructured engineering problems (i.e., those for which there is no single or ''correct solution)" [6, p. 978]. If a problem appears in engineering practice, analytic skills help to solve it but only if one assumes that the problem cannot be simply bypassed by the engineers. However, the case is different with moral issues emerging in the engineering practice. There, one has the option of not addressing the problem at all, or of not using one's analytic skills and just following the majority decision. Thus, while analytic skills are precious and need cultivation in EEE, these are not the end-all of skills. In EEE, we are still confronted with the thorny issue of engineers acting based on the moral knowledge gained in classroom. And this is, empathically, not something one can learn by accumulating solely analytics skills.

How to foster moral agency in EEE? Moral agency is traditionally linked with embodiment and intersubjectivity [7]: whenever we exercise our agency, we do it in the world, as situated beings, in the presence of others. We need to understand agency as not an intellectual affair, in our heads alone [8, pp. 1392-1393]. The intersubjective aspect of moral agency means that we need to practice it in the presence of others, not in our heads alone (as an exercise of imagination or reasoning). This poses a problem for the EEE programmes that are inclined to teach only analytical skills. In order to realise moral agency as a meta-competency, we need to train our students also and equally in practice-based skills. Teaching practice-based skills requires a different kind of pedagogy since such skills are experiential. There is no intellectual and detached way of learning the practice-based skills: a major way to learn them is through practice, i.e. by actually experiencing a variety of moral situations as a first-person moral agent; the other way is vicariously (such as watching movies, reading novels and other texts that allow oneself to be absorbed in someone else's experience). Moral agency takes place in small moments and choices occurring in everyday practice, not only in the major decisions:

"Ethical agency does not realize itself in the instant" [8, p. 1386]. Rather it is a "sedimented" [8, p. 1391] practice, i.e. realised through countless instances and encounters.

2 ROLE-PLAYING EXERCISES IN ENGINEERING ETHICS EDUCATION AND THE ROAD NOT TAKEN: IMPROVISATION-TECHNIQUES

In order to foster practice-based skills contributing to moral agency, very few pedagogical methods are available. Following Freiman, only two pedagogical methods have been specifically devised to instil practice-based skills: clinical ethical practice and role-plays [3, pp. 1291-1292]. An already well-established approach in EEE towards instilling practice-based skills is the pedagogy of role-playing exercises. A role-play consists in acting out a controversial decision (such as launching the Challenger shuttle or not, deploying a controversial technology, etc.) in a kind of a classroom performance where students do not receive scripts, but role descriptions. Students are then free to improvise their lines in the ensuing play-debate, while making sure that they stick to the character description and embody the character's motivations and interests. In our classes at TU Delft, there is also an external observer to the role-play (usually chosen from the students) who is specifically paying attention to the different group dynamics and individual motives, thus facilitating retroactive reflection on how people acted in the role-play. The outcome of the role-play is usually a moral decision.

Role-playing has already shown its unique educational success in EEE in pursuing certain learning goals. As discussed by [9], the many benefits of using role-plays in EEE entail the active stance taken on by students, fostering creativity in problem solving, helping students inhabit multiple perspectives on an issue. When role-playing, students experience first person the institutional constraints and dynamics, or they feel enticed to redesign of artefacts, or to change the policy [9]. This is because students take an active and creative stance towards the case they enact, and therefore cannot help but feel implicated and personally touched by the matters discussed. At a more abstract level, role-playing helps educators pursue macro-ethical goals, such as introducing students to complexity and showing them that ethics is not just about individual decisions taken in key moments by human actors, rather that there are also institutional, political and social forces, arrangements and discourses that shape options for action. However, this macro-ethical outlook is not the standard way in which role-plays are deployed in EEE [9], where usually the role-play focuses around one clear decision ("to launch or not to launch") taken by one main actor with a supporting cast.

Role-playing exercises have multiple pedagogical benefits in EEE, especially for instilling practice-based skills. However, role-playing has also some limitations insofar as moral agency is concerned because the very idea of playing a role creates some limitations for the students, especially with regards to developing one's own moral agency. It has been observed that students tend to play stereotypical versions of their roles [3], acting out clichés about that role (the expert not listening to the lay public, the manager ruling with an iron fist, the profit-obsessed shareholder etc.). While there is some improvisation in the role-playing exercise, as student-actors are free to improvise their own lines, there is the limitation of the set role, the character traits, and of the socio-cultural constraints with which it the role comes. Furthermore, the re-enacted situation is usually well-known, inspired by historical events, thus students do not feel called to change the parameters of the story. Role-playing can happen in a detached manner, especially when students re-enact historical decisions such as that of the Challenger launch - since the events they play took place more than three decades ago, in a different institutional culture. As Freiman observed, this detachment of the student from the role enacted in the role-play may undermine the pedagogical outcomes: “Students may perceive a role-play as requiring them to play a role external to themselves, and one in which they believe themselves unlikely to find themselves in the future; they thus may distance themselves from the experience even as they are engaged in it." [3, p. 1280]. Thus, one danger of relying exclusively on role-plays for practice-based learning is that it may not elicit the experiential learning we are after where students get to feel what it is like to act in the moment. To overcome this, we propose improvisation as complementary to role-playing in EEE.

Improvisation in the EEE classroom has the potential to overcome these limitations of role-playing while keeping intact the experiential aspect of practice-based skills. Improvisation is a performance-based technique that involves the performers inventing their own lines of text, actions, and characters. It is a horizontal form of creation, since “there is no script, no sets, minimal if any props, no predetermined roles, and a very different role for the director/producer" [10, p. 593]. Improvisational exercises in the classroom stir "spontaneity and intuition as two critical dimensions of improvisation" [10, p. 593]. The major difference between improvisation and role-playing is that role-playing makes students conform to a role (often stereotypical) and focusing on how to play it well. Improvisation, meanwhile, allows students to access their past experiences in order to make sense of the new situation. Since there is no clear role to play the students revert to creativity and will be more present in the pedagogical situation [3, p. 1280].

> Improvisation,' by contrast [to role-play], does not connote performance or otherness. To the contrary, we all improvise when confronted with difficult situations, cobbling together prior experiences to craft an appropriate response to a new situation. Using such a description may therefore make students more likely to be present during the exercise. [3, p. 1280]

Freiman theorised improvisation as a way of learning practice-based moral skills starting from the observation that, in order to acquire practice-based skills, one needs competence and confidence, which can be only instilled through repeated practice [3, p. 1297]. To provide practice-based skills, students need to rehearse the morally problematic situations one may encounter and thus to build resilience to tackle those in a safe environment. Improvisation, alongside role-play, is the main way to practice a skill by enacting it. There is very little literature on improvisation in ethics pedagogy, and as far as we know none dedicated to improvisation in EEE. For this reason, we designed an experiment to test how improvisation could work in a classroom at TU Delft.

3 A CASE-STUDY ON IMPROVISATION IN AN EEE CLASSROOM: GIVING VOICE TO A TECHNICAL ARTEFACT

In the autumn-winter semester of 2020, our colleague Bauke Steenhuisen created a course for honours-track students centred entirely around learning theatre skills and using improvisation to tell a story involving a technology. The course was guided by the question: what can we learn about technology and about being an engineer through theatre? The students were bachelor's and master's level coming from multiple faculties of TU Delft, all of them having had little to no prior ethics training. We gave some input into the designing of this course by proposing the case study (augmentative and alternative communication (AAC) technologies4) and providing the theme for the improvisation (what happens if an artefact had the power to speak? What does an artefact have to say?). The students were trained by two professional acting coaches, who introduced various performance-techniques during six meetings. The first two sessions were not yet focused on the AAC case, but primarily on getting familiar with improvisational techniques. The following four sessions were dedicated to students writing and rehearsing a short scene in groups of three, while being coached by the professional performers in every session. Students were free to write a scene about any aspect they considered relevant in the AAC tech usage, the only requirement was that the AAC device needed to be acted by a human actor. This requirement was added to grapple with the (pseudo)agency of technology and to open up the ethical issues, while letting students discover these issues on their own. The students received no hint of the possible ethical implications of using an AAC device nor did they receive any instruction in ethics during this course. They were explicitly asked to act out a scene where the technology plays a role, but not necessarily a morally problematic scenario. All teams of performers were made up of three students who all performed a sketch (there were three roles in each sketch: the patient, the expert, and the AAC device). There was no director, they all co-wrote the scenes, helped by a theatre coach only for the performance part. After rehearsing their scenes with the coaches, in the last meeting of the course (the seventh and final class), the students played their improvised scenes in front of their colleagues and of several external guests. After every group's performance, there was a plenary discussion with feedback and questions. Because of the Covid-19 restrictions, the entire course took place over Zoom although it was initially planned to be an in-person course.

[4] "Augmentative and Alternative Communication Technology, or AAC Tech, is a relatively young, multidisciplinary field aimed at developing technologies for people who are unable to use their natural speaking voice due to congenital or acquired disability." [11, p. 1].

4 METHODOLOGY

In order to better understand the potential of improvisation in EEE, we provided some specific input for designing the requirements for the scene, but we did not intervene in the actual teaching and we did not appear in classroom during the six sessions. We observed the final performance (seventh class) and took notes of the discussions. We hypothesised that if students would be asked to improvise a scene where a technology comes alive by acting, they will stumble on their own on moral issues and that they will recognise such issues as moral. Our hypothesis concerned primarily the moral sensitivity of the students which we hoped would increase. To check this hypothesis, we performed two sets of interviews with six students (out of the total of 21 participants) who had volunteered to take part in these interviews. The first set of interviews happened in the first week of the course, where we asked students how they see their roles as engineers, what are the expected moral and societal responsibilities of an engineer. The second set of interviews happened right after the final performance, when the course had ended; we asked the same questions as before, but, in addition, we asked students to comment on the ethical aspects emerging in their previous performances. The interviews were semi-structured, with open-ended questions, recorded audio only. We coded the interviews manually using thematic analysis (we looked for words and strings of words representing responsibility, moral problems/ dilemmas, and societal role of engineers) and we interpreted the themes using hermeneutic analysis [12].

5 FINDINGS AND DISCUSSION

5.1 The spectator effect and moral awareness

We were hoping that students untrained in ethics would start to notice on their own the various moral problems arising when a technology mediates communication between human beings. AAC devices are a relatively new technological innovation used for non-speaking persons. These devices were designed with the stated purpose of enhancing autonomy, safety, well-being. However, like many other technological developments, AAC devices can raise serious ethical concerns such as constraining the user’s range of expression, making their disability more visible and exposing them to social stigma, having one’s authenticity as a speaker questioned etc. (for a more complex discussion on this, see [11]. However, we were surprised to find out that the students, both when writing, rehearsing and acting the sketches, did not see any moral issues with the AAC device. In their scenes, most students saw AAC primarily as a technology for doing good, thus implicitly affirming the ethos of technological enthusiasm predominant among engineers [2]. Students worked hard to make their sketches interesting, funny, insightful, but with little concern for the power relations or injustices that a technical device can generate.

> *D: "during the course I didn’t really directly think that it had an impact on my thought on that subject, on what it means to be a good engineer. It was more just how to be a better person I think in general. And my opinion also just hasn’t changed"*

> *C: "To teach ethics in general, I think it's not only [about] ethics but some kind of like a perception about the word. I think they lie in our understanding of the world, and so I think that's not what we can teach others... So we can for sure apply our own understanding to certain fields. But to teach it, I don't think it's possible. But at the same time I too I think like the course tried to stimulate us to think about our thought. So and to formulate our thoughts. And I think that it can somehow boost our awareness about those issues, but not to teach us."*

During the final performances, several morally problematic issues emerged for most of the spectators – as evidenced by the questions and the discussions. We were hoping to observe a change in moral awareness for the students we interviewed. What we found was, instead, that students were struck by the moral issues at stake only when seeing them acted “on stage” by others. Seeing others play-act created a distancing effect that allowed students to notice the presence of moral issues in other’s scenes. Meanwhile, in their own scenes, students had difficulties in conceptualising the moral issue at stake: in the interviews, they mentioned the ethical issues as relating to emotions, shame, empathy, and creating artificial relations, and machine bias - and while these issues are indeed morally loaded, the students could not articulate what exactly was the problem there.

We have called this the spectator effect. It was in seeing others perform, and not in performing one’s own improvised lines that a distancing effect was created which allowed for moral awareness. Contrary to our expectations that a first person perspective coupled with an embodied experience would yield a morally sensitive and complex judgement, this aspect of improvisation did not play a major role. This indicates for us that there are other aspects of improvisational performance worth exploring for EEE besides the first-person engagement highlighted by the literature. Does this mean that watching others play theatre is enough to raise moral awareness in the spectators? Not necessarily. The improvisation exercises played a significant effect because one watches and criticises differently the scripts written by one’s peers, as equals, than the script written by authoritative figures such as teachers or scholars. It was precisely because of the perceived equality among the student-performers (who took turns between acting and being spectators) that they engaged so fully with the other’s representations. We speculate that the educational effect emerged because no one wanted to teach anyone anything in particular through their scripts. Students mentioned the lack of teaching as one of the main virtues of this course:

> *E: "...the lack of information, so we turned really everything from practice, and maybe that's a good thing. And maybe I am only saying this because I am I'm used to ... learn from articles or books or lectures ... It was a really a change to get information from only by doing it."*

5.2. A shared space for vulnerability

The acting exercises contributed relatively little to promoting moral sensitivity, yet these did seem to contribute a great deal to students’ embracing a more vulnerable exposed and empathic way of being and co-creating together. All team members were equal. All interviewees spoke fondly of the camaraderie that developed among them, not just in their own team, but in the entire class, of the kind and encouraging feedback that they received and that stimulated their creativity.

> *A: "You see I think people really transform through the course. Also, because me from like normally I'm an extrovert person so normally I don't really have a lot of problems with expressing myself, but also in the beginning you see a lot of people who do and I think it definitely helps."*

The students had the courage to try nonconformist lines of action or words precisely because they felt free to improvise, to express themselves since there was no judgement. The encouraging atmosphere was actively imposed by the theatre coaches from the first session. Instead of becoming detached from their roles and playing in a caricature-like mode their sketches, the students put out there their own personalities and dared to be vulnerable. This is in concordance with the observation made by Freiman that, in order to achieve practice-based skills, we do not want students to detach themselves from the situation, they need to be emotionally and (we would add) bodily involved in the moment. This means that the situations improvised by students were closer to what they would actually do in a real life scenario, than to the idealised projections or stereotypes. However, contrary to Freiman's work [3], in our study we did not find any evidence of students play-acting their own values or beliefs. In trying to come up with interesting scenes, students wrote scenarios aimed at being captivating for the spectators, often with punch-lines or situation reversals.

> *C: "But then we improvised a couple of times to figure out what kind of interaction we wanted to do and then one of them was that she started flirting with me. And we thought that was really funny and we left it there. So initially it was put there as a joke (...) I think the ethical aspect that at first it was more about how can machines help you? But then in in in the end it escalated to an extent that there was like a relationship and we thought it was it was a really exaggerated help"*

Thus, we have no indication that the students play-acted their own moral beliefs or values. Meanwhile, what they achieved still has significance for EEE, namely collectively building a common space of shared vulnerability, out-of-the-box thinking, and co-creation. This kind of space has educational significance because in real life it is very hard to achieve such a space safe for speaking one's mind and noticing moral issues. Perhaps the absence of this space explains the passivity of many engineers in their own workplace whereby they do not speak about nor perhaps even notice moral problem. To achieve moral awareness, one needs not only to notice that something is at stake morally, but also to have the space to express it in a way that will not immediately lead to being silenced or isolated socially. Thus, the creation of such spaces for noticing and exercising one's moral sensitivity is important for EEE in a procedural sense.

Improvisation entailed, in our experiment, two aspects: improvising the acting and improvising the lines which were then chiselled out through rehearsals. Since the students as actors-writers could not take enough distance from their own creations, the improvisation did achieve that experiential effect of being immersed in the situation we were looking for in the beginning of the paper, yet they needed to take some distance from this experience to be able to investigate its moral connotations.

It was the role of spectator and commentator of other's sketches that allowed for creating this distance needed for the moral awareness that the situation played on the stage had some normative undercurrents. To come back to the practice-based skills that we were after, we think that spectatorship is an important experiential situation that one can often come across in engineering practice. It is not always that the moral dilemma happens to the engineer herself, she may be exposed to it by looking at the struggles of one's colleagues. Being a witness for a situation unfolding in one's work environment entails also moral sensitivity and judgement (to intervene or not). This skills of witnessing and then becoming aware that something important morally is at stake is seldom if ever referenced in our EEE teaching. We seem to assume, in our building of case-studies and role-plays, that the student actors are always at the centre of the moral dilemma, that they need to take action. However, many morally problematic situations arise because the by-standers do not take an attitude or are silently complicit. In learning to notice that something morally significant is at stake by watching the scenes of their colleagues and then speaking up their minds, students are able to practice a skill often needed in the engineer's workplace but hardly if ever theorised. These two findings suggest an increased moral agency from the part of the students through the combined effects of witnessing others act and of the creation of a collective safe space for speaking and acting. However, our experiment was limited in scope and duration, and more iterations would be needed for us to confirm the moral agency hypothesis. By comparison, Freiman's course in improvisation for legal students lasted an entire academic year and yielded much more visible results [3].

6 Conclusions

For the teachers wishing to introduce improvisational exercises in their EEE classes, we sketch several recommendations. First, it is advisable to involve professional theatre coaches, such that they can teach the students basic acting skills but also, and more importantly, to impose a certain safe space by encouraging a respectful and open atmosphere whereby students can take the risk of being themselves in front of others. Secondly, while improvisation in the classical sense is about coming up with words on the spot, on the stage, participants noticed an increased sophistication in their scripts once they could rehearse these and rewrite their own scenes. Thus, we recommend that students come up with a script on their own, and then refine the lines in subsequent rehearsals. In the final discussion surrounding the performances, the participants noticed that their most brilliant ideas came in rehearsals. The rehearsal makes possible repetition and gives students a chance to change their mind about the topic at hand. Thirdly, an atmosphere of collegiality, equality and positive support must be fostered from the first session onward because moral awareness thrives in shared spaces of vulnerability. The teachers and trainers should lead by example with positive feedback and support such that students learn to use this tone when they comment on each other's performances. Most of our interviewees commented on how much this supportive atmosphere helped them try out and experiment with new ideas. We hypothesise that a hostile and competitive atmosphere can only annihilate the pedagogical potential of improvisation for allowing the students to engage with a situation from a place of vulnerability and openness, thus leading to disengagement and showing off.

We realise that most teachers working in EEE are not trained to use theatre techniques and will see improvisation as a sophisticated and perhaps too unpredictable type of exercise to even try. However, considering that we use role-play in most of our ethics teaching without prior training in the performance arts, a step further on this path should not be seen as a radical change of method. We see role-playing and improvisation on a continuum of performative techniques that can both be used successfully in the ethics classroom for engineers. While role-playing has acquired the status of a "classical" exercise in EEE, improvisation still needs to be adopted by ethics teachers. Our study was exploratory and did not confirm our initial hypothesis, while it did generate interesting directions to be explored such as the spectator effect and the meaning of shared spaces of common vulnerability. A future direction for research would be then to discover how many classes of improvisation are minimally needed to achieve practice-based skills in the moral domain and how can these be best combined with the other ethics classes focused on the analytical skills.

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ETHICS IS A DISEMPOWERED SUBJECT IN THE ENGINEERING CURRICULUM

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ABSTRACT

Power, as enacted in educational practices, is a critical issue that shapes all aspects of engineering education. Yet, there is little research within engineering education on how power manifests itself in what we teach and how we teach it. In this paper we use engineering ethics education as an exemplar to interrogate how power tacitly influences the practice of engineering ethics education. To infer the status of engineering ethics as an academic subject we examine, theorize, and elaborate on two aspects of power: (1) the internal power relations affecting the education of engineering ethics and how they manifest within engineering institutions, and (2) the exerting power of key external actors in and ways in which they impact engineering ethics education. Our methodological approach relies on autoethnographic data rooted in the perspective of the three authors. The autoethnographic cases are grounded in the authors' own teaching and research practices in engineering ethics education set in the US, Irish and Dutch context. We perform a cross-comparative analysis to reflect further on the impact of power relations on ethics as an academic subject and make recommendations for engineering ethics education research and practice.

1. INTRODUCTION

Power is a concept with a long history in philosophy and in the 20th century made its way also as a core concept for the social sciences. According to Bertrand Russell [1], power is as fundamental for social sciences as energy is for physics. With its long history come several theoretical articulations of the concept, and while it is outside the scope of the paper to posit one understanding of power as correct, we do want to raise awareness of the importance of this concept when considering the intersection between engineering practice and education.

1.1. Theorising power

Theories of power can be categorized as "micro-centric" in their focus on the actual or potential actions of individuals and groups, or "macro-centric" in their focus on the structural context that constrains, enables or shapes individuals. A pluralist stance does not see these different understandings as incompatible, but as providing different analytical lenses (Table 1, inspired by Allen [2] and Sattarov [3]). As such, it acknowledges both the capacity of individuals to make a difference, but also considers how they might be externally determined in their actions, dispositions or beliefs.

Table 1. *Theoretical conceptions of power*

Level	Type	Example
Micro	Dispositional	Power as the property of individual actors to bring about their desired outcome -- “X is able to”
Micro	Episodic	Power as the property of the relation between two or more individual or collective actors -- “X has influence over Y and Z”
Macro	Systemic	Power as structural pressure -- “X is constrained to act this way in her social community”
Macro	Constitutive	Power as a constitutive dimension -- “X is shaped in her social relations by external factors”

1.2. Power in engineering practice

Engineering practice has been described as political [4], inasmuch as it is embedded in power contexts [5], constitutive of power relations [6], shaped by power differentials [7], and a contributor to the distribution of power in society ([8]; [9]).

Nevertheless, we also encounter an epistemic myopia and lack of self-reflectiveness, with Little *et al* [10] signalling that it is “unlikely” that practicing engineers understand the political nature of their work, as well as an absence of discussions of power relations within organisations and how they affect the ends to which engineering is put [11]. More so, it has been argued that this conformity to the employer’s interests and lack of reflective resistance is built into the education of engineers [12].

1.3. Power in education practice

Not only is power essential to engineering practice, it is also enacted in educational practices and shapes all aspects of engineering education. Formal education is one of the central ways in which power and hierarchy are organized in society [13]. Learners learn early how to recognize and perform power, including the negative effects of it, like bias and marginalization [14]. Beyond the micro-context of classroom interactions where power is evident, there is also the macro-context of education and schooling where political power is embedded. Power struggles are encountered over the purpose of education, as well as about the selection and transformation of knowledge into curriculum, and its enactment in the classroom through teaching and assessment ([15], [16]).

1.4. Ethics as an exemplar for exploring power in engineering education

Despite the importance of power in both education and engineering practices, there is little research within engineering education on how power manifests itself to shape what and how we teach. The concept of power has been addressed in higher education studies to a lesser extent than in other disciplines of fundamental social interest [17]. More so, while educators can identify the manifestation of power in practice, this is mostly divorced from theorizing its mechanisms [18], or its epistemic dimension [19]. The concept of power thus appears to be either ignored or under-theorised in higher education research [20].

In this paper, we use engineering ethics education (EEE) as an exemplar to interrogate the issue of power within engineering education. Even when it is not made explicit, power tacitly shapes the EEE practice. Our contribution aims to explore how power is manifest and impacts EEE. To infer the status of engineering ethics as an academic subject we examine, theorize, and elaborate on two aspects of power: (1) the internal power relations affecting the education of engineering ethics and how they manifest within engineering institutions, and (2) the exerting power of key external actors in and ways in which they impact engineering ethics education.

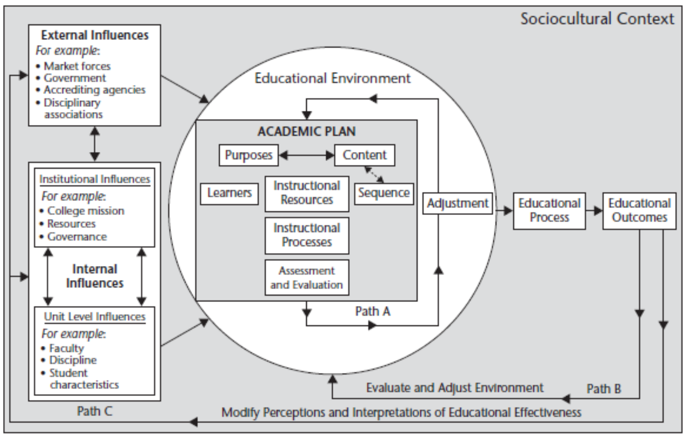
2. METHODOLOGY

To address these questions, we pursue an autoethnographical research approach that brings forward the authors' experiences, recounted against a model of the major influences impacting the higher education curriculum.

2.1. A sensemaking model of power relations in engineering ethics education

For the purpose of tracing the influences impacting EEE and situating our own experiences researching and teaching engineering ethics, we adopted the academic plan model developed by Lattuca and Stark [21]. The model (fig 1) is based on extensive literature review of the intended curriculum in higher education and puts forward a set of clearly defined and inter-related concepts operational at different levels. These are represented by the components of the curriculum itself (i.e. purpose, content, sequence, learners, instructional resources, instructional processes, assessment and evaluation), unit-level influences (i.e. faculty members, characteristics of the discipline, student characteristics), institutional influences (e.g. college mission, resources, governance) and external influences (i.e. market forces, government, accrediting agencies, disciplinary associations).

Fig 1. *The academic plan in sociocultural context (Lattuca & Stark [21], p.5)*



This model allows us to address some of the limitations of higher education research which tends to focus either on individual actors such as instructors or on the levels of institutions, policy and society as independent from each other ([22]; [23]; [24]). The model by Lattuca and Stark [21] also serves a pluralist understanding of power, by acknowledging different levels and manifestations of influence. It also views individual actors, such as engineering ethics instructors, as affected by forces external or internal to their academic environment, but also reacting to them and influencing the academic plan.

2.2. An autoethnographical approach to power in engineering ethics education

To render how these diverse influences play out in EEE, we use autoethnography. Autoethnography is an autobiographical ethnographic method of qualitative research. It is used to recount the researchers' personal experiences, that are then subjected to an analysis of the sociocultural context and of their implications ([25], [26]). The method has a descriptive component, inasmuch as it is "a means of telling one's story", and an analytical component, given the deep introspection involved and the attempts of reporting these experiences in a systematic manner [27]. Its strength lies in the insider perspective into a matter of significance, which might evade other research approaches in which the researcher's stance is more that of an "outsider looking in." The criticality that accompanies recounting is crucial for autoethnography [28]. Through its critical outlook, autoethnographic research can pose a challenge to entrenched beliefs and practices, linking story with theory to the point of merging [29].

The autoethnographic process behind this contribution unfolded between autumn 2020-spring 2021 over several stages:

Preliminary stage: spontaneous, unprompted reflection on how the topic of power is manifested in the authors' EEE practice. The dialogue led to the identification of power in EEE as a topic of concern;
Stage 1: recounting and documenting personal experiences related to the topic;
Stage 2: discussing theoretical understandings of the topic, and agreeing on a sensemaking model to frame the authors' experiences with teaching and researching engineering ethics (see Fig 1);
Stage 3: connecting theory and story, by articulating personal experiences with teaching and researching engineering ethics inspired by the sensemaking model.

3. RESULTS

To report the results of the fourth stage of the autoethnographic research process, we followed Adams *et al.*'s ([29], p.94) advice for connecting story and theory. Theory offers the foundation that guides the recounting of one's experiences and supports the elaboration in a critical manner of their meanings and implications. We incorporate this advice by mapping our experiences against the model presented in Fig 1.

3.1. Power in engineering ethics education in the Irish context

Statement of positionality: Author1 has examined for her doctoral study the implementation, teaching and accreditation of ethics in 6 institutions in Ireland. She also co-taught for 4 years with a social scientist in an Irish College of Engineering a course of professional formation for 1st year students.

The system of engineering education in Ireland is marked by a distinction in prestige between universities and institutes of technology [30]. It is also subject to accreditation by Engineers Ireland, which is an original signatory of the Washington Accord. Engineers Ireland has the double function of an accrediting body mandating the outcomes that engineering programmes across the country must meet, and a professional body representing the profession.

Prestige appeared to play a part in how the institutions offering the title of Chartered Engineer relate to the accrediting body and adapt their curricula to their recommendations. As a newer outcome, ethics started to make its way in the curriculum through the push of Engineers Ireland [31]. The increased presence of ethics following the introduction of a dedicated criterion more than a decade ago has been described as a move “from zero,” from “virtually nothing on ethics.” In my study [32], I “stumbled upon” the fact that the participant institutes of technology appear to have more courses with a contribution to the dedicated ethics outcome than university programmes do, especially high-ranking ones. Is then the focus on ethics in the engineering curriculum an instantiation of *power over,* and the lesser focus an act of resistance by actors who themselves are considered powerful in virtue of a long tradition of alumni, research and university rankings?

How many layers of *power over* can we identify? Indeed, the accrediting body influences the engineering curriculum, at minimum by having a set of broad outcomes that programmes have to meet. At the same time, every accreditation event includes an Employers’ session, the programme submission includes the Employers’ view, and the feedback of Employers is incorporated in recommendations -- recommendations that engineering programmes need to take on board or provide a strong justification for why they had not done so. Analysing accreditation reports and observing accreditation events for my doctoral study, some recurring recommendations were to “strengthen ties with industry” or “introducing employers in the advisory board”. Such recommendations were mentioned in connection with several outcomes, including ethics.

If ethics is an academic subject constituted through a power process, and an outcome of *a power over*, how does it relate to power actors, such as the big corporations set in Dublin which could very well be the Employer of future graduates? Are students taught in a way that serves these actors, or are they also taught to resist them?

What about the instructors teaching a subject that made its way in the curriculum in an unnatural manner, at the intervention of a powerful actor, rather than as an outcome of the beliefs of the faculty body and the programme leadership about what constitutes “good” engineering practice and education? In my study, I encountered instructors for whom the issue of empowerment mattered, as they described “fighting” a decades old battle for having ethics in the curriculum. Having a dedicated accreditation criterion helped them make the case to department leaders for the introduction of ethics in the curriculum. At the same time, the question of empowering ethics as an academic subject also matters, inasmuch as several of the instructors teaching dedicated ethics courses did not opt or did not want to teach ethics, and declare that were they in their students’ shoes, they would not even attend their sessions. What does it then mean to empower an academic subject and through what means?

3.2. Power in engineering ethics education in the Dutch context

Statement of positionality: Author2 is coordinator of a 20 ECTS program in a Dutch technological university. The program aims to raise engineering students’ awareness on users, society and entrepreneurship aspects of technological innovation.

Eindhoven University of Technology started in 2012 a 20 ECTS program on User, Society and Enterprise to raise awareness on these aspects of technological innovation. Back then, these credits shifted from the departments to the general level. EEE in the Netherlands is quite autonomous from accreditation bodies and disciplinary associations. Ethics teachers are not directed towards teaching or controlled to teach a particular vision or topic. From the personal perspective of the second author, we formulate the hypothesis that the resistance to the USE program might have epistemic, university-department and ecosystem power dynamic origins.

First, based on empirical evidence gained during discussions, we can state that, epistemically, many engineering faculty see less the relevance of these ethics and social sciences courses than they see the relevance of their “own” courses. Underlying is probably a more fundamental discussion between two epistemic views. On the one hand, a rational epistemic view considers that facts and engineering experts should be leading in societal discussions. On the other hand, a more discursive view that science and engineering knowledge and experts are one source in a societal decision making process with its particular strengths and weaknesses, next to other sources like democracy, politics, finances, marketing, law, or communication (Jasanoff, 1998).

We hypothesise that this tension is strengthened by a university-department power dynamic. In the financial approach of education of a university, 20 ECTS for the yearly 2000 students is a substantial financial amount. Because of the Dutch and the organisational translations of the higher education financial mechanisms, it therefore is understandable that the EEE discussions become linked with the financial ones.

As a third aspect of influence in this debate, it might be interesting to gain more insights in the role of industry in the ecosystem of the university. Times Higher Education, which ranked universities in terms of their relationships with innovative technology companies (known as Global Innovators), and the amount of scientific papers produced in such collaborations, puts TU/e at the top of this list. As a positive consequence, the close collaboration raises extra funding. It also inserts a tension of scientific independence and autonomy as companies might expect return on investment and might be able to increase their impact on the university as an organisation.

3.3. Power in engineering ethics education in the US context

Author 3: has taught the required ethics course in their program for 5 years and also done curriculum development for the course. They also undertake funded research on EEE.

At its core, in the engineering curriculum in the U.S., ethics is taught largely to fulfil accreditation requirements. Therefore, agencies that accredit degree programs have significant power over what the curricula should include and if it should have ethics. Beyond that there are also power issues and compromises within a local level unit, program or department, about how much space should be given to ethics, in particular, if there should be a standalone course for ethics instruction or if it should be part of other courses. There are negotiations that take place around it and concessions made. The other issue here is who is going to teach, and in my experience nobody really wants to or those who want to only do so for the reason that it might be an easier course to teach (e.g., go through some slides and assign some readings). The biggest power issue is that ethics is not empowered, it is neutral and not even considered something to focus on. This lack of agency and power reflects the space ethics occupies.

It is common to hear that “ethics is very important” as a refrain but not when it comes to making space for it within the curriculum. Why is that? One, it is disempowered because it is not a technical subject and not considered core to the discipline. Second, it is an interdisciplinary topic that does not have easily demarcated boundaries around it and therefore it is harder, compared to a technical subject, to design a syllabus. Third, it projects a certain image of the instructor and within the larger technical enterprise that image is marginalized -- someone who teaches non-technical topics.

Fourth, it brings up uncomfortable discussions with no easy or clear-cut answers that are hard for faculty who are not trained in the topic to lead. Overall, the disempowering situation of lack of recognition within the department; image of a course that someone *must* teach, and lack of resources also makes the course more neutral rather than critical.

From the student perspective, it is a topic which when taught well they find empowering. They are able to discuss topics that they find important, especially once they read about it, and which they are unable to discuss in any other space. In other words, a well taught ethics course puts pressure on other aspects of curriculum and course of study as well. The topics and use of cases from the industry also allow students to make a direct link between what is taught and workplace practices and although this might not lead directly to a job, it does lead to awareness from when students face these issues on the job.

4. CONCLUSION

We present autoethnography as *parrhesia*, a notion of truth speaking as speaking openly about one's own situation and making oneself vulnerable [33]. We know writing about power is sensitive, but we are convinced that this should not be a reason not to do so, especially because of the importance of this concept and its implicit impact. We hope this paper is a genuine contribution to improving EEE.

We see this article as a first reflection on the manifestation of power in EEE. We therefore clearly consider our approach as exploratory. Overall, based on our experiences, we can conclude that there is a strong merit in studying ethics as a potentially disempowered subject in the engineering curriculum. The disempowerment of ethics appears to be the outcome of two main forces, represented by the marketisation of education and the rationalist view on knowledge.

Furthermore, we highlight the importance of several research lines for strengthening our exploratory analysis of power in EEE by the following questions. How do engineers understand social responsibility and whose problems do they focus to solve in their practice? What is the implicit and explicit justification for introducing ethics in the engineering curriculum? How is the role and significance of ethics portrayed to students within their institutions? Is there a gap between the aspirational aspect of what ethics could offer to engineering education and what it actually provides? Is there an ideation gap between how educators teach ethics and how they would prefer to teach the subject? If yes, what is the nature of the constraints affecting educators and what are means to bridge this ideation gap? How can the constraints to engineering ethics education encountered at different levels be reacted to? What changes in public or institutional policy and social practices are needed and what resources and allies can contribute to "empowering" ethics in the engineering curriculum? How can the financial, organisational and ecosystem influences be understood and made more explicit in a way they lead to better engineering ethics education? Further research should prioritize and structure these questions.

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IMPACTS OF INTERDISCIPLINARY ENGINEERING EDUCATION: A SYSTEMATIC REVIEW OF THE LITERATURE

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ABSTRACT

With mono-disciplinary courses, students might have difficulties in understanding the role of the content and methods of multiple disciplines in solving complex problems, such as climate change and global health. Considering existing evidence that interdisciplinary learning environments contribute to student progress in e.g., learning, improving skills, a timely review on their impacts can serve as a comprehensive and convincing rationale for the development of these courses in higher engineering education. This systematic literature review aimed to examine peer-reviewed articles reporting on the impacts of interdisciplinary courses on students. The methods used for the review comprised of three phases: 1) search and inclusion of articles, 2) individual study review, and 3) a cross-study comparison. The key search terms identified to locate articles included “interdisciplinary” and “engineering”. The first phase ended with a screening to eliminate articles using the identified exclusion criteria. We completed the second phase that led to a rubric guided by our inclusion criteria (e.g., goals related to student outcomes, courses in engineering education). Part of the rubric included separate sections for student learning outcomes in the domains; knowledge/understanding, skills, and affect. The rubric then was finalized in the third phase following a cross-study comparison. The results can provide a conceptual basis for improving the current state of interdisciplinary courses in higher engineering education. Finally, researchers will be invited to think of new ways to improve the less positive outcomes that were identified, to assess these outcomes and to enhance interdisciplinary courses for online environments.

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1 INTRODUCTION

Over the past two decades, there has been an ongoing shift towards designing interdisciplinary learning environments in higher education contexts. An important characteristic of an interdisciplinary curriculum is its overarching nature which connects methods and content of multiple disciplines [1]. A holistic approach to curriculum facilitates preparing students as individuals who can better contribute to solving societal challenges, such as using resources, climate change, enabling natural security and health systems [2]. It is becoming increasingly important for higher engineering education to expose students to interdisciplinary learning experiences [3].

Multidisciplinarity, interdisciplinarity, and transdisciplinarity are considered as different types of curriculum integration. As seen in Figure 1, there are different curriculum integration approaches [4]. The fragmented approach is similar to the traditional and structured school curriculum with clear disciplinary distinctions; at the lowest end of integration. Multidisciplinary curriculum has a summative nature, whereas a transdisciplinary curriculum connects the disciplines in a way that their unique content becomes indistinguishable [1, 4]. In interdisciplinary courses, there is a loss of the knowledge and methods of the distinct disciplines, while overarching themes or issues are addressed across disciplines [4]. The content and the methods of multiple disciplines are integrated meaningfully around real-world problems [5]. With a similar rationale as that for the review on interdisciplinary engineering education [6], this review embraced both multidisciplinarity and interdisciplinarity due to their frequent interchangeable usage in higher education course contexts.

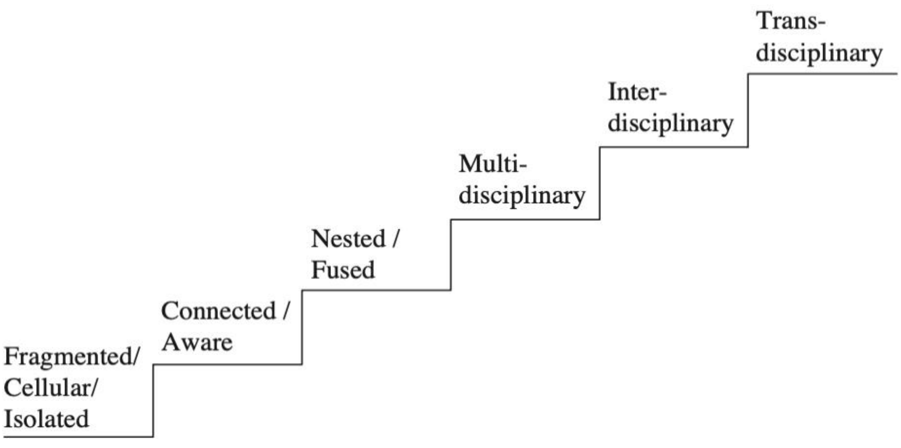

Figure 1. Curriculum integration approaches [4].

Interdisciplinary learning environments are addressed in multiple areas across higher education course contexts, such as health sciences, teacher education programs, social sciences [e.g., 7, 8, 9]. The analytical framework that has been created as a result of a comprehensive review [6], focused on how interdisciplinary engineering education can be best implemented. The review includes three complementary parts: a) vision; the value of and motivation for interdisciplinary education, b) teaching; learning objectives, activities and assessment, and c) support; help provided in terms of teachers, students and the institution. Figure 2 illustrates the details of the three themes of interdisciplinary engineering education.

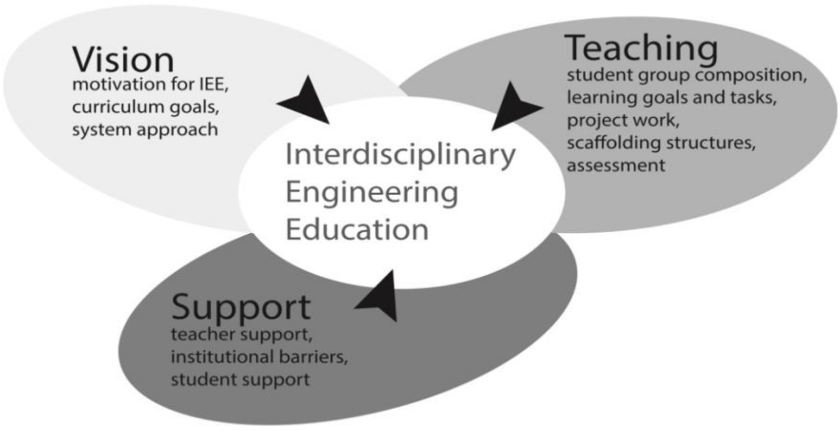

Figure 2. Educational processes of interdisciplinary engineering education [6, p. 511]

Considering the fact that interdisciplinary learning environments contribute to student progress e.g., learning, cognitive skills, competencies to work in multidisciplinary teams [3, 10, 11, 12], a review on student outcomes can serve as a comprehensive and convincing rationale for the development of interdisciplinary courses in higher engineering education. An exploratory study has been conducted on the impacts of interdisciplinary courses on engineering students' competencies [13]. The researchers surveyed a total of more than 4000 engineering students at different time intervals over two years. The findings showed that interdisciplinary coursework had a positive impact on students' leadership skills, interpersonal skills, creativity, and analytical thinking. The authors addressed the need to investigate the influences of similar interdisciplinary learning environments and integrated curriculum activities on engineering students. Integrated curricula have the potential to support engineering students' interdisciplinary thinking and habits of mind [3]. An interdisciplinary course curriculum that incorporated knowledge of neuroscience and engineering was developed [14]. The course content included systems and programming, computation, and neurophysiology. The authors concluded that compared to traditional course structures, the interdisciplinary course they designed for science, arts and engineering students led to an improvement in student learning of the course content.

This systematic review aims to build on the findings of earlier reviews that showed an interest in interdisciplinary engineering education. A literature review previously explored the potential skills and conditions that support interdisciplinary higher education [15]. The list of promising skills and conditions included: a) interdisciplinary thinking e.g., knowledge of disciplines, higher-order cognitive skills, b) student factors; personal characteristics and prior experiences, c) learning environment e.g., curriculum, teacher, assessment and d) learning processes [15]. A second literature review with a focus on vision, teaching and support in interdisciplinary engineering education systematically investigated the articles published until 2017. The authors built a framework helpful for the design of interdisciplinary courses in higher engineering education [6]. Because the schooling system is more commonly structured based on a differentiation of different disciplines, there are concerns about the value and benefits of interdisciplinary approaches [16, 17]. There is a need for further research on the positive impacts of interdisciplinary engineering education, which can eventually be translated into improved interdisciplinary education practices [3]. A timely review can draw attention to interdisciplinary learning environments in higher engineering education by presenting the associated student outcomes. The research question that guided this systematic review was: *What effects of interdisciplinary learning environments on students in higher engineering education have been reported?*

2 METHODOLOGY

This systematic literature review aimed at locating and examining articles published on the interdisciplinary learning contexts in higher engineering education with regards to student outcomes. Adopting a systematic review method helps researchers access, critically examine and synthesize existing research studies [18].

2.1 Phase 1: Search and Selection

The first step in the systematic review included identification of key search terms guided by the goals and the research question of the review. Multiple searches were conducted in the following databases: Web of Science, Ebscho, Proquest, Scopus, and Science Direct. The following key words and their combinations were used during the search trials: “interdisciplinary”, “multidisciplinary” “engineering education”, “students”, “courses”, “teamwork”, “teams”. The review was limited to peer-reviewed articles published between 2000-2021. A total of more than 1000 articles were located as a result of the initial search in the databases. Rayyan (https://www.rayyan.ai) is used for the initial screening and later the full-text examination of the articles. Removal of the duplicates resulted in 751 articles. Next, based on the objectives of the review, five criteria were identified to exclude the following: a) commentaries, book chapters, reviews, reports and conference proceedings, b) articles that do not discuss interdisciplinarity but rather focus on other construct and contexts e.g., distance education, problem-based learning, creativity, c) articles that only address other disciplines/programs (e.g., science, social sciences, health sciences, teacher education) rather than higher engineering education, d) articles on K-12 education and graduate courses, and e) articles not written in English and/or could not be reached full-text. Application of the exclusion criteria significantly decreased the number of articles to 332. As a final step for this phase, 16 articles were added from manual searches in Journal of Engineering Education and European Journal of Engineering Education.

2.2 Phase 2: Individual Study Review

During the second phase; *individual study review,* three inclusion criteria were specified. Identification of the inclusion criteria helped to retain articles eligible for further in-dept examination [18]. Accordingly, to be included in the further steps of this review, the articles had to: a) use a higher education interdisciplinary course, project, (learning) module, activity, or multidisciplinary teamwork as its context which engages engineering students; b) sufficiently present how their context is structured/organized; e.g., course curriculum/materials, elements of multidisciplinary teamwork, conceptual background on interdisciplinarity, etc., and c) report on student outcomes. During the application of the three criteria, the rationales for not including the articles included: solely describing a course or a framework development process and focusing on interdisciplinary research rather than an interdisciplinary learning environment. Using the complementary inclusion criteria, a total of 90 articles were retained.

To facilitate identification of the articles that are specifically linked to the research questions of this review, a quality assessment was also established [18]. The quality assessment was used to decide whether the articles presented sufficient details to be included in further individual analysis. The 90 articles were evaluated using a Quality Assessment Checklist [18, p. 127, 19, p. 742].

Table 1. Quality assessment checklist

	Questions/Indicators	Yes 1	No 0	Unclear 0.5
Objective(s)	Is the research objective clear?			
Method	Is the research context clearly described (e.g., participants, location)?			
	Do the authors state the research methods?			
	Do the authors give an argument for the methods chosen?			
Data	Is data collection clearly described?			
	Are the data analyzed adequately and pricesly?			
	Do the authors report on reliability and validity of the research?			
Conclusion	Are the findings on student outcomes supported by sufficient empirical evidence?			

For each of the indicators on the Quality Assessment Checklist (e.g., is the research objective clear?), the articles will separately be assigned scores; 0: no, 0.5: unclear and 1: yes. 68 articles in total that received more than half of the total score possible were included in the next step.

2.3. Phase 3: Cross Study Comparison

For the final phase of this systematic review; *cross-study comparison*, a rubric is created that includes the categories and the codes for use in the organization and synthesis of the findings [18]. The initial version of this rubric is presented in Table 2. This rubric is based on: a) an initial full-text examination of the 68 articles, b) research questions of this review, and c) the relevant literature. The frequencies and the percentages of the categories and the codes were calculated based on occurrences across the articles [18, 20]. The rubric will be refined for its final version as the authors will complete several more rounds for individual readings of the articles.

Considering trustworthiness, a clear description on how the articles are accessed, eliminated and coded, is provided. The authors are completing the full-text analysis of the articles individually. The rubric is being finalized based on the authors' discussions. An inter-rater reliability score of .80 was calculated as the authors scored the articles during quality assessment [18, 19]. In addition to conducting a reliability check, the meaning of the codes for each researcher will be discussed for the second time after a meaningful period of time (Fraenkel et al., 2012).

3 RESULTS

This rubric containing the frequencies and the percentages for the categories and the codes for 68 articles can be examined in Table 2.

Table 2. Rubric with categories and codes

Categories	Codes (with frequencies and percentages)
Disciplines	Single engineering discipline (n=4, 6%) Multiple engineering disciplines (n=24, 35%) Engineering and other disciplines (n=40, 59%)
Context	Interdisciplinary course (n=38, 56%) Other project-based courses (n=18, 26%) Extra-curriculuar contexts (n=12, 18%)
Anchors	Problem/challenge (n=51, 75%) Teams that represent multiple disciplines (n=58, 85%) Other (e.g., game, activity, research) (n=12, 18%)

Student outcomes	Beliefs and attitudes (n=42, 42%) Understanding and knowledge (n=24, 24%) Interdisciplinary construct (n=15, 15%) Design products (n=13, 13%) Teamwork skills (n=6, 6%)

The preliminary categories are: disciplines, student outomes, context, and anchor. The first category focuses on the disciplines represented by the students in the interdisciplinary learning environment. Initial examination shows that in some of the articles a single context borrows from the knowledge of multiple engineering disciplines in (e.g., computer engineering, mechanical engineering), whereas majority of the articles report including students from multiple disciplines that included other disciplines in addition to engineering e.g., STEM disciplines, architecture, design, nursing, social sciences, business, computer sciences. The third category; context, reports on the structure of the interdisciplinary learning environment. Results revealed that in majority of the cases, the articles described an interdisciplinary course design. The other interdisciplinary learning envrionments included other project-based courses, trainings, interventions, workshops. In great portion of the articles, multiple disciplines were integrated around a problem or a challenge (75%). Having students with multiple disciplinary backgrounds working tohether in teams is another anchor that is commonly used in interdisciplinary learning envrionments (85%). The final category illustrates the student outcomes in relation to an interdisciplinary learning environment.

4 SUMMARY

This systematic literature review aims to provide an overview of the interdisciplinary learning environments in higher engineering education with regards to student learning outcomes. Systematic reviews are helpful in summarizing and organizing a large body of existing research [18]. This review follows three phases: 1) search and selection, 2) individual study review, and 3) cross-study comparison. For the first phase, searches in multiple databases were conducted with identified keywords. The second phase entailed a further individual examination of the retained articles by using inclusion criteria. The quality check was carried out using a Quality Assesment Checklist with four general indicators: objective, method, data, and conclusion. Following the quality check, the authors are working on the third phase; cross-study comparison. As a result of a preliminary screening, the initial version of the rubric is constructed with frequencies and percentages (see Table 2). With minor modifications, the final version of the rubric will be created after more rounds of individual reading and coding of the articles. Following the creation of the final version of the rubric, the authors will construct a two-dimensional matrix that will show the relations between the identified codes. Based on this matrix, future directions will proposed for developing interdisciplinary learning environments in higher education.

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KNOWLEDGE DYNAMICS IN PROJECT-BASED LEARNING: AN ETHNOGRAPHIC CASE STUDY OF MULTI-DISCIPLINARY ENGINEERING GRADUATE STUDENT TEAMS

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ABSTRACT

What is going on in student project teams? How do students acquire, exchange, and integrate the knowledge necessary to collectively perform a given task? Although knowledge dynamics play a decisive role in project-based learning (PBL), they may happen during and/or between classes and thus take on diverse forms that are often difficult to track for students and teachers. Based on ethnographic research with in-

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situ observations and interviews, this paper sheds light on the knowledge dynamics of engineering graduate students in PBL courses beyond formal design reviews and graded project deliverables. The overall plot of the PBL-course mirrored quasi-real industrial work processes where lecturers acted as potential investors from industry. Our data suggest that knowledge dynamics in this context are related to two factors: (1) the individual student's learning aspirations and (2) the evolving salience of distinct (functional) roles and knowledge resources amongst the team members. We have distilled the findings into an improved educational concept to support working and learning in product development projects and will discuss the potential of ethnographic methods for research in and evaluation of PBL. In reaction to the pandemic, we have furthermore re-designed the concept to support online learning.

1 INTRODUCTION

Given the convergence of mechanics, electrics/electronics, software, and services in product design, product development increasingly demands the combined effort and knowledge exchange of different disciplines. This is not only a challenge for product development teams in industry, but also for university instructors who want to convey the necessary skills to their students. To do so, they, for instance, use project-based learning (PBL). Based on previous studies and conceptual considerations about knowledge dynamics in engineering teams [1] we report results of an ethnographic study to gain deeper insights into the everyday knowledge dynamics of students in PBL courses that is not captured in formal design reviews and graded project deliverables. We have distilled the findings into an improved educational concept to support working and learning in product development projects and will discuss the potential of ethnographic methods for research in and evaluation of PBL.

This paper commences with an overview of related work in the field and the set-up of the PBL course for our case study (Section 2). A description of the ethnographic study design (Section 3) is followed by the presentation of the results (Section 4), which are discussed in section 5 followed by concluding remarks (section 6).

2 BACKGROUND

2.1. Knowledge Dynamics and PBL

As knowledge is generated and applied by individuals in groups, successful product development teams must be able to share and negotiate increasingly heterogenous knowledge [1]. To convey the necessary skillset and to increase students' job readiness [2], PBL, which engages students in meaningful projects and the development of real-world products, has become a central element of engineering education [3; 4]. Consequently, several frameworks have come to the fore [5] and recent publications discuss the issues associated with PBL in engineering education [6] and the current status of PBL in Europe [7]. Other studies have focused on the perspective and experiences of teaching staff in PBL [8; 9] and the student's perspective on PBL in relation to specific topics such as sustainability [10;11], collaboration [12], and motivation [13]. To our knowledge, there is no research to date on what graduate students actually do in PBL engineering education projects in relation to the knowledge activities they perform. Although field-based methods such as in-situ observations are ideally suited to shed light on actual work practices, they have so far played a marginal role in the evaluation of PBL (a recent review by Guo et al. [14] reported that only two out of 76 studies have used observation-based methods).

2.2. PBL in a multidisciplinary Engineering Project Seminar

The engineering project seminar in focus is specifically designed to train students abilities for knowledge integration and to foster collaboration within multi-disciplinary teams. A project team comprises 9-12 students and works through the entire product development process from the initial idea to the implementation of a real prototype. The members of the project teams have different engineering backgrounds and are enrolled in either of two modules. Both modules are part of the engineering Masters programs at TU Berlin and have either a management focus (“Development and Management of Digital Product Creation Processes (EMP)) or a development oriented focus (“Applications of Industrial Information Technology (AIIT)). The combination of these two modules within a single PBL set-up (fig. 1) provides students with an opportunity to experience the challenges arising from the different tasks, interests and priorities that can be found in actual product development projects in the industry.

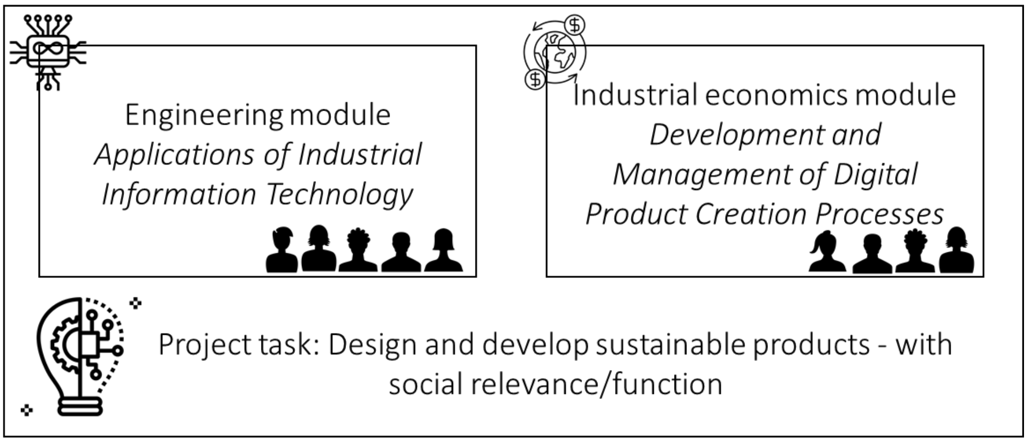

Figure 1: Overview of project team compositions in the PBL Course

The projects we studied ran from October 2019 until February 2020 (Winter Semester 2019/20). In total 47 students (22 from the EMP module, 25 from the AIIT module) formed 5 project teams. Their main task was to design and develop sustainable products with a socially relevant functionality. The product should support mental activity and learning for young children or help to maintain the memory capabilities of elderly people. The overall outline of the course mirrored quasi-real industrial work processes and functions: the lecturers acted as potential investors from industry during the design reviews and the project teams were given a budget to procure the parts required to produce a prototype. In two design reviews the teams presented their ideas and had to defend their concepts in challenging discussions as if their team would compete for the investment. The product concept and final prototype were assessed on the basis of ecological sustainability (use of sustainable materials) and economical sustainability (needing as few money as possible), the fit-to-purpose of the product (stimulation of cognitive ability) and the operational performance during the project (team work, division of work time). In order to gain insights into how the project teams worked and the knowledge dynamics within them, an ethnographic study design was applied.

3 METHODOLOGY

3.1. Research Design

Ethnography is a method originating in the social sciences. The idea is to gain insights into practices through presence in the social setting of interest, that is, by "walking a mile in the shoes of others" [15]. For research on students' activities in PBL-courses we used in-situ observations, as this method allows for maximal flexibility to adapt data collection to the dynamics of project team interactions.

The study design was developed as part of a research seminar for advanced students in the Human Factors (HF) MSc. degree at TU Berlin. A small group of eight HF students was trained to apply ethnographic methods and then assigned as participant observers to one of the five engineering student PBL project teams for the duration of one semester. The research question focused on the knowledge-related activies among the team members. The project teams were fully informed about the purpose of the study and that student researchers participated in the project team meetings, observed construction sessions, and were included in the communication threads before the design reviews. The researching students were often seen as part of the team, which enabled them to experience the everyday work of the PBL-course participants.They also conducted semi-structured interviews with members of the PBL teams based on an interview guide jointly developed with the course instructors to complement the observational data. The data collection took place from October 2019 to February 2020 and encompasses 160 hours of observation and 40 interviews (each lasting 20-30 minutes). The interviews were held with 4-5 members from each team. The HF students chose their interlocutors on the basis of the observed interaction activities and mixed views from active and more quiet team members. Partially the same students were interviewed twice (i.e. at the beginning and the end of the project) to get first-hand views on the transition of roles and responsibilities within the group.

3.2. Data Analysis

Data analysis was inspired by Grounded Theory [16] with several data coding iterations, using a software for qualitative data analysis (AtlasTI Version). Each student initially reviewed their own ethnographic data and then developed a first set of emic codes, i.e., data-driven code categories. In joint data analysis workshops we deduced recurring topics and patterns related to Knowledge Dynamics from the initial codes. Then, a more analytical perspective was developed to come up with conceptually-driven codes. These codes were grouped and re-grouped over the course of the analysis process, and the results from the individual HF-student projects were then collated into two overarching themes consisting of multiple subthemes.

4 RESULTS

In the following, we elaborate the two overarching themes that shed light on knowledge dynamics in student project teams: the student's individual learning aspirations (1) and the salience of distinctive (functional) roles and knowledge resources amongst the team members (2). To illustrate the lived working practice in student teams and the performed knowledge dynamics/activities with respect to each theme, we present exerpts from our ethnographic study.

4.1. Extension vs. Intensification: Students' Learning Aspirations

The first theme relates to students' individual learning aspirations and expectations for the project. The data from observations and interviews suggest that students' learning aspirations can be positioned on a scale between the acquisition of new knowledge and skills (extension) on the one end and the improvement of existing skills on the other (intensification). In general, however, students performed those tasks that primarily required their existing knowledge and skills as a way to obtain the best possible grades as a team. This objective overruled individual interests to acquire new knowledge and skills, as the following interview quote illustrates[2]:

> *I: You have distributed/assigned the work tasks in such a way, that the people do/execute the things they are able to do, did I get that right?*
>
> *S: Yes. Self-evidently that's not ideal for the learning progress, but for the project's progress you want to make sure to get the best possible grade. We are here to get good marks. Of course we also want to learn, but we seek to utilize the strenghts [of everyone] to have a solid result at the end. (Interview S1)*

The student's assessment in the quote is in line with data from the observation of project team meetings where the task distribution was discussed with a strong focus on existing expertise and the interpretation of what might be expected by the lecturers to receive the best grade for the output. For some topics such as sustainability or specific project management tasks, the teams could not rely on existing expertise of one of their members and hence the sudden need to extend knowledge arose. Although the students felt that they primarily intensified existing knowledge rather than amplyfying it, the evaluation of this circumstance varied substantially.

> *„I am comfortable with the tasks assigned to me in this project, I'm fully capable to fulfill them as that's what I have done before in other contexts. So principally I am happy with this, but I would have also liked to have a new challenge.“ (Interview S3)*

This person clearly expresses the aspiration to expand the knowledge base instead of intensifying existing skills. A fellow student from another project team, however, expressed a different view:

> *"I'm almost at the end of my studies and I know which topics I want to focus on. Therefore, for me it was a matter of getting better within my focus area and not necessarily to develop expertise for completely new topics." (Interview S4)*

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[2] The interview quotes have been translated into English by the authors from the original data set.

The students‘ learning aspirations for the Project Seminar are thus strongly dependent on individual preferences and possibly how advanced they are in their studies. The assignment of tasks in practice is, as illustrated above, mainly influenced by the project teams‘ objective to obtain the best possible grades and thus based on the question who might be able to complete the task with the best possible result. This practice does not always overlap with the students‘ individual learning aspirations: Not everyone who wants to learn new skills gets the opportunity, whereas others who might want to intensify their existing skill set may have to expand knowledge in hitherto unknown areas. Knowledge dynamics and the corresponding activities within the project teams are thus taking place in a field of conflict between students' individual learning aspirations and their objective to obtain good marks.

4.2. Negotiating functional Roles within the Team

As one of their first tasks, project teams are required to submit a list with the functional role(s) assigned within the team. The roles (e.g. Project Lead, Construction Lead or Sustainability Expert) are a central didactic element of the PBL approach as they are a way to create a quasi-realistic set-up for students' project work. Usually, the assignment of functional roles is initially understood as a task that has to be completed, rather than an integral part of the project formation process as illustrated by a vignette from a team meeting during the early project phase and an interview quote:

> *The team's discussion shifts to a new issue: "Ah, and let's distribute those roles prior to the design review. The lecturers seem to be extremely keen on them." The remark immediately triggers a discussion about the plausibility of the roles. The team members are in doubt whether the areas of responsibility for the different roles are clearly demarcated. (field notes team meeting A3)*

> *"The distribution of roles is somewhat artificial and far-fetched. Well, it was required, so we did it. But in fact we are jointly working together on the tasks. So in the end we are effectively all doing the same." (Interview S12)*

The interview quote refers to the fluidity of roles amongst team members who are directly involved in the technical construction and development of the prototype: students reported that it frequently happened that when a fellow student was asked for feedback they ended up actively working on the task together instead of just providing feedback to their peers. The students recognized, however, a clear distinction between the roles and tasks associated with project management. Especially the role of Project Lead started to stand out over the course of the semester – not always positively, but in a multi-facetted way that was clearly distinguished from other roles:

> *"Our team lead is the communication hub to the outside world [i.e. lecturers]" (Interview S22)*

> *"I am not so content with our team lead as I don't have the impression that he has an overview on what's going on in the different work streams and is closely following up on the tasks." (Inteview S14)*

Although the last quote is critical, it implies an expectation of what kind of activities should be performed by the Project Lead and hence the recognition of the role as a relevant part of the team. In particular, the challenging atmosphere created by the lecturers in the Design Review sessions seemed to foster the crystallisation of the

Project Lead as a distinct role over the course of the semester. Our results thus suggest that, while at the beginning students perceived the distribution of functional roles within their teams as a rather artificial requirement, more clear-cut expectations seemed to emerge over time with respect to roles, which coordinate and communicate tasks within the team and with outsiders.

5 DISCUSSION AND RECOMMENDATIONS

The students individual learning aspirations vary on a continuum between intensification of existing knowledge and the extension of knowledge to new areas. Our data suggest that these aspirations are not always met in project teams, because students' primary goal is mostly a top grade and this goal might be harder to achieve when learning curves may result in less efficient knowledge activities at least at the outset. On the one hand, these results speak to the value of grades, which apparently functioned as a target unifying the project teams and aligning their everyday working practices. All students strived to achieve the best possible grading for their project deliverables, and this was a common goal they were all working towards. This goal overrode students' individual learning aspirations as tasks were preferably assigned to team members with an existing skillsets.

On the other hand, the results highlight that "knowledge and skills" are primarily categorized by the students as technical or project management skills (such as programming micro-controllers or resource planning). Less quantifyable, meta-level skills and experiences such as teamwork and adaptive communication strategies students did not necessarily perceive as knowledge. This finding relates to a wider discussion on the re-adjustment in engineering curricula to more explicitly target the acquisition of soft skills [17]. Further research to understand students' perception and differentiation of these skills could feed into the successful design of communication and training formats to foster the wider acceptance of soft skills as relevant for professional excellence in engineering practice.

At the beginning of the semester, students furthermore tended to perceive role assignments as an artificial structure imposed by the instructors, which was incongruent with their lived working practice and the way how tasks and deliverables were completed. Yet, over time the emergence of subgroups focusing either on project coordination or product development fostered the perception of distinctive team roles. The relatively large team-size (9-10 members) might have had an impact on the results as the ability of the teams to set up an efficient organisation was decisive. For future research, a comparison with smaller teams would be necessary, yet the ability to manage work within large teams is also a challenge the aspiring engineers would have to overcome in the industry.

The results yield three practical implications for an improved design of PBL courses: (1) In order to support the individual skill development of the students a balanced distribution of experience and skills across the project teams is necessary to shorten the group finding process and more clearly allocate roles and responsibilities within the teams. This could be achieved by lecturers assigning the students to a team based on each student's expectations, goals, experience and skills as stated prior to the beginning of the course. (2) Reducing the number of management-oriented students while increasing the number of development-oriented students may not only mirror more closely the situation in the industry but also simplify the role identification process as there are now clearer responsibilities within the teams due to an increase of development-related tasks and the decrease of management tasks. (3) Providing a more precise fit of individual work packages and tasks to the functional roles within the team could help to overcome the spontatneous shifts of responsibilities and lead to a more continuous role structure within the teams. To account for a fully virtual teaching situation, the work instructions should be provided in written form and also with documentation templates corresponding to the tasks given (e.g. for the documentation of decisionmaking and development processes). With these changes the student teams should not only be able to install functional roles and assign tasks to individual members more directly but also to stay on track with project management while allowing for and encouraging creativity within those margins.

6 CONCLUSION

This paper illustrates the lived working practice of engineering student teams and the knowledge dynamics emerging in PBL courses. The results revealed opportunities to improve both the setting of the PBL course as well as the evaluation method: Firstly, the formation of the project teams and the functional roles within them would benefit from a centralized assignment of project roles by the lecturers to reduce role-finding conflicts, a more balanced team structure and to incorporate students' individual learning aspirations. Secondly, in-situ ethnographic observation and interviews have proven to be a suitable method for research on students' activities in PBL-courses, as the different observation and interview phases allowed for insights into the lived working practice of student teams.

The study therefore contributes to existing scholarship by providing a student-centred perspective on PBL courses and the knowledge dynamics at play in the project teams. It furthermore highlights the potential for further observation-based research into the role of hard vs. soft skills and the related learning expectations of engineering students to help adjust future teaching curricula to include a balanced combination of both hard *and* soft skills. How to best assess and judge the likelihood that digital engineering task requirements are met by engineers with varying capabilities for managing knowledge dynamics remains, however, an open methodological question, which invites further research in this field.

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HAVING IT ALL: AUTO-GRADERS REDUCE WORKLOAD YET INCREASE THE QUANTITY AND QUALITY OF FEEDBACK

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ABSTRACT

Due to COVID-19, teaching has moved online at an accelerated pace, and this movement will partially be permanent. Online teaching implies an automatic assessment of exercises. Using automated grading, the studied web development course (N=257) managed to serve students promptly and increase the amount of feedback received by students even if the number of submissions increased remarkably.

Automatic graders guaranteed the uniformity of feedback, equal treatment, and most importantly, reduced the routine work of the personnel. Being less burdened, the course personnel could concentrate on assisting students in online discussion channels, where discussions were targeted for the students needing more help and support. Compared with previous manually assisted course implementations, the workload moved from "in situ" to prior to the course, where the most laborious part was the design of the exercises and the implementation of automatic graders. The amount of work for grading the exercises and assignment was decreased by about 70 per cent.

In the graders, the feedback given by them is of paramount importance and should suggest necessary improvements. The graders enforced good coding conventions and other targets set for the code (e.g., maintainability and accessibility). In some cases, this feedback was modified during the course based on the difficulties experienced to give more targeted advice. Automatic grading provided a way for students to iteratively improve their code based on the feedback. The software and methods used in this course could be applied to such other courses and domains, where automatic grading is considered helpful.

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1 INTRODUCTION

The International Association of Universities (IAU) studied the impacts of COVID-19 on higher education institutions (HEIs) and reports about remarkable changes worldwide, e.g.: 59% of HEIs have ceased all on-campus teaching, and two-thirds of them reported replacing classroom teaching with online distance teaching. While acknowledging the difficulties of these transitions, the study findings highlight the opportunities afforded by "more flexible learning possibilities, exploring blended and hybrid learning, and mixing synchronous learning with asynchronous learning." [1] The effects of COVID-19 may not be only temporary, but are anticipated to alter educational practices permanently.

Even before the pandemic, the trend had been in the direction of online education and larger student groups. For example, in 2019, the Finnish Ministry of Education set a goal of utilising digital environments and artificial intelligence in learning on a larger scale [2]. In the studied Web programming course, hereafter WebDev1, the goal legitimized the effort to make all the exercises automatically graded. In the previous course implementation, the grading of weekly exercises was already automatized. In this implementation, the effort was made to automate the grading of the assignment and exam as well.

In online learning, students often need to be more autonomous, as scaffolding from the course personnel is only available in online forums. Lecture slides and links to internet materials were provided. Also short hands-on and lecture videos were created – short, because cutting the material in shorter portions has proven to increase student engagement in the earlier studies [3–5]. While adherents of 'flipped learning' promote shortening videos with one voice, other details are still under debate, such as, which length then is the most optimal (according to Bergmann five minutes [4]), and whether the same size fits all (males and students with learning disabilities tend to favor shorter videos [5]).

Programming exercises need to be designed and instructed so that a student can do them with as little additional support from the course personnel as possible. In addition to well-structured exercise instructions, exercise graders should provide sufficient feedback for students. In order to cover most potential error sources in student's code and to give proper, actionable feedback for fixing them, grader's code may be many-fold compared with the student's submission. Often the code for an exercise's grader would have several hundreds of lines of code, whereas complete student submission to the exercise could be well under a hundred.

In this article, we compare the time required by automatic vs. manual grading, and discuss the effect the automatic grading had on students' code quality. We also compare the course's processes and tools to those used in the software industry, as a way of validating these choices.

2 RELATED WORK

Peer reviews and automatic grading are two of the methods which have been studied for lessening the personnel's workload on courses with scarce resources. In an earlier implementation of the WebDev1, automatic grading was used in the first half of the course and peer-reviews in the latter. In the course's post-survey, students' attitudes towards automatic grading were more positive than for peer-reviews. [6]

Obviously, manual grading requires more teaching resources if the number of students increases [7]. However, teaching resources are not that easily available, and if inexperienced TAs are extensively used, the quality of feedback and the variety in given points start to increase, leading to unequal treatment of students. In their study, Leite et al. claim that students who received human feedback perform slightly better than those who receive automatic feedback [8]. Quiz and exam results, and course grades showed human feedback led to better conceptual understanding and better performance overall. As a result, the study deduces that human-provided feedback about the relation of the syntax and logic in students' code could be a primary mechanism for human feedback to improve learning outcomes.

Software quality is a widely studied field, Boehm et al. formed the Software Quality Characteristics Tree from the related terms [9]. Related to software quality, the feedback given to the student's code submissions can affect their learning negatively or positively, positively if it helps them on their path to good performance and better code quality.[10] Feedback in the teaching of programming has been studied earlier, for example Stegeman et al. suggested a rubric for feedback [11], as do Marceau et al. when studying the effects error messages had on learning[12]. The effect of the feedback on the software quality in the context of a university programming course. There is a tension in teaching programming in university: how much of the teaching should concentrate on the pure theory, and how much time should be given to teaching practical programming skills.[13], usually students prefer to rapidly learn coding skills which lead to employment. This tension can partly be eased by selecting tools and processes for the course which are already in use in the industry.

Plussa development has been paralleled with a study of different exercise and assessment methods and their pedagogical value. In addition to auto-grading, various learning activities such as visualizations of different algorithms [14, 15] and runtime behaviour [16] have been on focus. Runtime visualizations illustrate, e.g., call stack and heap behavior while executing code (e.g., Annotation editor exercise about recursion). Visualizations are an apt tool for lowering the threshold of difficult topics, and, e.g., WebDev1 exploited Loupe - event loop visualization in internalizing the JavaScript concurrency model. However, visualization systems are often short-lived research prototypes where the user controls the program animations [17]. Yet these comprehension aids are good for novices, but more advanced students, such as in WebDev1, do not need toys but real tools for gaining experience. The writers demonstrate the utility of GitLab as a dissemination and grading tool in integration with Plussa learning management system [18]. Since GitLab also provides some DevOps capabilities, WebDev1 aimed at acquainting students with these DevOps practises, i.e., to teach GitOps on the side. GitOps could be further extended with Kubernetes, which would provide a fully-fledged automated orchestration solution for the courses of Web&Cloud domain [19].

Inspired by the earlier studies, we set the following RQs:

1. How do the TAs workload and the intensity of work differ in automatically graded courses when compared to those that are manually graded?
2. How does auto-grading affect the quality of code?
3. Are the course's processes and tools similar to ones used in the industry?

3 RESEARCH CONTEXT

WebDev1 provided a comprehensive introduction to both front-end and back-end web technologies: front-end technologies consist of HTML5, CSS, and JavaScript, whereas the back-end introduces Node.js. Unlike previous years, the utilization of Node.js frameworks, such as Express and Handlebars, was omitted. Instead, the vanilla JavaScript approach was used primarily for pedagogical reasons: frameworks come and go, but HTTP and generic client-server architecture will stay. The course is targeted to third- and fourth-year students. The prerequisites for this course include three basic programming courses, and a basic database course. Prerequisites imply that course participants should have a considerable amount of programming routine, including a basic understanding of project work, e.g., Agile project management.

The WebDev1 course will be developed in iteration cycles twice a year. The development started in the 2019-2020 academic year [6]. In the next academic year, it was continued by the introduction of auto-graders for assignment containing both unit tests but substantially more static code analysis. Cyclic development with reflective redesign phases is characteristic of design-based research (DBR) [20] [21] [22]. DBR mandates a guiding background theory, and this study leans on the previous findings of flipped learning in the course arrangements [23–25]. In DBR, educational solutions are combined with the empirical interventions and proof: DBR systematizes course development cycles of *design, development, enactment, and analysis* [26–28]. Here the *cycle* represents a course term. The retrospective analysis inserts requirements into the design of the next implementation [29–31]. The redesign implies *'reflective conversation with the situation'* [32], whereby course personnel observe the effects of new arrangements and refine them if necessary.

The study was conducted during the global COVID restrictions, where moving to remote teaching was a general recommendation. Thus, WebDev1 course replaced previous lectures with video recordings and on-premises tutoring with online tutoring sessions. Students struggling with the exercises or the coursework assignment could get help during these so-called Kooditorio sessions, which were held in Teams. Kooditorio is a tutoring practice a-kin to primetime [33], except voluntary, where teachers and assistants answer questions, debug and co-implement students' code and scaffold them finalizing their exercises.

3.1 Tools used: Plussa and Gitlab

Learning management system Plussa was used during the course [34] to host course materials such as slides, exercises and videos. The videos handled the subject matters of the week, and were largely based on the lecture slides. A few selected topics were introduced by visiting lectures, such as accessibility and security. For some weeks there were also hands-on videos, which demonstrated using specific technologies. Personnel were inspired by the principles of flipped learning, where short videos and related exercises take turns.

In addition to Plussa, Gitlab is a central tool throughout the course. Gitlab functions as a normal version control system, but also provides means for project management and DevOps. The course personnel create students' and groups' Git projects to Gitlab using an in-house tool named Repolainen. Plussa submissions are done by giving the GitLab URL of one's repository. Repolainen is also in charge of communication with other systems, such as Gitlab, or SonarQube static code analysis.

The creation of the student repositories is done at the beginning of the course, group repositories are created after group formation. To create them, Repolainen is fed a list of students, or group's members. Course personnel are given maintainer level permissions, students are granted developer permissions. CI pipeline was introduced to the students, as they will go deeper into DevOps in their further studies. Gitlab CI pipelines are configurable with the .gitlab-ci.yml file. This file could be edited by the student groups in their own repository. Exercise instructions were either in Plussa or in the Git upstream repository, sometimes in both. The 'course upstream' is a Gitlab repository for pulling only. Course personnel maintain the upstream, new instructions and possible file skeletons are released at the beginning of each exercise round.

The assignment started with the creation of GitLab group repositories. Gitlab Issue Board was recommended as a tool for project management to coordinate tasks. The Issue Board provides a Kanban-like issue management view, where issues can be moved in steps from the backlog, to the 'Doing' and finally to the 'Closed' board. These moves inform other group members not to touch on-going work. A couple of Plussa exercises were used to orient students in using the Issue Board. In the assignment instructions, the required documentation included an appropriate use of issues: groups were advised to list user stories as issues, and assign tasks in the Gitlab Issue Board. All in all, when correctly applied, issues provided a panoptic view of the progress of each group.

3.2 Automatic grading

To complete the course, students had to pass weekly exercises, a coursework assignment, and an exam. The maximum course grade was five: +1 for weekly exercises, +2 for assignment, +2 for the exam.

The grading of exercises and the coursework assignment was automated where possible. Without automation, the amount of work would have been enormous, the theoretical maximum total number of submissions was 205.600. Course personnel of three could not have assessed this number of submissions manually. Maximum number of submissions $N_{subs.}$ can be calculated using equation 1:

$$\begin{aligned} N_{subs.} &= N_{students} \times N_{modules} \times N_{exercises/module} \times N_{subs./exercise} \\ &= 257 \times 10 \times 8 \times 10 = 205.600 \end{aligned} \tag{1}$$

The level of automation has increased remarkably during successive course implementations: in 2019 half of the course was auto-graded [6]; in 2020 everything but documentation and 'UI wow' were auto-graded.

For the coursework assignment students were paired, which resulted in 257/2 = 129 groups. In 2020, the groups implemented on-line shops. Exercise rounds eight through ten comprised the mandatory part of the assignment: having passed the tenth exercise round students received a passing grade for the coursework assignment. Then students chose either to accept this result or to continue to higher grades. This can be interpreted as a partial application of flipped assessment [35]: students can 'select' the grade they are after. Level1 implied a grade one for the assignment. The level 1 assessment was fully automated including Mocha tests and JSDoc linting. Level2, in turn, implied a grade of two, and also contained parts left for course personnel to assess manually, such as the quality of documentation and the usability and prestige of UI, the so-called 'UI wow'. Level2 cumulatively adds more automatic tests to Level1, with automatic graders for functional programming, eslinting, static code analysis with SonarQube, and coverage.

Fig.2 illustrates the process of auto-grading. Process starts when a student commits code to Gitlab, and then submits their Gitlab URL on an exercise page in Plussa. As a system, Plussa divides into two parts, both run as Docker containers: Plussa frontend "run-aplus-front container in the picture", and MOOC grader, "run-mooc-grader". Plussa frontend provides the UI, and maintains a grade repository.

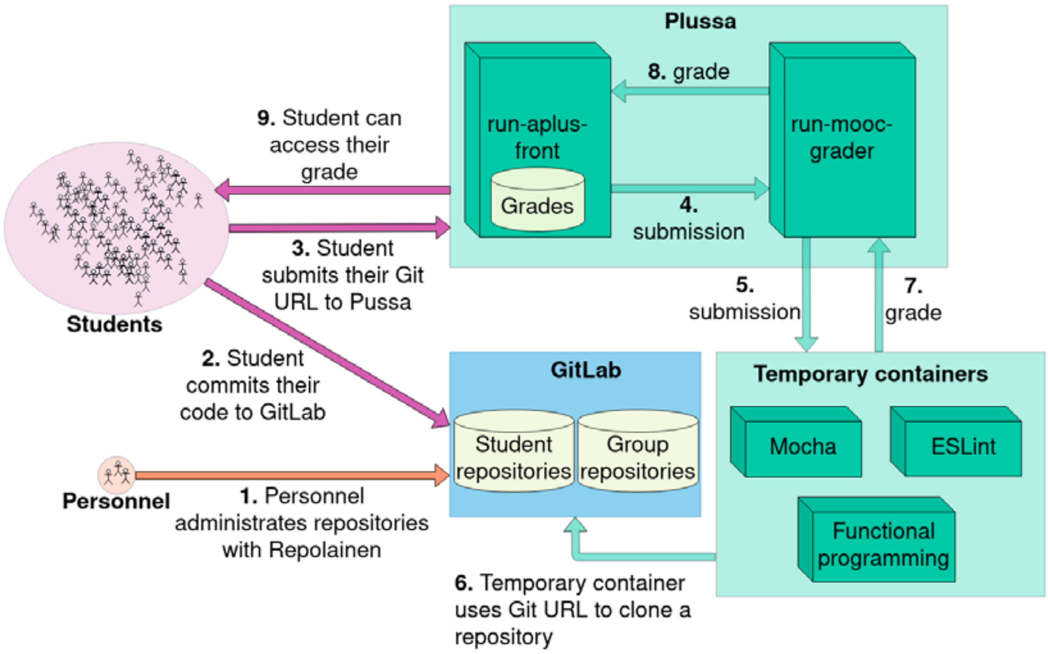


Figure 1: The interplay of Plussa, GitLab and Repolainen in auto-grading

MOOC grader, in turn, provides the exercises and takes care of grading. It launches temporary Docker containers that are started only to perform the grading. In Fig.2, ESLint, functional programming, or Mocha graders are examples of such graders. Usually, the grader clones a student's git repository and executes the grading as instructed in a shell script.

Since testing was not particularly central in the course curriculum, most of the tests were given to students purpose-built to familiarize with Mocha and its execution; respective Plussa graders ran the same tests. In local tests, students received the same feedback as given by the Plussa graders, which decreased the number of needed submissions. Running the tests locally gave students a view of how their work would be graded in Plussa.

3.3 Method and research instruments

We looked at how the feedback from the automatic graders affected the quality of students' code, as evident from the number and type of errors reported by the automatic graders. The tools and processes selected for the course were evaluated by comparing them with those reported in StackOverflow's Developer Survey (SODS)[36] with about 65,000 responses from software developers from 186 countries, and JetBrains' The State of Developer Ecosystem (JBSODE) survey of 19,696 developers[37].

4 RESULTS AND DISCUSSION

4.1 Comparison of work workload and intensity between auto- vs manually assessed course

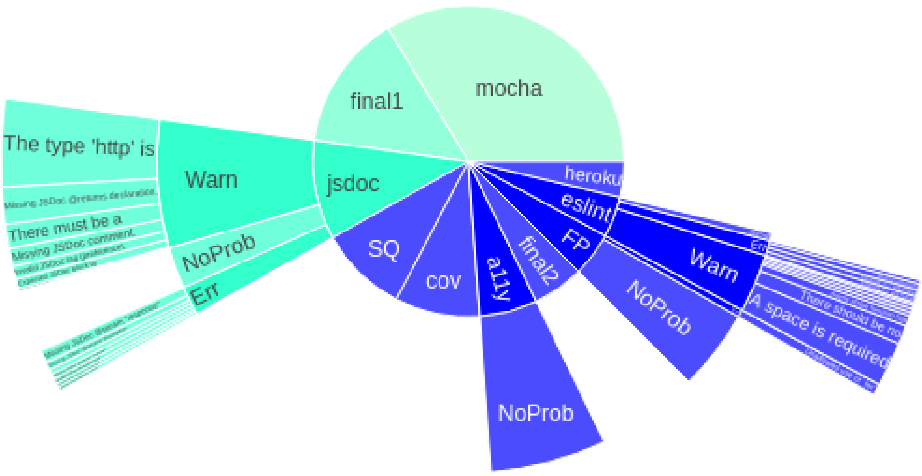
The answer to this RQ can be estimated based on the current automatically-graded WebDev1 course implementation, and previous manually graded basic web programming courses. On the current implementation, practically everything was automated, including the grading of the exercises, group assignment, and the exam in Plussa. Personnel worked on the design and implementation of these. The current course had 50 automatically graded exercises with graders, and 9 graders for the assignment. When an estimated 12 hours on average was spent on the design and implementation of a grader, the total hours were 59 * 12h = 708h. This course implementation featured newly designed graders, and in future implementations these can be used as the basis for creating others, thus reducing the required time.

Based on similar earlier courses in Tampere University, when manually grading and giving feedback a TA could use an estimated 15 minutes per exercise, and 1 hour in grading assignment. In manual grading, the number of students becomes significant: the course's assignment stage was participated in by 173 students in 85 groups. For the exercises the required TA work time for grading and feedback would equal 0.25h * 50 exercises * 173 students = 2165,2h. Grading the group assignment would take 1h * 85 groups = 85h. The combined time consumed is 2247,5h. Thus, the time required for manual grading is far greater than for creating the automatic graders (708h). It is resource-wise a sound decision to automatically grade as many exercises as possible.

4.2 How does auto-grading affect the quality of code?

The assignment complied with the principles of flipped assessment [35], where students may select a harder assignment if they estimate themselves to be competent enough. Students could choose between No assignment, Level-1 or -2. Fig. 2 illustrates the graders color-coded into Level-1 (cyan) and Level-2 (blue) graders. Each passed level improves grade with +1. Level-1 was tried by 126 students (for reference, 157 concluded the course). By far the most frequent was mocha unit test grader. 'No pass' in mocha led to giving up the assignment and filtered submitters for later jsdoc and final1 graders. Final graders 'final1' and 'final2' combined separate graders of respective levels and executed all tests in a sequence. This prevented the manipulation of a submission: e.g., 'pass' could be ensured only with a selected functionality, and after the pass, the quality of code could again be compromised.

After the final1 grader, there was no use to continue without passing Level1, thus, in the transfer to Level-2, the number of students decreased by half. Most of the Level-2 submitters were testing with eslint first. Besides being the first in the list, eslint or linting in general is utilized in other courses as well, so many students are familiar with it and its functionality as a grader is straight-forward. Gradual improvement is evident based on the students' submissions. The first submission was often very buggy, almost like going on a fishing expedition. Once students got a grasp of what is the spirit of a game and how exactly the grading is done, the errors converged to zero quite rapidly. Characteristic of the error hunt was a non-stop process, where subsequent submissions followed each other at high frequency.



px

Figure 2: Auto-grading and provided error and warnings

Table 1 illustrates the most common error and warning types in a descending order of occurrences. Here, the most common eslint errors, such as strict comparison and semicolon issues could be focused on more thoroughly during the lessons based on the analysis. In addition, warnings expose defects with async-await in combination with arrow functions.

4.3 Are the course's processes and tools similar to ones used in the industry?

In both SODS (69.7%) and JBSODE (70%), JavaScript was the most commonly used programming language. On the SODS list of most liked programming languages, JavaScript is in the tenth position in the rankings of most used languages, TypeScript which builds on JavaScript was in second place. In the rankings of languages developers would like to work with, JavaScript was in second place, TypeScript being fourth. So, the language selection of the course gave students experience with languages they will likely use in the future, as current developer preferences can determine the languages selected for upcoming projects. In SODS the category of 'Other frameworks, libraries, and tools', Node.js is ranked as the most desired future tool. MongoDB fares well in the category of 'Databases' coming third in 'the most used' ranking.

Table 1: The occurrences of errors and warnings in a detail

grader	cat	type	val	heroku			84
mocha			765	eslint	NoPrb		9
jsdoc	NoPrb		49		Err	Expected ’===’ and instead saw ’==’.	5
	Err	Missing JSDoc @param response description.	10		Err	Missing semicolon.	5
	Err	Missing JSDoc @returns description.	6		Err	Expected ’!==’ and instead saw ’!=’.	5
	Err	Missing JSDoc @param request description.	4		Err	Global variable leak, declare the variable if it is inte..	1
	Err	Invalid JSDoc @returns type Object; prefer: object.	4		Err	Identifier ’current$_u ser'isnotincamelcase$.	1
	Err	Missing JSDoc @param userId description.	3		Err	Unexpected var, use let or const instead.	1
	Err	Invalid JSDoc @param currentUser type Object; prefer: obj	3		Warn	A space is required after ’,’.	35
	Err	Invalid JSDoc @param userData type Object; prefer: object	1		Warn	There should be no space before ’,’.	15
	Err	Missing JSDoc @param password description.	1		Warn	Async arrow function has no ’await’ expression.	8
	Err	Missing JSDoc @param filePath description.	1		Warn	Missing space after =>.	3
	Err	Invalid JSDoc @param user type Object; prefer: object.	1		Warn	Use an object spread instead of ‘Object.assign‘ eg:	3
	Warn	The type ’http’ is undefined.	69		Warn	Missing space before =>.	3
	Warn	Missing JSDoc @returns declaration.	29		Warn	Async function has no ’await’ expression.	2
	Warn	There must be a newline after the description of the JSD	19	cov			200
	Warn	Missing JSDoc comment.	14	FP	NoPrb		95
	Warn	Invalid JSDoc tag (preference). Replace return JSDoc ta	10		Err	Unallowed use of ‘for‘ loop	9
	Warn	Expected JSDoc block to be aligned.	8	a11y	NoPrb		137
	Warn	Missing JSDoc @param response type.	2	SQ			209
final1			322	final2			121

Git-related collaboration tools were ranked high in ‘Collaboration tools’ in SODS, with GitHub being top-ranked and GitLab fifth for ‘professional developer’ respondents. During WebDev1 students used Git and GitLab extensively, so they gathered valuable experience with version control and issue management. Further, WebDev1 encouraged students to experiment with DevOps by creating and assigning issues and running a CI pipeline. In SODS half of the respondents see DevOps as ‘extremely important’, and that their organization has at least one person working on DevOps, while in JBSODE half of the respondents were involved in DevOps to some extent. While WebDev1’s DevOps treatment was quite light, students acquired knowledge and experience with the basics of DevOps.

5 CONCLUSIONS

In WebDev1, auto-grading decreased the effort spent with routine tasks by 70%, yet the amount of feedback, the consistency of it, and submissions made by students all increased. By examining the submissions, the improvement of code quality was obvious: most students kept iterating till they managed to pass both the functional tests and static analysis of the code. The pass was rewarded with a better grade that being allegedly the major motivation. However, compared with “black-box assessment” done by the personnel (or a peer), incremental improvement of code, where students are in control of the process, can be seen as the source of empowerment. In addition, the grading system used complies with the DevOps practices of industry, therefore training students better for their future and increasing their employability. Having it all done – faster and better than expected – the course personnel can rejoice all their way till well-deserved summer holidays.

6 FURTHER STUDIES

Data collected by Plussa and GitLab is massive and would provide material for learning analytics; the results should be accessible for both teachers and students. Students could be keen on performance comparisons, though this might induce unnecessary competition. Comparing students’ performance to their own earlier performance is safer. Current Plussa graders check code quality and conventions. In addition, a grader visualizing the learning process would be handy in improving students’ consciousness of their strengths and weaknesses, preferably with suggestions of exercises to fill the gaps. The anticipated grader is called a self-reflection grader.

Another interesting research path would be investigating the most pedagogically fruitful way of combining automatic grading and the teaching and support provided by the course personnel. While automatic grading was shown to be effective and also sensible resource-wise, during course implementations numerous students have expressed their need for support from the course personnel, and time saved with automatic grading could enable giving this support. Here Teams channels were useful in student-peer and student-teacher interactions. But especially during the current COVID pandemic, which places more psychological strain on students, design-based research course design process should integrate student support to the design phase with instructional design. As an example, one aspect of the course this integration could improve is teacher-student communication. Currently the interaction strategy on the course is focused on selecting the appropriate tools, such as Teams channels or emails. How these tools are used: what is communicated, using which tool, and by whom is often decided in ad hoc manner. A more structured approached would make communication during implementations more predictable.

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COVID-19, A LASTING CHANGE?: FACTORS FOR INSTRUCTORS TO DEVELOP BLENDED LEARNING

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ABSTRACT

The COVID-19 pandemic ushered in a rapid shift to online learning. Nearly all university instructors gained experience in emergency remote teaching. Prior to the pandemic, embracing blended learning was a choice for instructors[1]; however, the pandemic made it a requirement. The question arises if the existing factors for instructors to adopt blended learning are still valid. After witnessing emergency remote teaching due to the pandemic, this study aims to re-investigate and re-examine the influential factors for Dutch technical university instructors to develop blended learning. A literature review is undertaken to recognize intrinsic influential factors (technical literacy, pedagogical readiness, belief and attitude) and extrinsic influential factors (time commitment, Organization incentive and professional development support). Future improvements and new influential reasons for instructors to incorporate blended learning are identified. Beyond COVID-19, the findings of this study serve as a source of information and a new starting point for successful professional growth and support in blended education.

1 INTRODUCTION

Two-thirds of higher education institutions (HEIs) had to make an immediate transition to online education during the COVID-19 pandemic (UN, 2020). In part

[1] In this article, the term *instructor* is used in the higher education context, instead of teacher or lecturer.

because of the COVID-19 experience, JISC in the UK predicted a potential blended education model in partnership with over 1000 UK higher education organizations (Maguire, 2020). According to a recent study at University Twente, in the Netherlands, both instructor and student groups chose blended learning as the most favored education model when they returned to campus after the pandemic (Pei, 2020).

The COVID-19 pandemic has accelerated the adoption of digital technology. University instructors have gained experience in teaching online, which they may not have had prior to the pandemic (Crawford et al., 2020). Prior to the pandemic, blended learning was a choice. In the future, it might be necessity. The university education landscape is being reshaped by COVID-19. In this transformative time, the instructors are the most important players. The quality of any educational advancement is likely to be decided by how instructors embrace innovative ideas and put them into effect. The importance of researching and re-examining the influential factors for instructors to improve blended learning is recognized in this study. This study aims to answer the following questions:

- What are the influential factors for instructors to implement blended learning in higher education?
- Are there any new influences or changes on the existing factors as a result of emergency remote teaching after the pandemic?
- What are the recommendations for professional development on blended learning beyond COVID-19?

2 LITERATURE REVIEW

2.1 Blended learning

Blended learning is not a new phenomenon for higher education. There are multiple definitions which put the focus on various aspects (Vandeput, Tambuyser, & De Gruyter, 2011). This study chooses the definitions of Graham (2006), which emphasizes the combining technology with face-to-face teaching led by an instructor (Graham, 2006). In the past, a considerable number of studies have been carried out to supply recommendations for university instructors to ensure the effective implementation of blended learning (Albrecht, 2006; Bonk, Kim, & Zeng, 2005; Duderstadt, Atkins, Van Houweling, & Van Houweling, 2002; Garrison, & Vaughan, N. D., 2008; Güzer & Caner, 2014). Among them, Garrison and Kanuka (2004) has further pointed out blended learning is “the thoughtful integration of classroom face to face learning experiences with online learning experiences”, which requires a careful design with use of the best features of online and face-to-face components to foster deep learning.

2.2 Factors for influencing instructors to adopt blended learning

Numerous studies have been conducted to investigate the factors that influence the production of effective blended learning (Lim & Morris, 2009; Moskal, Dziuban, & Hartman, 2013; So & Brush, 2008; Stacey & Gerbic, 2008). A few studies further categorize the influential factors on instructors to develop blended learning as intrinsic factors (such as beliefs, attitude, skills and competences) and extrinsic factors (institutional factors, technological infrastructure, support, workload) (Brown, 2016; Osika, Johnson, & Butea, 2009).

2.3 Intrinsic factors

Technological literacy

One of the most significant obstacles for instructors to develop blended learning is to acquire sufficient technical competency. Instructor's technological literacy is considered as one of the intrinsic factors (Brown, 2016; Lightner & Lightner-Laws, 2016; Rasheed, Kamsin, & Abdullah, 2020). Instructors' ability to build blended learning courses can be hampered by a lack of 1) technological ability, 2) awareness, and 3) trust (Allen & Seaman, 2012). Moreover, instructors' decisions to build and manage blended education can be influenced by unreliable technological infrastructure and incompatible hardware and software (Derntl & Motschnig-Pitrik, 2005).

Pedagogical readiness

In a blended learning environment, the instructor's position shifts from teacher to facilitator to build and sustain a learning community, in which students can be socially connected to collaborate, discourse and reflect (Garrison & Kanuka, 2004). This requires instructors to adapt or even create new pedagogy to redesign teaching strategies and learning activities. To maximize the teaching and learning process in such a blended learning context, instructors need to integrate the knowledge of technology (TK), knowledge of pedagogy (PK) and knowledge of domain content (CK) and reinforce relationships between TK, PK and CK (Mishra & Koehler, 2006).

Belief and attitude

Instructor skepticism and misunderstandings about blended learning have been proven as a predictor of blended education creation failure (Benson et al., 2011; Lightner & Lightner-Laws, 2016). Instructors need to be assured of the value and efficacy of blended learning before they can begin the blended learning design process (Benson et al., 2011; Lightner & Lightner-Laws, 2016). Bruggeman et al. (2021) reported simply having an educational belief was not enough, instructors need to realize a pedagogical need for change. Diverse pedagogical needs such as activating students in large groups or promoting student-centered learning experiences act as triggers for instructors to implement blended learning (Bruggeman et al., 2021).

2.4 Extrinsic factors

Time commitment

New skills and expertise need extra effort and time, which is often overlooked and can have a detrimental effect on instructors' attitudes toward blended learning (Brown, 2016; Ooms, Burke, Linsey, & Heaton-Shrestha, 2008). In the past, instructors find developing and teaching blended learning courses to be time-consuming and difficult (Benson, Anderson, & Ooms, 2011; Ibrahim & Nat, 2019;

Ocak, 2011; Vaughan, 2007). Instructors in higher education also have several roles. When compared to research and projects, teaching is rather a lower priority. This, logically, means that less time is invested in educational creativity.

Organization incentive

Blending learning, "on the course, program, and institutional levels, is a dynamic process" (Brown, 2016; Garrison & Kanuka, 2004). To safeguard blended learning development, higher education institutions need to be reshaped and reorganized, which could include improvements to strategy, policy, ICT facilities, technological infrastructure, technical and pedagogical support, and faculty incentives (Brown, 2016; Graham, Woodfield, & Harrison, 2013; Mishra & Koehler, 2006; Ocak, 2011).

Professional development support

Among these extrinsic factors, professional development is recognized by the literature as necessary to successful blended learning endeavors (Moskal et al., 2013). Instructors receive professional development support to help them better integrate blended learning instructional design concepts and standards into their courses (Garrison & Kanuka, 2004; Martin, 2003; Porter, Graham, Spring, & Welch, 2014). Prior study advocated that an effective professional development itself increases the instructor's knowledge and skills and can have a positive impact on their attitudes and beliefs, which in turn improve their instruction and eventually increase student learning (Desimone, 2009; Philipsen, Tondeur, Roblin, Vanslambrouck, & Zhu, 2019). Moreover, professional development must interweave pedagogical and technological skills together with a good strategy (Wach, Broughton, & Powers, 2011). A few professional development recommendations for blended learning are as follows:

- exploring the use of educational technologies available to design and manage the online portions of blended learning (Bower, 2001)
- facilitating instructors to understand the wide variety of pedagogical methods and choose proper pedagogical instructions for a blended choice (Graham et al., 2013; Sharpe, Benfield, Roberts, & Francis, 2006)
- working in teams (Bower, 2001)
- developing a learner-centered mindset (Garrison, & Vaughan, N. D., 2008)
- embedding blended learning into the academics' daily practice (Rienties, Brouwer, & Lygo-Baker, 2013; Gast, Schildkamp, and van der Veen,2015)

3 METHOD AND DATA ANALYSIS

To find answers to the research questions proposed in the introduction, instructors at University Twente were invited to fill in a questionnaire. The questionnaire has been designed with multiple choice questions, questions with a Likert scale and open-ended questions to validate the influential factors for instructors to develop blended education. It consisted of 25 questions. The questionnaire has been distributed to 68 instructors of four different bachelor programmers across three faculties: International Business Administration (faculty of Behavioural Management and Social sciences), Electrical Engineering (faculty of Electrical Engineering

Mathematics and Computer Science), Chemical Science and Engineering (faculty of Science and Technology), Advanced Technology (faculty of Science and Technology). The results were analyzed using a software package called 'EvaSys'.

4 RESULTS

In the end, 47 out of 68 instructors have completed the questionnaire (response rate: 69%). (This questionnaire is available upon request.)

5 CONCLUSION AND DISCUSSION

In addition to the known influencing factors in the literature, several new factors have been identified as well. The specific conclusions and discussion of the data are presented accordingly below:

5.1 Technical infrastructure and technological literacy

Prior to the pandemic, technical awareness and competency have been identified as one of the biggest barriers for instructors in designing blended learning from the literature study. According to the questionnaire's results during the pandemic, more than half of the instructors from this study (61.7%) possess the technical equipment and software they needed to teach online. The rest of the instructors group did not indicate major problems caused by the COVID-19 shift. Evidently, having a stable internet connection also plays a key role in teaching online, the instructors have rated theirs with an average 8.3 out 10.

Furthermore, instructors have reported to use drawing tablets, video conferencing platforms and different other tools to stream and record video lectures. According to the questionnaire, instructors have clearly improved their technical skills in a relatively short period of time. However, there's room for improvement and professional development on education design with ICT competences.

5.2 Beliefs attitudes and willingness to invest time for blended learning

66% of instructors from the research group have chosen blended learning as the preferred education mode in the future. Further, instructors recognize the potential of blended education and would like to get more allocated time to experiment with online and blended learning (41.5%).

"Online teaching could make the teaching experiences more flexible and diverse. A blended learning for students would be the interest for both teachers and students" – instructor

Instructors from our research clearly demonstrate strong interests and confidence in blended learning. The instructor's willingness to spend time exploring blended learning reflects this optimistic mindset and appreciation of blended learning for the future.

5.3 Pedagogical readiness

The primary goal of higher education during an epidemic, particularly at the start of the lockdown period, is to ensure continuity of teaching. The attention and time of the instructors are inevitably focused on the technical aspects. However, as the pandemic continued and time passed, concerns about the quality of teaching and learning became more prevalent. On the one side, the majority of instructors claim to be able to teach without difficulty (31.9% strongly agree; 42,6% agree). On the other hand, maintaining social connections with students and keeping them motivated and engaged in learning is challenging for them:

“Motivation issue will have a stronger impact because the social distancing makes it harder to create a motivation environment for the student.” – instructor

According to the literature, blended learning requires different pedagogical skills to foster a learning community and design teaching and learning activities to keep students socially connected (Garrison & Kanuka, 2004). The results of the questionnaire revealed that, while instructors can quickly pick up technical skills, they still need to improve their pedagogical skills, especially in terms of designing and implementing social activities in the learning process.

5.4 Organization

At the organizational level, COVID-19 makes reshaping and reorganizing necessary. Due to COVID-19, education made a quick switch to online education. Strategic policies, ICT facilities and the support structure also need to be adjusted to keep up with the changed reality and make this quick change a lasting change. The questionnaire results clearly show the needs from the instructors to explore and experiment with online and blended learning further. To support these initiatives and promote innovational education, universities needs to look beyond the COVID-19 crisis and create long-term strategies for a future-proofed university.

Next to developing a long-term strategy, the university needs to focus on the support infrastructure. Instructors reported that they would like to receive didactical and technical support in the future, but they also highly value the opportunity to exchange experience with their colleagues.

5.5 Professional development

COVID-19 forced a large number of instructors to switch their face-to-face education to online education. Even instructors highly critical towards online education suddenly needed to make this mandatory change. In the past, most of the formal professional development activities (courses, information) are focused on individual innovative lecturers. This study recognize new opportunities for future professional development:

During COVID-19, 72.3% of the instructors (n=47) from our study got the information support, training to study online from colleagues. An effective professional development should take this into consideration and focus more on the team level (Bower, 2001). The innovative competent teachers can provide a great deal of support to the less experienced co-workers.

6 LIMITATIONS AND FUTURE RESEARCH

The findings of this study have to be seen in light of some limitations. First, the questionnaire was only distributed to a select number of programmes that agreed to participate in this survey. This also led to a relatively small group size (47 instructors completed the survey), compared to the total number of instructors at University Twente. Future research should preferably focus on a broader target group. Secondly, due to the sudden nature of the COVID-19 change we have no pre- COVID-19 comparison group. Thirdly, due to time constraints, we were unable to include qualitative data in this research paper. There is a need for focus group sessions to gain a deeper understanding of possible changes after instructors have experienced online teaching during the lockdown time. Further, the focus group interview would help us to understand their perceptions for professional development in blended learning for the future. A qualitative research could give us insights in how to move the professional support from emergency support to long term professional support. Nonetheless, we hope that the results of this study will be useful as feedback for successful blended education professional growth beyond COVID-19.

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ANALYSIS OF THE EVOLUTION OF A STEAM LECTURER-TRAINING PROGRAM BASED ON COMPETENCIES IN AN HYBRID CONTEXT

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ABSTRACT

The objective of this work is to present an innovative lecturer's training program developed at UPC-BarcelonaTech while transitioning to a semi-presential hybrid scenario due to the pandemic. This "Postgraduate Degree in University Teaching in STEAM" was designed based on the teaching competencies that a lecturer should possess in Engineering-related subjects. Focus was placed on a final project to help lecturers implement innovations in class with their students. When the confinement

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due to the pandemic started, it was evident that many lecturers had a clear deficit on digital competencies to conduct their teaching on-line. This paper presents an analysis on the changes undertaken in the program after a year of hybrid teaching, their impact on the teachers and on the participants of the program. A more flexible syllabus, the addition of digital education courses for lecturers, and a more research-oriented program are important factors that have improved the quality of the program. Results show that participation in the courses offered during this exceptional period radically increased for some areas such as digital on-line technologies for education, while the egressed number of participants did not change significantly from previous editions. Specific recommendations are provided for Engineering Education programs, as the perception of the importance of some of these competences by the instructors are found to be significantly different among different STEAM fields of knowledge. Valuable lessons have been learned in this process, with some of the changes undertaken having a good prospect to stay in the near future.

1 INTRODUCTION

The pedagogical training of university lecturers is usually the result of voluntary self-training based on seminars or training activities, and above all on reflections arising from teaching experience. Lecturers' opinions of their own work as teachers derive from previous experience: former students who attend their lectures, the subject being taught, and mainly on their own beliefs, which induce them work as if these beliefs were true. Such beliefs are relatively static and resistant to change, as well as being consistent with the teaching style of each lecturer. It is difficult for lecturers to change their beliefs, particularly if they are intuitively reasonable [1].

We present a teachers' training program designed at our university, the Universitat Politècnica de Catalunya – BarcelonaTECH (UPC), undertaken by the Institute of Education Sciences (ICE), to which the authors of this work belong. This training is non-mandatory for the participants, because, no specific pedagogical background is required for teaching at our universities, other than knowledge of the subject to be taught. Since the training programme is voluntary, lecturer enrolment is usually rather low, so specific motivation tips are required to increase participation.

Our University is a technical one, specialized in architecture, mathematics, science and engineering. In our University we have no schools and departments of psychology or education, or any tradition of using social science methods. Provided this context, our lecturers have the technical competencies required for teaching, but not necessarily the professional competencies required for conducting this teaching.

Non-mandatory lecturer training is particularly problematic in the particular context of engineering studies, which traditionally have one of the highest dropout rates in higher education. We certainly agree with Patricia Cross [2] when she states that teaching will not acquire status until teachers do consider their classes as laboratories for research and innovation. The problem is that the innovation and research that are conducted at our university (mostly technical) do not use the same methods as those traditionally used in the social sciences, which are precisely the ones that would apply to education. Thus, it is necessary for our faculty also to acquire competencies related to these issues.

Our previous training programme followed the pre-Bologna pattern: it measured on-site hours and was based on course content rather than on the competencies to be acquired by the teachers participating in the training activities. Degrees have moved from content-based learning to competencies-based learning, the focus being on learning rather than on teaching [3]. Hence we proposed a training program whose objectives were:

- To design a training itinerary for lecturers based on the competencies they must acquire as teachers, as well as providing a qualification certifying to that fact. This training should also cover lecturer evaluation and promotion.
- To increase the number of lecturers enrolling in our training programme.
- To use this training programme to promote a scholarship in engineering education research, a field of scientific inquiry that has usually been ignored by our teaching staff. Our aim is to promote the creation of a inner university network of engineering education researchers who innovate and publish their innovations.

First of all, we were interested in identifying which were the teacher competencies that were important for their professional practice at UPC, including an hybrid educational context. Second, we wanted to address the difficulties faced by the teachers following an academic career to improve their teachers competencies, with a design of an hybrid postgraduate training program based on competencies.

2 METHODOLOGY

2.1 Understanding lecturers' competencies

Lecturer training in Engineering has been the object of study in recent years (e.g. [4]). These studies focus on the methods and tools required for quality teaching practice. The inclusion of professional competencies in engineering studies has also been widely studied. The ABET engineering criteria [5] can be divided into hard and professional competencies. The rapid changes in contemporary society make the acquisition of professional competencies increasingly indispensable, so the question of how to teach and assess these competencies has in recent years been the focus of several works (see for instance, the comprehensive review by Shuman et al. [6]).

In 2011, the Interuniversity Training Group for Teachers (GIFD), consisting of teachers responsible for training at the eight Catalan public universities, conducted a bibliographic study on the competencies that a university professor should possess. These eight universities account for 149,116 out of the 169,418 university students in Catalonia at the time (88%). A focus group composed of 64 teachers in which all fields of knowledge were represented discussed the initial results. From this study, and once the validation was concluded, the following six competencies required by a university teacher were identified:

- Interpersonal competence: know-how to help students to develop critical thinking, and the recognition of diversity and individual needs.
- Methodological competence: knowledge of the modern methods and strategies of teaching and learning, and awareness of different learning models.
- Communicative competence: teachers should develop communication processes in an appropriate and efficient way, which means reception, performance, production and transmission of messages through various media channels in a contextualized teaching-learning situation.
- Planning and management competence: know-how to design, guide and develop content; training and evaluation so that the results can be measured and suggestions for improvement be made.
- Teamwork competence: this competence does not consist in teachers leading a group of students working together, but rather the ability of teachers to collaborate and participate as the member of a group.
- Innovation competence: know-how to create and apply new knowledge, perspectives, methodologies and resources in the different dimensions of teaching.

As a consequence, our first decision was that the training programme should be based on these six competencies. The training for the lecturers was based on a continuous improvement process: design, teach, evaluate and supervise. Courses were designed by providing some basic principles of the topical skill followed by a reflection on the teachers' practice and a supervised action plan for improvement.

2.2 Scholarship of Teaching and Learning

Promotion of lecturers is based mainly on research, so good teaching (and therefore lecturer training) seldom is an important factor taken into account and may even be a handicap, because every minute devoted to improving the quality of students' learning is time during which lecturers are neither producing papers nor applying for research grants. Given this situation, we decided to organize the training programme as a Postgraduate Degree for our lecturers. In order to bring about a real change in the way our teachers address the teaching-learning process, our lecturers must consider their classes as laboratories for research and innovation. Engineering Education Research has become an emerging field of scientific research. There is a growing community of scholars involved in reflective practice concerning the so-called "Scholarship of Teaching and Learning (SoTL)". Boyer [7] defined it and since then the concept has become a process in which "faculty frame and systematically investigate questions related to student learning".

It is perhaps somewhat ambitious to ask our lecturers to undertake a deep research task in education, because they are occupied in their own field of research. However, there exist three areas of this scholarship [8]: 1) Scholarship of discovery, where contributions are primarily in the form of new knowledge; 2) Scholarship of integration, where contributions are multidisciplinary, integrative, and/or interpretive syntheses across vast prior research to identify patterns, themes, trends, needs and opportunities upon which other scholars can build; and 3) Scholarship of application, where contributions often describe how prior research into learning and teaching has been applied to creating or designing educational activities. Part of the training programme is aimed at building a research network to enable lecturers interested in education to get to know each other, collaborate together and publish their findings. It is also necessary to detect the key players in our university Engineering Education Research network in order to provide them with institutional support to continue working in the teaching-learning process.

3 OUR STEAM LECTURER-TRAINING PROGRAMME PROPOSAL

3.1 Initial proposal

After analysing and reflecting on what competencies were needed for our teaching staff, planning was started and a competency-based training programme for trainers was designed using an action research methodology [9] based on interviews with teachers and current and former students. A postgraduate degree in University Teaching in Science, Technology, Engineering, Arts and Mathematics (STEAM) was created and officially started in September 2015.

This postgraduate programme consists of 15 ECTS credits for student dedication, which are divided into 6 credits corresponding to the acquisition of the six basic competencies, 6 credits devoted to a Final Project, and the remaining 3 to complementary training. Learning consists of training activities in which postgraduate monitoring is based on a teacher portfolio. The Postgraduate diploma will be awarded if the student passes at least 1 ECTS (25 hours) for each of the six core skills; and successfully defends her or his Final Project.

3.2 Transition to an hybrid teaching context

After 15th March 2020 a strict lockout was ordered by the Spanish Government due to the pandemic outbreak. The Mayor of the University ordered that all presential classes should continue online. By then, it was evident that many of the academic staff did not have the technology nor the skills to undertake such a sudden radical change in their teaching. The Institute of Education Sciences (ICE) in our University, responsible for teachers training, immediately started a fast-track series of online courses specifically aimed at this emergency requirements. Among them, there were courses designed to use the technology (hardware and software including Google Meet), design classes online, provide communication skills in an online environment, and providing videos and podcasts with tips to increase teachers' competencies.

Regarding the Postgraduate program, we introduced some changes that were scheduled for the next course, and others specific for this situation. Flexibility measures were enforced letting all students undertaking the Final Project to present it in the format of a research or practice paper, instead of requiring a 50-page project. Taking into account the huge load of work and pressure that the academic staff was experiencing at the time, we were sure that this was going to facilitate the completion of their degree without renouncing to the academic rigour of the Degree. All courses were changed to online settings, including the defence of the Final Projects. Regarding the already scheduled changes for the next year, we allowed that mandatory workshops could be substituted by other courses in the ICE teachers' training program which also contributed to the training in the same skill. An accountability was enforced so that each student will be assessed by the successful completion of training in each of the aforementioned skills, taking into account that different courses may provide training in different skills at the same time, with a differentiate training load for each one of the competencies. At the end, all students in the program should have completed 1 ECTS of dedication in training for each of the skills. Finally, an additional skill ("Training in digital education") was added as mandatory to complete the program. This skill considered training in online teaching design, use of technology, educational software and tools, and digital skills.

4 RESULTS

4.1 Initial Results

The Postgraduate Degree in University Teaching in Science, Technology, Engineering and Mathematics (STEM) started in September 2015. A total of 114 participants (approximately 5% of the total number of teachers at our university) enrolled for this programme. Most participants come from the Civil Engineering department (19), Management (15) and Computer Science (15).

Most participants are in the mid-stages of their careers (associate professors, 64%), while the least represented category in the programme corresponds to Full Professors (7%). Initial stage teachers represent 29% of the participants. With respect to teachers' perceptions, the general average of surveys in mandatory subjects is 4.3 (out of 5, Likert Scale). We sought the participants' opinions on the training received in two basic ways: open questions when being surveyed and some focus groups with external observers at the end of this latter term. Participants outline as very positive the workshops structure of the program, as they perceived that their teaching experience has benefit from it. This may be the result of a design based on the SoTL principles. They also expressed their difficulties for having to followed a fixed presential schedule to be able to complete the program. Current regulations in Universities in Spain do not make training programs such as this one as mandatory, as the promotion of lecturers are mainly based on their research productivity. It is expected that a creation of SoTL culture in higher education may present this field of practice more attractive for the lecturers to invest their time on it.

4.2 Results after the transition to an hybrid context

The demand for immediate training from the UPC Faculty was huge, but a big effort was put in place by ICE and the Academic Board of the Postgraduate Program to respond to these unprecedented training requirements. More than 50 online courses were programmed since lockout in the academic course 2019-20, with more than 1,500 hours of online training being put in place for the first time. At least 1 out of 3 teachers from the UPC academic staff took at least one training course, which is an unprecedented number. These facts reflect the outstanding interest by the academic staff for training in order to respond to the needs of their students in this obviously unexpected learning context. Ten students from the STEAM Postgraduate Degree successfully finished their Final Project, which is a figure reported similar to that in previous years (Table 1) or indeed higher. When compared to previous training programs such as PROFI and PIDU, the STEAM program scores favourably in terms of teachers participation and certification. An estimate number of 15 students more are expected to finish their Degree during this Academic Year 2020-21. During the academic course 2020-21, as restrictions due to the pandemic were still enforced, all the training courses were held online, and all previous changes in the training program were held.

Table 1. Participants and certified students at ICE-UPC teacher's training programs.

Program	PROFI	PIDU	STEAM
Years	1999-2012 (13 years)	2012-2015 (3 years)	2015- ongoing (6 years so far)
Training hours	130	150	375
Total participants	979	70	1.536
Certified	197	7	45 (15 more expected by 2021)

Regarding the students' satisfaction, according to the usual survey conducted at completion of each training course, an average of 4.6 out of 5 in a Likert scale was obtained, which is very satisfactory outcome, higher than the average value in the last three academic courses (4.2). Some open comments were received, including a specific approval of the flexibility measures introduced in the Postgraduate Degree.

5 DISCUSSION

In our opinion, engaging our lecturers in the teaching-learning process requires similar approaches to those employed in student engagement, such as those presented by Astin [10]. We have applied the same principles to our lecturers: First, to encourage them to participate in challenging activities; second, to show them that the knowledge they are acquiring is relevant for their professional future. In the third place, convince them that the profession they chose has a real impact on the world, and stimulating them to reach creative solutions for resolving real problems, and, finally, Create collaborative activities to enable lecturers to cooperate in order to achieve a deep knowledge of their profession. It is our aim that our former Postgraduate Degree students become mentors of the new projects by involving them in the Education Engineering Research network and encouraging them to try new approaches and get out of their comfort zone. To this end, a new Doctorate in Engineering Education has started this academic course in our University, based on this EER group.

The pandemic outbreak has tested the capacity of the teachers' training programmes and staff in an unprecedented and unexpected way. The key elements to overcome the huge challenge of responding to a peak of sudden demand in training were:

- Rapid determination of new needs and evaluation of resources.
- Use of digital technologies
- Flexible syllabus
- Rapid adaptation to the online format for training
- Proactive communication with the teachers
- Orientation to skills training rather than teaching based on contents.

6 CONCLUSIONS

In this paper an innovative STEAM Postgraduate Teachers' Training Program based on competencies has been presented. Its design was based on the principles of the Scholarship of Teaching and Learning as a reflective practice. A successful fast transition to an hybrid educational context has been described. Results from its implementation in a technical university after six years of implementation have been shown and discussed with a promising outcome.

We are certainly convinced that the main reason for the success of the programme is that our lecturers find the training programme both challenging and useful for their present needs, and for their career as well. They also benefit from the incentive of belonging to a network of colleagues who share the same interests, concerns and goals. This is particularly true for a sudden, unexpected situation such as the pandemic outbreak.

More research is required to detect the real impact this work is having on both students learning and performance and on the number of lecturers who are becoming increasingly involved in the engineering education innovation and research field. Some of the changes undertaken regarding an online, hybrid teaching environment are likely to stay after the pandemic restrictions are over. New studies will be needed to evaluate how this evolution enforces new changes in the way quality higher education teachers' training is conducted.

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DO HIGHER EDUCATION ENTRANCE EXAMS PREDICT SUCCESS IN ENGINEERING STUDY?

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Keywords: *engineering education; student success; university entrance exams*

ABSTRACT

In South Africa, as elsewhere in the world, graduation rates in engineering study are notoriously low. A 2017 report by the American Society for Engineering Education, for example, shows that fewer than 40% of students who enter into an engineering qualification in the United States graduate in the minimum time of four years. This paper investigates the predictive value of the national higher education (HE) entrance exam in South Africa, the National Benchmark Tests (NBTs), for success in engineering study in one HE institution in South Africa. The NBTs attempt to redress the problem of poor throughput and graduation rates by providing institutions with more information about the preparedness of school-leavers prior to entry into HE. In South Africa, the NBTs include three assessments, one each in academic literacy, quantitative literacy and mathematics. The performance of students in these three assessments was captured and correlated with student success in engineering study (measured as either having graduated, continuing study or having dropped out). Across all three assessments, it was found that there is a correlation between performance on the NBTs and success in engineering study, and that performance on the NBTs offers the potential for a rich and nuanced understanding of student success in engineering.

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1 INTRODUCTION

Higher education in South Africa – including engineering education – is characterised by low throughput rates and high dropout rates. This problem is not unique to South Africa: in the United States, the American Society for Engineering Education [1] shows that fewer than 40% of students who enter into an engineering qualification graduate in the minimum time of four years. Nonetheless, in South Africa, these challenges are exacerbated by the particular historical inequities that have shaped the country's history. In particular, the legacy of apartheid has meant that higher education participation and success continue to be skewed along racial lines.

In the first instance, participation rates in higher education in South Africa are low (at only 19% of school-leavers in 2015, the most recent statistics available) [2, p. 5], particularly amongst black school-leavers (only 16% in 2015) [2, p. 5]. Making matters worse, in addition to these low participation rates, graduation rates are low and dropout rates high. In four-year degree programmes, such as those offered in engineering, only 47.9% of the 2015 entering cohort graduated in minimum time, while 13.5% dropped out [3, p. 29]. Again, these graduation rates are skewed along racial lines.

One of the strategies to overcome this situation was the effort of Higher Education South Africa (HESA) to develop the National Benchmark Tests Project (NBTP). This project saw the development of a suite of assessments aimed at establishing the preparedness of South African school-leavers for the demands of higher education. Since their introduction, several higher education institutions in the country now use the National Benchmark Tests (NBTs) for a variety of reasons, including selection, placement and curriculum reform.

This paper investigates whether or not the NBTs are indeed suitable predictors of success – in engineering study, specifically. It does this by analysing the performance of a particular cohort of students over six years in an engineering faculty in a university in South Africa. First, however, it discusses the relevant literature pertaining to school-leaving and university entrance testing.

2 LITERATURE REVIEW

In South Africa, specifically, the contribution that the National Senior Certificate (NSC – the statutory national school-leaving examinations) and the National Benchmark Tests (NBT) could play in terms of admission and placement has been investigated by a number of authors [4, 5, 6, 7, 8, 9, 10]. These authors have examined their effectiveness at predicting success and generated varying conclusions, as is summarised in the paragraphs that follow.

Some studies have found that particular school and entrance exam scores have more predictive power in specific contexts than others. Allers et al. [4], for example, compared the NSC results and NBT results of second-year Physiology students in 2011 and concluded that achievement of high marks in the NSC subjects, English and Life Sciences and the NBT Quantitative Literacy test were predictors of success in Physiology. The NBT, according to these authors, “could have some value in predicting the success of candidates in their second year of study” [4, p. 83]. Jacobs et al. [5] also found that both the NSC and the NBT Mathematics tests have predictive value. They investigated the predictive power of the NSC Mathematics results and the NBT for success in first year university science courses and recommended a strategy for post-admission placement of students that includes the use of NBT scores. Du Plessis and Gerber [7] examined the recommendations of the NBT Project that to be successful in university-level Mathematics, students’ NBT scores should place them in the Proficient category. Their data showed that students whose scores placed them in the Basic category were not able to succeed in their university Mathematics modules. Their conclusion was that higher NBT scores were necessary for success in university courses such as Actuarial Science and Mathematics, but they were not necessary in courses such as biological, earth, and agricultural sciences. In the European context, Häkkinen [11] compared the predictive value of school results and university entrance exams in three fields (social science, engineering and education) and finds that, while in education, school results are a better predictor of success, the opposite is true in social science and, especially, in engineering. Similarly, in Flanders, positioning tests were found to be able to discriminate between students who achieved high, middle and low success in engineering and science degrees, specifically [12].

Other studies have found that admissions test scores overall were a predictor of success in specific university courses and that combining them with school scores improved predictive ability. For example, in examining the predictive ability of the NBT and the NSC at two South African universities for success in an identical first-year Economics test in order to determine whether NBT scores should be used as a determining factor in university admissions, Rankin et al. [6] concluded that the NSC marks on their own were better predictors of success in the Economics test than the NBT scores on their own, but that combining the scores improved the tests’ predictive ability: “a combination of NSC Mathematics marks and the full set of NBT scores improves the predictive power [of the NSC] significantly” [6, p. 579]. Prince et al. [10], having studied the performance of Engineering students over four years, recommend that, “due to the clear contribution which the NBT aggregate score makes in explaining subsequent performance, the NBT aggregate score could be used in addition to the NSC aggregate score for selection and placement”.

Still further studies have focussed on the ability of entrance exams to assist in the development of teaching and learning interventions. For example, Case et al. [8] argue that in general, NBT results show that most students are under-prepared for university study and that therefore, placement in extended curriculum programmes would be appropriate, while Cliff [9] argues for the use of the NBT AL test scores to determine the level of preparedness of first-time entering university students and to assist in developing teaching and learning interventions that could help improve students’ performance.

Generally, the literature suggests that there is a relationship between university entrance examinations and subsequent higher education performance, whether in the form of grade point average [13] or successful completion [14]. The current study builds on this foregoing research and focusses on a cohort from the Engineering and the Built Environment Faculty at a South African University to investigate the ability of the NBTs in explaining performance in Engineering studies at the end of four and six years.

3 METHODOLOGY

The NBTs are a suite of three assessments, focusing on academic literacy, quantitative literacy and mathematics. In some disciplines, only the first two tests are written but in disciplines such as engineering, all three assessments are completed. As such, this paper examines performance on all three assessments and compares this with performance in a four-year engineering degree programme undertaken at a university in South Africa. Performance on the NBTs is captured as a score out of 100.

Performance in engineering degree study is captured in terms of overall outcome of study after both four years (the minimum duration of the programme) and six years (two years longer than the expected duration of the programme). Overall outcome is captured as either QUAL (meaning that the student has graduated), CONT (meaning the student is still continuing their studies), or RENN (meaning the student has either dropped out or failed). Two-way analysis of variance (ANOVA) was used to determine the relationship between overall outcome (after both four and six years) and performance on each of the three NBT assessments.

This analysis is undertaken on one cohort of students, over a period of six years. This cohort consists of 856 first-time entering students in an engineering faculty at a higher education institution in South Africa. Of these students, only 268 (31.3%) graduated in minimum time (four years), while 541 (63.2%) graduated after six years. After four years, 226 (26.4%) had dropped out or failed, which decreased to 223 (26.1%) after six years, as students who drop out may return after placing their studies in abeyance (albeit within limits). As a result, after four years, 362 (42.3%) of the students were continuing with their studies, of which 92 (10.7%) were still continuing after six years.

What is noteworthy about these student outcomes is that less than one-third of students graduated in the expected, or minimum, time – and at least a quarter never graduated. Hence, this study seeks to determine whether the NBT assessments offer any predictive value with regard to these outcomes.

4 RESULTS AND DISCUSSION

Fig. 1 shows the mean scores obtained in the NBT Academic Literacy (AL) assessment for the cohort of first-time entering students, grouped according to their overall outcome after four years. The figure also shows the medians and inter-quartile ranges for each group. As can be seen in the figure, those students who performed better – on average – on the NBT AL assessment were more likely to graduate in minimum time (QUAL). Similarly, those continuing their studies outperformed those who had dropped out or failed (RENN). The same pattern can be seen in Fig. 2, which shows the mean scores (and median and inter-quartile ranges) for each group after six years. As is to be expected, there is little change in the RENN group, as almost all the drop out in the programme occurs within the first four years, and there is little drop out thereafter. As is also to be expected, the gap between the QUAL and CONT groups narrows after six years, as a number of those in the CONT group in Fig. 1 subsequently joined the QUAL group in Fig. 2. In the case of the NBT AL assessment, there are statistically significant differences between all groups, after both periods of time, except between the QUAL and CONT groups after six years (p = 0.056). This is different, as will be shown, from the other assessments and suggests that, while AL may be a good identifier of those students who may fail or drop out of engineering study, and those who will graduate in the minimum time, it offers less explanatory potential regarding those students who remain in the system beyond four years, suggesting that other factors are more likely at play amongst such students.

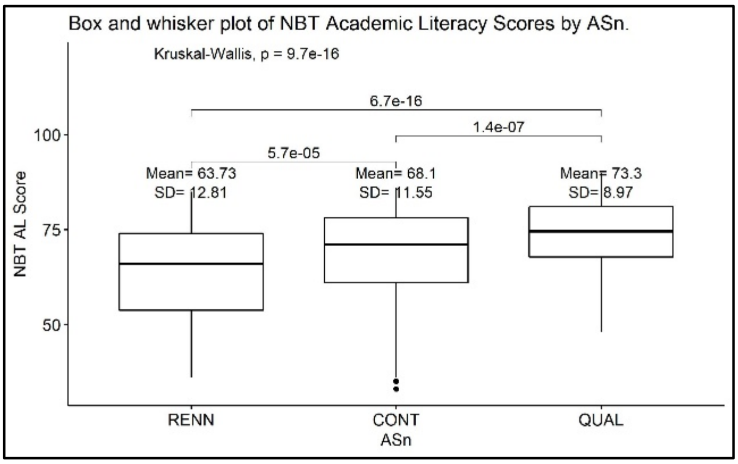

Fig. 1. NBT AL scores, grouped by outcome, after four years; F(2,797)=42.47, p<0.001

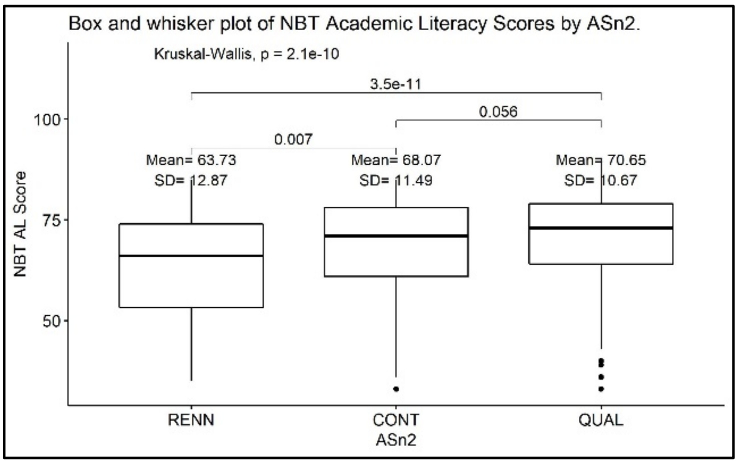

Fig. 2. NBT AL scores, grouped by outcome, after six years; F(2,797)=27.3, p<0.001

A similar pattern was seen with regard to the NBT Quantitative Literacy (QL) assessment. This can be seen in Fig. 3 (which shows the performance of the cohort of students, grouped according to overall outcome after four years) and in Fig. 4 (which shows this performance after six years). Again, the differences between all three groups were found to be statistically significant for the data after four years and six years ($p < 0.05$), with the only exception being the difference between the CONT and RENN groups after six years ($p = 0.1$). This differs from the finding for the NBT AL assessment, and suggests that performance on the NBT QL assessment is a more reliable predictor of long-term retention, suggesting that students with lower NBT QL scores are unlikely to be successful in engineering study, even after an extended period of six years (which, nominally, is the maximum time allowed to complete an engineering degree, though this is not always strictly enforced).

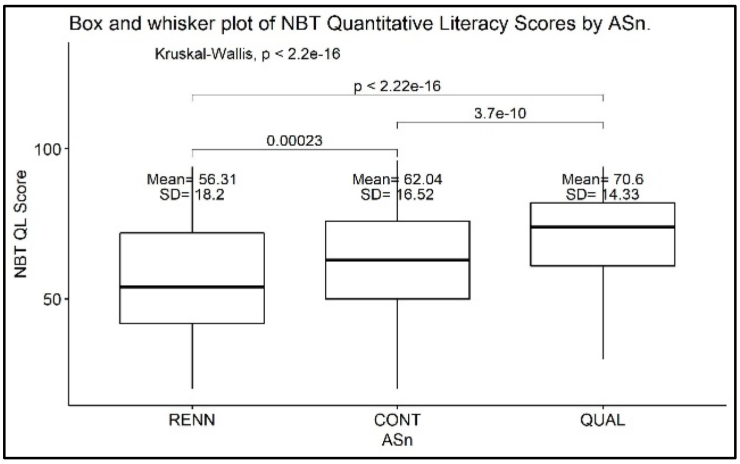

Fig. 3. NBT QL scores, grouped by outcome, after four years; F(2,797)=45.25, p<0.001

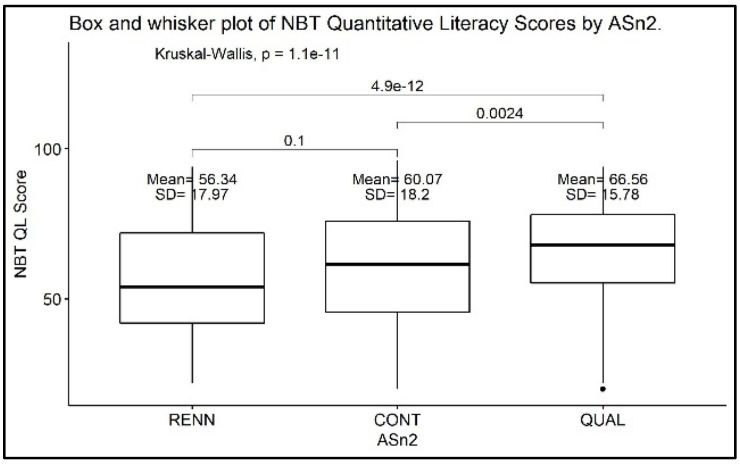

Fig. 4. NBT QL scores, grouped by outcome, after six years; F(2,797)=29.37, p<0.001

Finally, with regard to the NBT Maths assessment, the same patterns emerge. After four years, those students who graduated in the minimum expected time outperformed both other groups, and those continuing their studies showed better results in the NBT Maths assessment than those who had dropped out or failed. The same applies after six years, albeit that the gap between the QUAL and CONT groups narrows. All of these differences were found to be statistically significant except, again, between the CONT and RENN groups after six years. Again, this suggests that students with low NBT Maths scores are unlikely to successfully complete engineering study, even after six years.

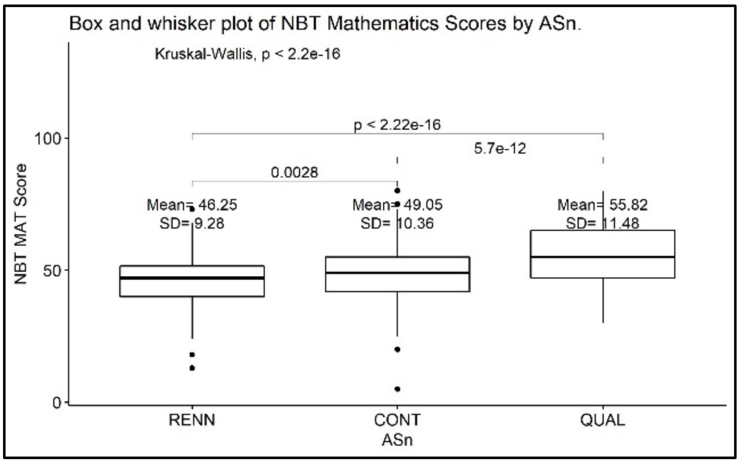

Fig. 5. NBT Maths scores, grouped by outcome, after four years; F(2,752)=50.2, p<0.001

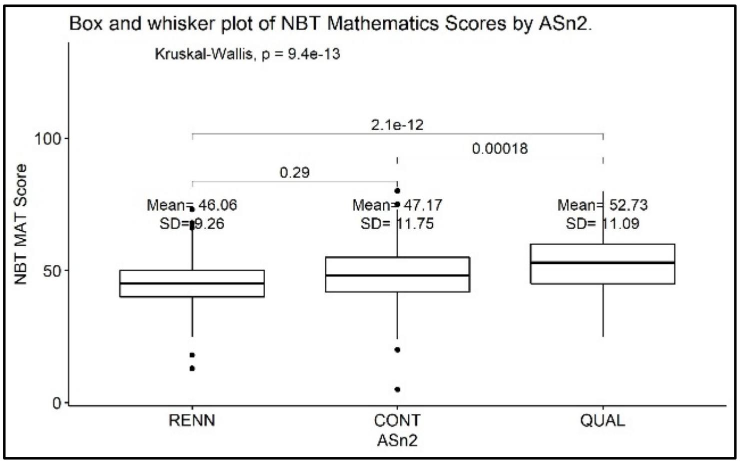

Fig. 6. NBT Maths scores, grouped by outcome, after six years; F(2,752)=30.15, p<0.001

5 CONCLUSIONS

Performance on the NBTs appears to offer the potential for rich and nuanced understanding of student success in engineering. As has been shown, all three NBT assessments offer some predictive value for determining success in engineering study – particularly within four years. This paper has focused on drop out, continuation and completion only, and further research should also focus on student experiences as well as performance, in the form of student grades.

Nonetheless, the paper has shown that, in the case of all three NBT assessments, it is possible to discern that performance on these assessments might be useful for predicting ultimate success, and success in minimum time specifically. This is because, in the case of all three assessments, there is a statistically significant difference between the performance of those students who graduate in the minimum expected time of four years, and those who do not. However, after six years, this difference is lessened, such that, in the case of the NBT Academic Literacy assessment, at least, the difference ceases to be statistically significant. This suggests that there is a group of students who, with additional support and time, are able to ‘catch up’ to those students who perform better in the NBT assessments. If institutions of higher learning can gather this information with a view to identifying such students and offering the necessary additional support, these students may be assisted to complete their studies more quickly, thus overcoming, perhaps only in part, one of the major challenges facing higher education in South Africa and elsewhere, namely, poor throughput.

An issue that remains to be discussed is that of student dropout and failure. Although this paper demonstrates that students who perform poorly on the various NBT assessments are more likely to drop out or fail, the solution cannot be to simply exclude such students from higher education, given that higher education participation rates are already low. Instead, greater research needs to be conducted to understand where and how students who perform poorly on the NBT assessments – as a measure of preparedness for higher education – can be additionally supported to nonetheless achieve success at university. Indeed, we would argue that this is the singular challenge facing universities in South Africa, and elsewhere. Higher education admissions tests may offer some support in this regard – though a need for additional investigation remains.

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A STUDY OF EXPERIENCES WITH DISTANCE AND ONLINE TEACHING IN MECHANICAL ENGINEERING COURSES

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ABSTRACT

Due to the university lockdown caused by COVID-19, teachers and students at the Department of Mechanical Engineering, Technical University of Denmark experienced a sudden and massive change from face-to-face to distance and online teaching in spring 2020. To obtain an overview of the tools used for online teaching and the experiences gained, the department conducted a survey among its teachers. This questionnaire consisted of two key questions: “What worked well?” and “What worked less well?”. A second survey containing similar questions was conducted by the university among all students.

A qualitative analysis of the empirical data generated by the surveys provides an overview of the teaching tools and methods used after the forced conversion to distance and online teaching. The analysis illuminates the strengths and weaknesses of the different teaching methods, from both teachers’ and students’ perspectives. Based on the findings, recommendations are made to support teachers as they guide students towards learning strategies that best fit the chosen teaching methods.

1 INTRODUCTION

Due to the COVID-19 pandemic, the Technical University of Denmark (DTU) was locked down in spring 2020. Overnight, teachers and students experienced a massive emergency change in teaching and learning, away from physical, face-to-

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face to distance and online activities. This new online teaching environment had two important characteristics: first, most teachers had little or no experience and were left with no guidelines or support from the university. Second, it was unknown how long this situation would last - a week, a month or longer? Thus, teachers were left to their own devices and had to transition their courses relying only on their traditional teaching experiences.

The purpose of this research is to collect experiences with emergency online teaching from both teachers' and students' perspectives, and to analyse these experiences to find out what worked well and what worked less well. Going forward, the old ways of teaching, based purely on physical attendance, will likely be replaced by a hybrid model that combines online and in person education. It is therefore important to learn from these experiences, and thus, this research focuses on two questions:

- Which issues can be observed with respect to emergency distance and online teaching?
- What practices should be implemented into teaching when transitioning to a hybrid model?

1.1 Related work

The massive emergency change to online teaching and learning caused by COVID-19 was a novel, worldwide experience. Although online teaching and learning is not new, transitioning to an online format was prior to COVID-19 typically a well-planned activity. However, in spring 2020, the lockdown of colleges and universities and the ensuing change to online teaching and learning was anything but well-planned. Planning, preparing, and developing an online university course typically takes months. In March 2020, the term emergency remote teaching (ERT) was introduced to distinguish between teaching and learning that was planned and designed to be online, and the temporary shift to an alternate mode in response to the crisis [1].

Online teaching and learning has been studied for decades, and numerous well-planned transformations to online formats are described in existing literature. However, research related to COVID-19 emergency online changes is more limited. Additionally, different foci are presented. While [2] reflects on the crisis-response migration methods employed by universities, students and faculty members, the questionnaire-based case study with 44 teachers in mechanical engineering at a vocational high school in Indonesia, [3], focuses on learning strategies, platforms, and instructional media during a pandemic. Only few case studies exist on teachers' and students' perception of the emergency online teaching and learning during university lockdowns. For example, in an interview-based case study with 12 faculty members and 12 students from University College of Medicine and University College of Dentistry, Lahore, Pakistan, [4] explores the perception of teachers and students regarding advantages, limitations and recommendations with ERT. The case study in [5] is based on interviews with 11 undergraduate engineering students at University of San Diego, USA, and investigates the methods students used to adapt to remote learning, and what faculty can do to support students during ERT. The case study in [6] is based on an anonymous survey with 183 participants from a Midwestern university in the U.S. Quantitative data analysis is used to examine faculty members' perceptions of online teaching during the pandemic and their satisfaction with the transition.

In this paper, we focus on the perceptions of both faculty members and students in courses taught in spring 2020 at the Department of Mechanical Engineering at DTU.

1.2 The research aim

The aim of this research is twofold. Based on the generated empirical data the first aim is to create an overview of the different teaching methods used, and to identify the strengths and weaknesses. Based on these findings, the second aim is to make recommendations that support teachers as they guide students towards learning strategies that best fit the chosen teaching methods. Students use different learning strategies; some students use a deep learning strategy while others use surface learning [7]. Teachers' awareness of both strategies is relevant not only in the context of traditional face-to-face teaching but also in emergency teaching and learning as well as when transitioning to a hybrid model that combines online and in person education.

2 RESEARCH METHOD

The present exploratory study is based on a qualitative research approach. The empirical data for this study were generated through two questionnaires. First, the Department of Mechanical Engineering emailed a questionnaire to the teachers in the department. This questionnaire contained two key questions: "What worked well?" and "What worked less well?". Answers from teachers of approximately 40 mechanical engineering courses were collected through this survey. Second, a university-wide questionnaire was sent to all students focusing on teaching during the university lockdown. This questionnaire included two key questions: "What has worked well? Please tell us about any positive aspects of on-line teaching that you think DTU can use in the future", and "What did not work well? Please tell us about aspects of on-line teaching that could be improved" The answers from students who in spring 2020 participated in mechanical engineering courses were thereby collected. Next, these data were added to two documents listing what worked well and what worked less well. Statements from teachers were coloured blue and statements from students were coloured red to easily distinguish between the different perspectives.

In total, the two questionnaires resulted in 251 statements concerning mechanical engineering courses. This included 39 statements from teachers regarding what worked well, and 49 statements what worked less well. Also included are 91 statements from students regarding what worked well, and 72 statements what worked less well. Since 251 statements distributed across 40 courses do not say much about the teaching in each individual course, the research team decided to structure the empirical data through a bottom-up process with the help of an affinity diagram [8]. The statements were first printed on individual paper slips and mixed up. Next, the statements were read carefully and similar statements were grouped. Finally, each group was given a title reflecting the theme of the grouped statements. Figure 1 shows a picture of the affinity diagram in its making.

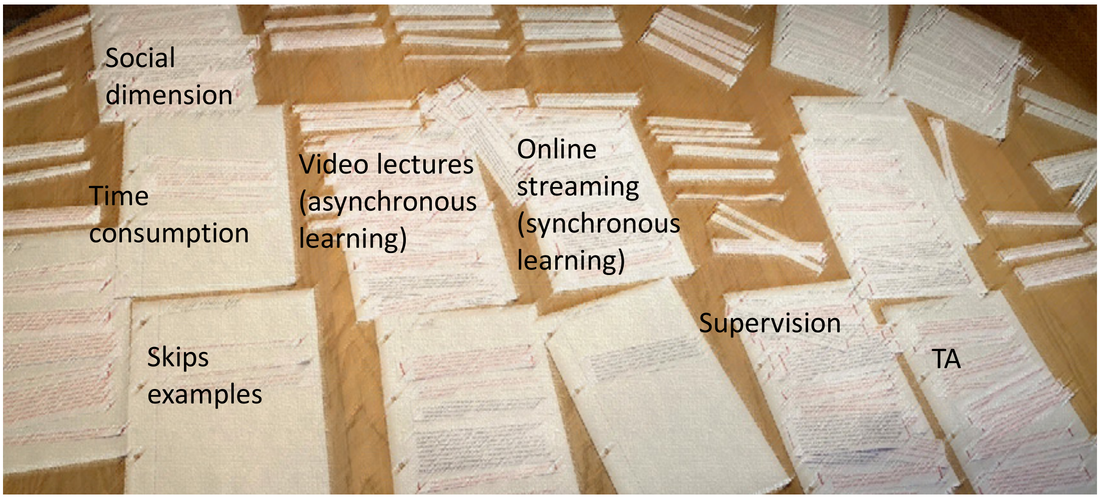

Figure 1. The affinity diagram in its making. Some themes have already emerged: Social dimension, time consumption, skips examples, video lectures etc.

From the affinity diagram it was possible to create a rich picture of the experiences seen from both the teachers' and students' perspectives. It was not the intention to use statistical methods to analyse these statements, because it is not the frequency of single statements that is of interest, but the richness of the picture.

3 RESULTS

The following themes emerged from the affinity diagram: Online lectures (synchronous learning), Video lectures (asynchronous learning), Group work and supervision, E-mail supervision, Teaching assistant (TA), Videos explaining answers to previous exams (asynchronous learning), Time consumption/Time management, The social dimension, No transportation, Lack of physical materials/models, Technical issues incl. software tools.

3.1 Overview of software tools used

At DTU, teachers and students had to transform to the online format overnight, and neither guidelines nor support were available. Thus, the teachers began teaching online based on their individual experiences, and the software tools listed by the teachers reflect many different choices as shown in Table 1.

Table 1. Software tools chosen by the teachers

Teaching method	Software tools
Online streaming (synchronous learning)	Zoom, Skype, Teams
Pre-recorded lectures (asynchronous learning)	pdf-files with voice over, YouTube videos, Adobe Connect
Lectures without voice/self-study (asynchronous learning)	PowerPoint slides
Supervision	e-mail, Piazza.com, Discord, Mural

The multiplicity of software tools used was not necessarily viewed positively by the students. For example, two students wrote:

- *“It was annoying that two different platforms were used for this.”*
- *“…Also an absolute MUST is for the teachers to use a unified streaming platform. We have been using 3 different ones during the semester and that is not good. Zoom seems nice, but Discord/Microsoft Teams is also nice for group work.”*

3.2 Observations of live streaming lectures

With respect to synchronous live streaming of lectures, some teachers reported that it was difficult to sense students’ reaction. For example, two teachers wrote:

- *“It was difficult to see the reactions of the students, so it is a bit difficult to judge whether there is a good response from the students. There is no feedback during the lecture itself.”*
- *“It is difficult to sense whether the students received the teaching as intended - when asked, it was typically the same student who answered.”*

However synchronous live streaming may help students’ motivation as the following four student statements suggest:

- *“Holding LIVE lectures online has been really good! It keeps you motivated to do what you have to do and participate in the course each week, so you do not fall behind / postpone it.”*
- *“Worked really well with Skype teaching especially because there could be a communication between lecturer and students. Also mildly "forced" one to follow the normal schedule rhythm because it [the lecture] was not [recorded]”*
- *“It seemed good that the teacher was very aware of whether those who followed had understood the material correctly... both by stopping and asking if you are involved, but also asking academic questions to the students”*
- *“The drawback is you cannot ask direct questions during the course. You still have the opportunity to ask questions, but it cannot be compared to the lecture being conducted in person”*

3.3 Observations of recorded video lectures

Some teachers reported positive feedback from the students when lectures were pre-recorded for asynchronous use. For example, two teachers wrote:

- *“There was positive feedback about the digital lectures. They were happy to have the opportunity to use them at their own pace“*
- *“Audio-annotated lecture slides. (The majority of the feedback from the students on these has been very positive)”*

However, both positive and negative feedback regarding video lectures was received, and two students wrote:

- *“Audio annotations for teaching slides were good as they could be heard again.”*
- *“I was not good at keeping up when the teaching worked as it did having PowerPoints with speak. I found it difficult to get involved in this form of teaching. I therefore made all previous exam sets instead.”*

The students were not able to ask questions during recorded video lectures and some found it difficult to engage in teaching as these four student statements suggest:

- *“The videos do not allow you to ask questions during the lecture.”*
- *“It has been really good with the videos - especially when you have been able to rewind and hear something an extra time if you did not get a detail. I would always prefer to get physical education, but to be honest I almost think I have benefited more from watching the videos rather than blackboard teaching (if the exact same thing was said). The downside is of course that you cannot ask for details. Of course you can write an email, but it just seems cumbersome and heavy.”*
- *“Honestly, I thought that the online teaching was way too easy. - Just following a video step by step reminds me of being a little kid trying to learn different software by watching YouTube videos.”*
- *“Online teaching is a bit like a cheap copy of coca cola. It's a second rank version of the real cola. One can perfect the recipe as much as one wants, but the "secret ingredient" is the physical attendance, one cannot imitate and the quality of teaching will be markedly inferior!”*

The possibility of choosing their individual time schedule when viewing the recorded lectures was received positively by some, as two students wrote:

- *“What worked the best was not having to wake up super early and saving money not having to drive two hours a day…”*
- *“Offhand, the only advantage is that you have been able to adapt the teaching to your own scheduling”*

3.4 Observations of e-mail supervision

Some teachers considered e-mail as an open invitation to ask questions that students could easily use. Thus, two teachers wrote:

- *"Mail correspondence with the students. I have the impression that those who wrote felt well helped, and I have been happy for that source of contact."*
- *"The (most) students who made use of the offer took the time to formulate their questions well so that it was (relatively) easy to give a good answer."*

However, the students did not have the same perception regarding the ease of formulating questions in writing, e-mailing the teacher, and receiving a helpful answer. Three students wrote:

- *"I missed having the TA being present for help after the lectures. It is more difficult to describe your questions via mail and you also hesitate more to ask."*
- *"On the other hand, the course form is difficult in online format, because often questions regarding assignments are best clarified by drawing and discussing rather than writing over the web."*
- *"It was really hard to conduct the exercises, since the teachers would not answer to emails (we had to send the same email multiple times until we got a not really satisfying/helpful answer)…"*

3.5 Observations of time consumption

The only theme where students and teachers seemed to agree was time consumption. Both parties considered emergency online teaching to be more time consuming than physical, face-to-face teaching.

Two teachers wrote:

- *"Much more time has been spent on supervision than I usually do because it takes longer to explain than when sitting next to each other."*
- *"Video lectures take a lot of time and provide no interaction with the students. Digital whiteboard with a tablet is difficult to use compared to a physical whiteboard."*

Five students wrote:

- *"I do not think online teaching can replace real [face-to-face] teaching. I use a lot of asking questions, and learn a lot from it, but there was not the same opportunity for it online ... Several times I experienced that what I wrote was misunderstood, and it would be done much faster in reality [face-to-face]"*
- "*I really liked the online course content on YouTube. All the small details you would miss in class, you had right in front of you. This said, the analysis of each lecture took a lot more time than normal. Personally I have spent 4-6 hours on each lecture, as you have a tendency to stop and play all the time. This is without the time spent on the exercises."*

- *"The only negative aspect was that it increased around 30% the time to dedicate to the subject, it took on average 3.5 hours to "translate" in notes the lectures"*
- *"… Also not to stereotype, but it might be that a lot of engineering students are dyslexic, me for instance, reading is therefore highly time consuming task compared to lectures…"*
- *"The delays in the lectures, together with the lecturer clearly being on the verge of collapse with stress!"*

4 DISCUSSION

The involuntary transformation to online teaching in spring 2020 was a novel experience for everyone. The present study shows that both teachers and students found emergency remote teaching more challenging and problematic than face-to-face teaching. First, the use of multiple software tools was frustrating for some students. Second, the new format required more time from both teachers and students. Some teachers used more time on supervision and preparing lectures, while some students used more time on formulating questions in writing, revisiting lectures and creating notes by transcribing online content.

A strength of pre-recorded video lectures is that students can review the content when it is convenient for them and at their own pace. Weaknesses are a lack of interaction with teachers and fellow students, and that students may end up focusing on details rather than the overall content and structure of the lecture.

Strengths of live streamed lectures are that teachers and students can interact in real time, and that students are required to follow a scheduled timeline, providing structure for their studies. A weakness of lectures that are only live streamed and not recorded is that they cannot be revisit by students for clarifying difficult details at a later time. Additionally, students may be reluctant to ask questions online as they may need to leave their comfort zone in order to interact with others.

From the teachers' perspective, e-mail support may have been seen as an open invitation for students to ask questions. However, students found it difficult to formulate questions when they did not understand an assignment or felt they had limited knowledge about a subject.

The study's observations from teachers and students should be considered as universities adopt hybrid teaching that combines online and in person education. Departments could agree on a few common software tools that are used across all courses as use of multiple software tools was found to cause students' frustration. We recommend e-mail supervision replaced by online Q&A sessions to give students the option to ask questions orally and allow other students to benefit from the discussion as well. Regardless of whether teachers choose pre-recorded or live-streamed lectures, the chosen methods' strengths and weaknesses should be discussed with students to help guide them towards learning strategies that best fit those methods.

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E-LEARNING CHALLENGES IN TEACHING CONTENT IN ENVIRONMENTAL ENGINEERING WITHIN THE FRAMEWORK OF COVID 19.

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Conference Key Areas:*Sustaable Changes Beyond covid-19. Academic teachers needs and support for online teaching.*
Keywords *COVID 19, Teaching, Colombia, Environmental Engineer.Content*

Abstract

The global COVID-19 pandemic has led to the suspension ofteaching in many countries. At the university level, the urgent transformation of classroom classes into an online format hasbeen carried out in a way that can be described as generally acceptable, although the measures taken have been adapted with urgency and not with a well-considered, a priori plan to teach a subject with a completely online methodology. Carrying to massive online evaluation is something that universities had never faced from an institutional perspective. Therefore, the faculty and the student must work together to provide a response that integrates methodological and technological decisions, while at the same time ensuring equity, legal certainty, and transparency for all actors, both internal and external. This article aims to analyze the treatment given to the formation and development of learning done through the e-learning platform, or Learning Management System in several virtual learning spaces in the Environmental Engineering program of two Colombian universities with different characteristics. These platforms use methods that combine tutorial and in-person teaching/learning of content in order to facilitate this experience in current conditions (COVID 19 for the large number of teachers who share this problem at this exceptional moment around the world).

INTRODUCTION

The teaching and learning of the tutorial modality are attuned to that of the classroom modality, the latter of which is characterized by the physical presence of the students and the teacher in the classroom. This interactive context is essential for the teaching and oral learning of a foreign language and the development of communicative competence.

The COVID-19 pandemic has directly impacted the educational systems in every country in affecting students, households, ministries, secretariats, educational centers, educators, and administrators. The closing of schools as part of measures taken to contain the spread of the virus has more than 165 million students not attending schools, from preschools to higher education, in 25 countries in the region (UNESCO, 2020). 2

The economic and social costs of the pandemic are still unknown, but an economic crisis unprecedented in modern history is looming. It is estimated that widespread declines in GDP worldwide will affect developing countries the most. The IDB's Macroeconomic Report "Policies to Combat the Pandemic" estimates a drop in regional GDP to 5.5%. (Nuguer, V., & Powell, A, 2020). 4

While the economic and social costs of the pandemic are still unknown, an economic crisis never seen in modern history approaches. [SOURCE] estimates that falling GDP around the world will be felt most acutely in developing countries.The IDB's Report, "Policies to Combat the Pandemic," estimates that GDP in [Latin America and the Caribbean?] has declined 5.5% since the start of the pandemic. (Or "The IDB's Report, "Policies to Combat the Pandemic," estimates that GDP in [Latin America and the Caribbean?] will decline by 5.5% between 20xx and 20xx).

This situation may be further aggravated in educational systems that do not have effective mechanisms for distance education in line with household characteristics 7, which may further widen the gaps between students with greater or lesser access to them. LAC countries have launched Remote Education Emergency Initiatives 8 to provide short-term solutions and maintain some continuity in learning processes.

The solutions adopted have depended on the capacities and modalities of each country, as well as the content available to build an emergency model of distance education. For example, most ministries had digitized printed educational resources (e.g. textbooks, libraries, etc.), educational portals and online resources for students and teachers. Few countries had content platforms and learning management systems. It is key to understand, however, that these resources were designed for an education that would otherwise be delivered in person or semi-in person and not entirely remotely.

Most governments around the world have temporarily shut down educational institutions in an attempt to contain the spread of the COVID-19 pandemic. These nationwide closures affect about 70 percent of the world's student population.

UNESCO is supporting countries in their efforts to mitigate the immediate impact of school closures, particularly for the most vulnerable and disadvantaged communities, and to facilitate the continuity of education for all through remote learning.

Current pedagogy seeks to provide a foundation for how to reach students of the present generation most appropriately so that they master conceptual, procedural and attitudinal knowledge for their daily life and career. This includes a foreign language, in most cases English, for international communication, as an expression of culture, and a way to update or educate professionals in training in Colombia, technically or humanistically.

In the face of current challenges, some studies examine the blended model between in-person and e-learning, which offers a new frame of reference for an educational implementation that differs from the traditional one; however, the necessary standards of excellence have not yet been achieved and the best ways to incorporate in-person learning in English with the activities of the blended model have not been explained.

The professional finds more opportunities to access cutting-edge research knowledge in this area of engineering in English. Online LMS learning is currently offered, but that does not rule out blended methodology as a bet on the successful development of skills in this language. Hossein Moradimokhles & Gwo-Jen Hwang (2020): The effect of online vs. blended learning in developing English language skills by nursing student: an experimental study, Interactive Learning Environments, DOI: 10.1080/10494820.2020.1739079.

1 METHODOLOGY

This article was developed in a systematic review using databases and institutional repositories using searches with keywords such as “e-learning,” “COVID-19 and education,” and “virtual education”

Analysis of the data

To say that face-to-face education is better than digital is completely erroneous. The possibilities of digital education have been brought to the table by such important institutions as the Massachusetts Institute of Technology (MIT), the University of Chicago, and the Universidad San Ignacio de Loyola. Let us reflect. Who is better prepared to face a challenge like COVID-19: the one who has studied for several years in a digital environment, and who is very familiar with this environment, or someone who is facing it for the first time? There has been talked of the democratization of knowledge, which exists and is real, but let us speak of the "commoditization" of knowledge. (Nuguer, V., & Powell, A. 2020). 5

Knowledge 2,000 years ago was reserved for a few in educational institutions, but today it is accessible to everyone. With this, knowledge has expanded, and has done so with a marginal cost that tends to zero. Therefore, more than democratization, it is a "commoditization" of knowledge. Therefore, the most important thing in this Fourth Industrial Revolution is that we understand what is happening. We live in a present where the old does not stop dying and the news does not stop appearing. We are immersed in this transitive property where we do not know, yet, if we are analog or if we are digital. The generations that follow will live in a different reality.

A World Bank study says that, in four or five years, 65% of today's young people will have jobs that do not yet exist. Therefore, universities must prepare students for the new jobs that will arise, to use technology that has not yet been invented and to solve problems about which we do not yet know. Moreover, we must focus on the development of soft skills and digital skills, skills that the labor market will require. And what are some of those skills? Problem-solving, critical thinking, creativity, personnel management, emotional intelligence.

The purpose or intention of the assessment distinguishes, primarily, between the assessment of learning, which is designed to aid in the learning process y providing feedback to students (Mcalpine, 2002), and the summative assessment, which ends a learning period with a final judgment on the overall student performance (Earl, 2013. When the student is more deeply involved in the process of formative evaluation, through self-monitoring and evaluation, or by his or her peers, it is called assessment as learning (Earl, 2013). Additionally, the diagnostic evaluation tries to predict the future performance of the student body. As shown in Figure 1, there is a strong relationship between the time dimension and the functional dimension of the assessment.

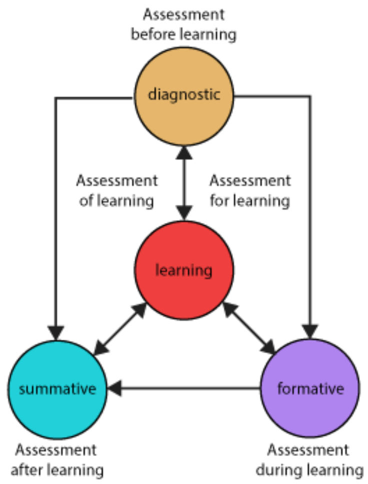

Figure 1. Schedule of diagnostic, formative assessment. Source: based on Stalljohann (2012, p. 11).

Depending on the length of the assessment, it may be a partial evaluation, which focuses on some components of a subject, or an overall evaluation, when it tries to cover all components of a student, course, program, center, etc. When the focus is on transparency, there is a range between formal and informal (Mcalpine, 2002). Formal assessment is easily recognized by the student body, as in the case of examinations or evaluable tasks. Informal evaluation accompanies other activities and is not as apparent, for example, participation in a discussion forum on the virtual campus. The subject of the assessment may be a product when it is based on the idea of the transfer of knowledge from the teaching profession to the student body, but when more emphasis is placed on competencies, the process is a more suitable subject for evaluation. However, assessing how a task has been carried out is always more complex than evaluating the outcome of a task.

According to the origin of the evaluators, we traditionally speak of internal evaluation and external evaluation. Internal evaluation is promoted and carried out from within, by the members of the teaching team themselves, while in an external evaluation, the evaluated and the evaluator belong to different bodies. This dimension may include open evaluation, which refers to the practice of obtaining and presenting credentials by demonstrating what has been learned. In this way, the process and procedures leading to the evaluation of these credentials are known, rather than maintaining and imposing a monopoly on the recognition of learning.

An example is to publish instructions, questions and headings for the evaluation of these, in such a way that any external agency wishing to evaluate students in a course (whom themselves want to be evaluated) could do so. In this situation, for a given course there is no single form of evaluation, but there can be as many forms of evaluation as there are students; the assessment of individual performance is independent, that is, it is separated from the course content and its instruction (Downes, 2012).From the perspective of the actors involved in the evaluation, a distinction is made between:

- Self-assessment: students evaluate their performance.
- Heteroevaluation: evaluators and the evaluated are not the same people
- Co-evaluation: certain people or groups mutually evaluate each other, that is, evaluators and the evaluated exchange their role alternately (Castillo Arredondo and Cabrerizo Diago, 2009). Coevaluation can also be applied to situations where students are allowed
- to assess themselves while allowing the teaching team to maintain the necessary control over final evaluations (Hall, 1995).
- Peer evaluation: the process through which students grade their peers (Falchikov, 1995).

Coevaluation can be used for summative purposes, while self-evaluation and peer evaluation tend to be used in a formative manner (Dochy, Segers and Sluijsmans, 1999). Finally, based on the normotype, there is a differentiation between normative evaluation and criteria evaluation., In a normative evaluation, the benchmark is the general level of a given normative group. It establishes the comparison between the performance of each student and the average performance of his group. Criterial evaluation refers to a prior criterion (evaluation criterion), or a precise and concrete determination of the expected yields (Castillo Arredondo and Cabrerizo Diago, 2009; Popham, 1980).

E-proctoring systems in education

The development of online educational programs has evolved significantly based on pedagogical models and advances in learning technologies, but assessment or certification of learning remains one of its weakest points. In situations with few students and models focused on teacher-student interaction (Seoane-Pardo and García-Peñalvo, 2006; Seoane-Pardo and García-Peñalvo, 2008), continuous evaluation-based models are perfectly manageable and admissible. On the other hand, when the number of students grows, as is the case of the MOOC (Massive Open Online Courses) (García-Peñalvo, Fidalgo-Blanco and Sein-Echaluce, 2017, 2018), models based on continuous evaluation alone are no longer as feasible. then tends to extremes that lead to the development of personality assessment in specific physical locations (Shuey, 2002) or to the use of disruptive solutions based on open assessment (Downes, 2012), which are often not widely accepted in formal university training. Accordingly, there is an increase in demand for technological solutions that allow for online supervision of an evaluation (Fluck, 2019; Pathak, 2016), due as much to the limitation of having to resort to an in-person evaluation for an online education, as to studies that support the idea that unsupervised examinations have a higher potential risk of inappropriate ethical behavior or inflation (Carstairs and Myors, 2009; Prince, Fulton and Garsombke, 2009). However, few studies make an in-depth comparison of dishonest conduct in on-site testing and online testing as they are conducted (Chirumamilla, Sindre and Nguyen-Duc, 2020; Sindre and Vegendla, 2015).

Remote monitoring systems are called e-proctoring systems. The use of these remote monitoring systems is conceived as an attempt to equalize the incidence of academic dishonesty between online and personality assessment tests (Harmon and Lambrinos, 2008), to lend a higher degree of confidence for both teachers and external agencies that must accredit the quality of the diplomas that are not taught person, but either 100% online or blended. There is an awareness that, as with the supervision of on-site examinations, there is no perfect virtual monitoring method.

An important factor that differentiates between private and public institutions is the recruitment of students and their performance in the Saber Pro tests, The tests on the quality of undergraduate in Colombia, now called SABER PRO, have been suggested as standardized external evaluation instruments that are part of a set of processes undertaken by the National Government in an attempt to assess the quality of public education and do inspection and surveillance. Castro and Ruíz (2019) show in the first scenario the following: …, students with higher synthetic Saber 11 indices continue their higher education at a university, compared to a technical institution… good high school students continue to be good superior education students." Concerning student recruitment, studies indicate/the data indicate/analysis indicates that private secondary and higher institutions attract more students than public entities, however, when analyzing quality (average, low and high Saber Pro scores) the public institutions in superior education . (Castro, M., & Ruiz, J. 2019). Secondary and higher education in Colombia as observed Saber tests. Praxis & Saber, 10(24), 341-24.

These efforts by universities now include exceptional regulations covering the different methods of online assessment, entailing not a change in the rules governing the organization of teaching, but rather an adaptation to the online assessment. These assessments differ from the methods traditionally implemented in teaching guides, guides that will need to be modified to record, in a general way, the methodological changes and changes to the evaluation system.

For virtual/distance evaluation tests, these regulations should consider general or specific contingency procedures in the case of problems that may arise (virtual classroom crash, video conferencing system, individual connectivity problems, etc.) and performance guidelines in such cases (Cordon et al., 2020). 4.

It is essential to collect evidence from assessments carried out through systems that ensure compliance with legislation on data protection and digital rights of individuals. The durability and accessibility of evidence must be guaranteed during the review period and legal custody in order to be able to deal with possible complaints from students, audits by quality agencies or regulatory compliance (Cordón et al., 2020).

Online evaluation of the theoretical and practical aspects of the subjects

In general, when using oral examinations or written response examinations, whether synchronous or asynchronous, best practice is to avoid questions that require memorized answers or that can be looked up on the internet. They should be replaced by reflection questions, which assess students' understanding, discretion, or judgment or which require the application of some type of cognitive process, for example, causing them to do some work before submitting/providing an answer. The levels of self-identification of students for the different tests are summarized as:

• Basic level: Access to virtual platforms via ID and custom passwords is personal and non-transferable information that de facto identifies students. Improper and fraudulent use of these identification keys can have legal consequences.

• Average level: equivalent to an in-person evaluation. In a videoconference, they are asked to show the camera an identification card (code or other equivalent documents with the student's name, surname, identification number and photograph) before taking a test.

• High level: biometric identity checks are carried out. It requires prior registration of students, installation on their equipment of complementary tools, and authorization to use the webcams and/or contents of the work desk.

Online assessment scenarios for the different parts of a subject can be classified into two initial categories: synchronous and asynchronous tests. In online teaching models, it is advisable to give feedback to students on the positive aspects of the tasks they deliver and the areas with room for improvement, and to inform them of the elements on which they are being evaluated. In a continuous evaluation scenario, there is permanent student-teacher feedback.

Online Evaluation Tools

So far there has been talked of online assessment strategies; this section gathers some of the most common tools that can be used to develop evaluation systems in university institutional technological ecosystems (García-Peñalvo, 2018a). Although most of these tools can be found on the different eLearning or LMS (Learning Management Systems) platforms,Moodle will be used as a reference because of its widespread implementation in university systems worldwide (https://stats.moodle.org/).

Strategies to promote motivation in online teaching

The motivational role that teachers play in online teaching is crucial. The way in which teachers help to develop students' autonomy and competence occurs in two ways: directly through learning activities, and indirectly through the nature and organization of these same activities (instructional design).

A well-known model on motivation to learn (ARCS, Keller s, 2010) proposes four categories of analysis. These are the categories of attention, relevance, confidence, and satisfaction, which serve as guides for the development of teaching strategies. They consist of capturing the student's attention, establishing the relevance of the learning, increasing the student's confidence, and helping to generate feelings of satisfaction through intrinsic and extrinsic rewards.

Another important methodological framework, which helps to create motivational strategies for learning, is proposed by Ginsberg and Wlodkowski (2000). This framework consists of four principles: establishing inclusion, developing attitude, enhancing meaning and engendering competence. The use of these principles can lead to high motivation and quality for all students:

Creating inclusive environments refers to the creation of learning environments in which students and teachers feel mutual respect, through rules, procedures and structures that allow the creation of an aid community. The role of the teacher is essential to this goal, creating an environment of open communication, treating students equally, and helping all students to express their ideas and thoughts.

Engendering competence refers to helping the student to develop a sense of effectiveness before a required task and the feeling that they can achieve a skill/competence with mastery, and in this way, attach importance to their self-control in terms of effort and strategies used. Accordingly, students need sufficient information, guides (e.g. Study Guide), and timely feedback to create their judgments of their needs to complete the assigned task. A key to developing skills in distance learners is to provide them with self-evaluation opportunities with an appropriate level of feedback.

And concerning unrealized and difficult to virtualize practices?

As soon as the health situation and the conditions of social distancing permit, within the academic period defined for the current course, priority should be given to those practices that, not having been completed or replaced, are difficult to carry virtually due to time and cost issues, with special attention to those in their final academic year of a bachelor's or master's degree. In the worst-case scenario, except for the final year of the degree, teachers can find that the skills that could not be acquired due to the situation can be practiced and assessed; specific instructional designs, at no economic cost to students and with the endorsement of departments, degree committees and teaching bodies.

There is evidence of the benefit of considering blended training. Students must overcome resistance due to their existing ties to and experience with the teacher's presence and advice. That said, a study on students' perception of this modality mentions that it is now easier to accept new technologies and faster to learn their implementation, but they indicate that not all areas are possible to implement completely virtually. Aguilar-Salinas, Wendolyn E., Fuentes-FuentesLara, Maximiliano de las, Justo-López, Araceli, & Rivera-Castellón, Ruth E. (2019). Students' Perception of the Blended Model of Teaching Basic Engineering Sciences. A University Case Study. University Education, 12(3), 15-26. https://dx.doi.org/10.4067/S0718-50062019000300015

COVID-19, in public and private, means "Stay at home; but don't keep what you usually do at home." It is a call to action, it is an opportunity to innovate, to adopt simulation methodologies and virtual laboratories that are necessary and now mandatory to consider in curricula.

2 RESULTS

Online distance education continues to grow in universities today, and at this time when almost every country in the world is affected by the COVID-19 pandemic, it is one of the alternatives for students to access educational programs from their homes. Accordingly, teachers must pay attention to motivation, understanding its complexity and multifaceted nature, to design and develop successful, quality learning experiences. They should also use teaching strategies that include aspects of motivation such as meaning and expectation, which help to understand complex theories, concepts and evidence.

The motivation for online learning involves stimulating, sustaining and giving direction to the student learning, in the context of teaching designed for this purpose that determines its expression as a permanent activity for self-improvement.

Achieving motivation in the online teaching and learning process requires the development of activities that enable a proactive attitude that is conscious of inquiry and the content search. In this way, learning will implicitly bring the integration of the students' intention to acquire knowledge and develop their intellect, to the extent to which they are taught to think, to express their ideas, to reflect, to argue and to value what they learn and can thus operate with knowledge towards new and higher levels of demand that stimulate their development.

3 SUMMARY AND ACKNOWLEDGMENTS

The COVID-19 pandemic has created an unprecedented situation in all areas of education. The state of lockdown has affected all levels of education. This article focuses on the specific case of university studies and more specifically on in-person universities that have had to make an emergency adaptation of in-person classes to a remote format that, in the best cases, have been able to integrate some of the basic principles of quality online education.

What was initially proposed as a replacement for teaching activities has inevitably led to non-classroom assessment scenarios that have traditionally been seen as the most complex aspect of managing university degrees online, beyond continuous assessment activities, most universities, whether remote or online, base their assessment processes on formats that require the physical presence of those who choose to take these tests.

If online teaching was already a challenge, and in many cases a shock, for the university community, remote evaluation is the biggest obstacle to completing the academic year. In addition to people's natural resistance to change, universities also face the technical limitations of systems designed to give specific IT support to mostly in-person activities and reluctance and lack of strong support from certain key players in the political and academic management of this process.

With the aim of assisting the faculty director and the student body indirectly, this article has included a set of recommendations aimed at designing online evaluation mechanisms and strategies, leading to a fair evaluation process for all. They are exactly that, recommendations, never impositions or absolute truths, because academic freedom and decision-making belong to the faculty. Professors must take their students into account in all phases of the instructional design of teaching activities and evaluations, as well as inform them in detail of the decisions made and the changes that the subject will undergo due as a consequence of the sudden causes of this crisis. In the context of these sudden changes, many teaching adaptations have had to be made in urgent conditions, so as not to paralyze academic activity.

Furthermore, if no one is to be excluded or harmed by the conditions resulting from distance education, the possibilities and students' limitations and impacts must be known in order to establish contingency plans adapted to each case. The teacher should be aware of them and they should be integrated into the institutional strategy defined for this purpose. Finally, there is palpable fear and mistrust on the part of many of the teaching staff towards their students: they intend to exercise strict control over those being tested to detect all student practices contrary to academic ethics.

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STUDENTS' PERCEPTIONS OF MASTER PROGRAMMES: READY FOR WORK IN 2021?

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ABSTRACT

Educating engineering graduates to confidently tackle issues in their future jobs demands a well-balanced curriculum that integrates development of essential conceptual knowledge, professional skills and attitudes for ethical conduct. Often, it is the case that priority is given to developing a strong knowledge base, with an expectation that other professional elements will gradually emerge in the course of students' engagement with either project-related work or other collaborative tasks. Designing a comprehensive Master programme requires careful balancing of technical and professional skills, hence in this paper we expose the results of a study that looks at the strengths and weaknesses of five Master courses of our institution, from the students' point of view. Data gathered through a survey that contains quantitative scales and open-ended qualitative questions provides the perceptions of students on their gains in terms of both conceptual knowledge and professional skills. Results indicate strong student outcomes in theoretical knowledge across several disciplines, but a clear request for a more practical and real-life based approach. Moreover according to the students' opinions, there is an expectation for more learning experiences regarding project management skills, use of IT tools and understanding on some ethical, legal and environmental aspects of engineering.

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Observations and conclusions of this study also include reflections on the extent to which the COVID-19 lockdown impacted the overall student experience of the Master courses.

1 INTRODUCTION

1.1 Background

By the end of the last century, a significant volume of academic literature pointing to the need of reorienting teaching and learning to better respond to 21st century challenges had been produced [1]. There is an existing need to include more complex critical thinking skills, an interdisciplinary understanding of problems, and reflections on solutions that encompass ethics and equity. This is particularly applicable to engineering education [2], which has been criticised for its significant shortfalls in teaching transversal skills within its main curriculum [1][3][4]. The demand for a more holistic engineering education [3] with versatile workviews and the capacity to understand different dimensions of problems is completely justifiable when looking at the first 20 years of this century, culminating with the current challenges brought on by the ongoing pandemic.

However, are engineering graduates prepared for these challenges? As a result of a global lockdown of higher education institutions, the generation graduating in academic year 2020/2021 is the first to finish their education under these unprecedented circumstances. We examined five Master programmes of our university, a higher education institution that offers Bachelor, Master and Doctoral degrees in engineering and architecture. By collecting quantitative and qualitative answers from students, we aimed to understand how prepared for work the students felt at the time of their graduation. This paper presents the main results and invites a discussion on positive and negative aspects of current engineering programmes and how to move forward.

1.2 Literature overview

There is an overall agreement that the “purpose of engineering education is to provide the learning required by students to become successful engineers - technical expertise, social awareness, and a bias toward innovation”[5, p.1]. The combination of adequate knowledge, skills and attitudes necessary for successfully engaging in the engineering profession has been a driving force for change. Yet, the change is slow-paced and at many institutions tectonic pedagogic changes are needed in order to arrive at a well-balanced curriculum[6]. Additionally, the future trends of engineering education shows shifts “towards socially-relevant and outward-facing engineering curricula”, one that is based on interdisciplinarity and examples outside the classroom with close examination of its social impacts [7].

While there is a strong need for interdisciplinarity and social skills in the engineering curriculum, much of the engineering curriculum is based on a single discipline [8]. Current studies show that graduates often lack some of the core skills that can help them in the transition from university to work [9].

Adapted from a European Commission’s document, Torres et al (2018) [1] sketched a structure of skills profiles specifying the job specific “hard” skills as one small part, sitting on top of a wide spectrum of “soft” transversal skills, including legislative and regulation awareness, economic awareness, basic skills in science and technology, environmental awareness, ICT skills and foreign language skills. The bottom layer of this skills pyramid are components that are closely related to project management and self-esteem, including personal effectiveness, relationship and impact and influence skill clusters. Additionally, as a response to some of the issues in the current engineering education curriculum, a Conceive-Design-Implement-Operate (CDIO) approach was developed [5]. The CDIO approach emphasises on mastering the four components of conceiving, designing, implementing and operating "complex, value-added engineering products, processes, and systems in a modern, team-based environment" [5, p.7] and embeds learning in a cultural environment to enhance learning within a context.

1.3 Context of the study

Our study focused on the perception that students have towards the achievement that they reached at the end of their training regarding both disciplinary and professional Learning Outcomes. The main question was:

> How prepared do students feel for working effectively in engineering after finishing their Master programme?

In order to break down and properly answer this complex question, we designed three sub-questions that provide specific dimensions for our evaluation:

1. What is the students' evaluation of their knowledge and skills?
2. What do students perceive as strengths and weaknesses of the programmes?
3. How did COVID-19 impact their studies?

Our intention through this paper is to provide empirical evidence on the three sub-questions and evoke a discussion around our leading question that will stem from the analysis of the answers to the three sub-questions.

2 METHODOLOGY

2.1 Instrument

An evaluation of the Bachelor's and Master's programmes was implemented in our institution in 2017, following accreditation requirements. A questionnaire containing quantitative and qualitative aspects and targeting students at the end of the Master's programme is one of the instruments of this evaluation. This paper is based on 181 answers across 5 Master programmes, from the 2020 survey.

Data was collected between May and December 2020, with a response rate between 21% and 84% among the respective Master programmes. The sample included 29% of female students, 69% male and 2% of those that did not identify with either.

The quantitative part of the questionnaire was implemented in a format of four-grade scales (including the options excellent, adequate, insufficient and none, but not missing[2]). The surveys differed slightly since the implementation of the programme

[2] Category « None, but not missing » refers to students not learning a skill/knowledge and perceiving it as not necessary.

evaluation was an on-going process in 2020. For this study, we keep only questions that were the same for at least 3 of the 5 Master programmes. These included:

Q1:"How do you assess your level of competence in these core areas at the end of the Master in XXX?" (5 programmes)

Q2 "How important do you perceive the development of the following skills at the end of your Master training?" (3 programmes).

The qualitative side of the survey included the following open-ended questions:

- What should be added concerning the contents of the Master?
- In your opinion, what are the strengths of the Master programme?
- Please, give us your comments and suggestions for improvement
- How has the COVID-19 situation affected your internship or Master Project?
- How has the COVID-19 situation affected your studies?

Additional questions were asked in Masters A, B and C, as following:

- Master A and B: In your opinion, what are the weaknesses of the Master programme?
- Master C: In your opinion, are there any areas/domains in this Master programme that may be underrepresented or absent (courses offered). If yes, please tell us which ones.

2.2 Procedures

The quantitative data was analysed using descriptive statistics. After combining extracts from the five Master files, we constructed a table for each question, and we presented the responses in the form of bar charts. The percentage for each of the four-grade scale was calculated on the number of effective answers. In the bar chart, each bar is attached to a sub-question. Sub-questions were grouped according to the categories from the CDIO competences framework [5] as far as possible.

The qualititative questions were analysed following deductive and open coding techniques. The names of the five Masters' programmes have been anonymised and replaced in respondents answers by the letters A-E before the coding phase. We used the framework provided by CDIO to start with the procedure, and the initial coding included codes ranging from teamwork, professional skills, personal skills, communication and foreign language. The first iteration of coding involved the same segment of data, coded by three independent researchers. During the first round, we realised that some data did not fit the pre-existing categories of CDIO, so for the second iteration we used open coding techniques to add codes that better described the data. The added open codes included self-esteem, emotions, remote work and impact of COVID-19, assessment and flexibility of the programme. We observed that some of the aspects missing from the CDIO framework were specifically related to students' personal feelings, as well as the more technical characteristics of the programme which seemed to influence students' opinions. The open codes were strictly defined and discussed among the three researchers, therefore the final codebook included a mix of CDIO and agreed open codes that were then used for the final third iteration.

3 RESULTS

Across all data, the most interesting finding, which is equally represented in quantitative and qualitative answers, is the way students regard the quality of the Master programme, both from the perspective of strong disciplinary knowledge and the choice of subjects they were provided with. In a similar fashion, we notice that overall, students perceived that during their Master education there had been missed opportunities to gain professional transversal skills and hands-on experience.

3.1 Knowledge and skills

In more detail, the first such discrepancy is noticeable with how students assessed scientific knowledge and professional skills, presented in Fig. 1.

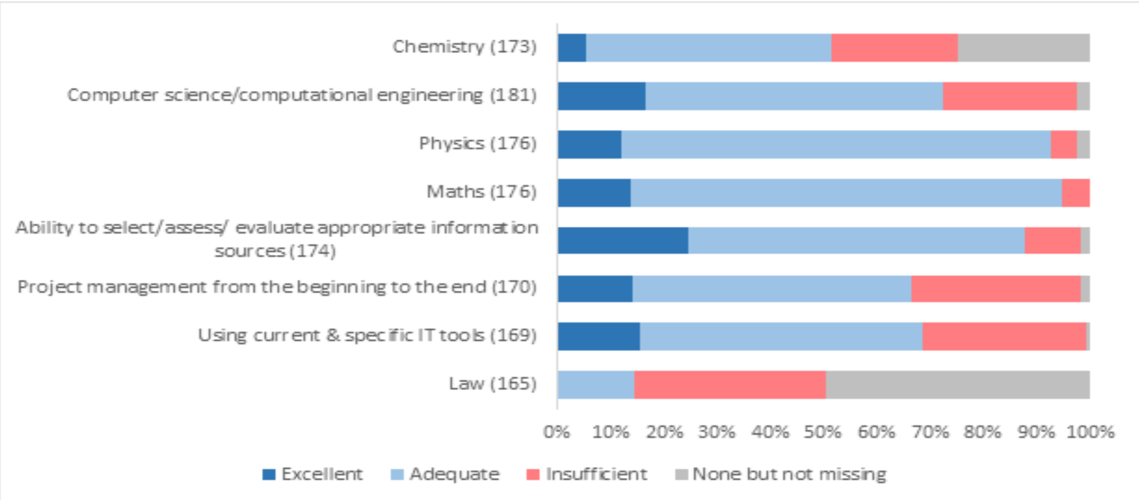

Fig. 1. Self-assessment of knowledge and professional skills – Five Master programmes.

In reading these results we can see that:

- A majority of respondents are satisfied with the level of knowledge in mathematics, physics and computer science, and about half in chemistry
- However, 24% of respondents found their level of knowledge insufficient in Computer sciences / computational engineering
- In chemistry, 23% of respondents found their level of knowledge insufficient, while 24% believe they do not have the adequate knowledge but it is not missing

In comparison to professional skills:

- Most students feel they have the ability to select / assess / evaluate appropriate information sources

- However, 32% of respondents found their ability level insufficient in project management, and about the same proportion noted this for using current and specific IT tools
- Strikingly, when it comes to law, only 15% of students assessed their skill level as adequate, while 35% of students rated it insufficient and half of the population as something they do not miss.

These results go hand in hand with the qualitative answers where overall, students seem to be satisfied with the level of knowledge, however in some cases they do suggest specific subject related courses, some transversal skills and better balance between theoretical and experiential learning. Some of the student quotes confirm this:

“We obtain an excellent level in maths and this is very appreciated worldwide.” (169)

“Great theoretical set of courses, especially the ones that are taken in the 3rd semester (which are in fact from the doctoral school).” (165)

“Extremely good education in my field, compared with world top universities. Great teachers.” (151)

On the side of professional skills, however, students’ answers indicate that even though our institution offers the opportunity to carry out interesting and challenging projects, there are aspects of professional skills that could be improved. The participants (70 comments out of 208) show their willingness to apply the theory in a more practical way and more contextualised in a real world situation. Some of the most repeated examples are:

- Project management: experience all the process and phases.
- Foster interdisciplinary projects.
- Practise: build robots, lab immersion.
- Collaborate with real companies, face real challenges

Opinions of several students showed that the programme should be more balanced.

"[We should be] focusing on soft skills which are often MORE important than technical / hard skills" (134)

“Not enough practical and real life applications. I know that it is hard to implement. But I learn so much during association project rather than master courses” (26)

This is also examined in the following section, which looks specifically at strengths and weaknesses of the programmes.

3.2 Strengths and weaknesses of the programmes

A very high proportion of respondents (97%) considered their capacity for critical thinking to be a strength of their training. Most of them (95%) also considered as other strengths of their training the development of their oral and written communication skills, their capacity to keep/acquire new knowledge, their ability to communicate and collaborate with others, and, to a lesser extent (90%), their ability to use an appropriate work methodology and to give/receive feedback.

The main identified weaknesses are related to the responsibility skills. More than 40% of respondents perceived their ability to take responsibility for the environmental impact of their actions and decisions to be weak, and 25% their ability to respect ethical codes for their profession. Lastly, the ability to use both general and specific IT resources and tools is perceived as weak by 19% of respondents.

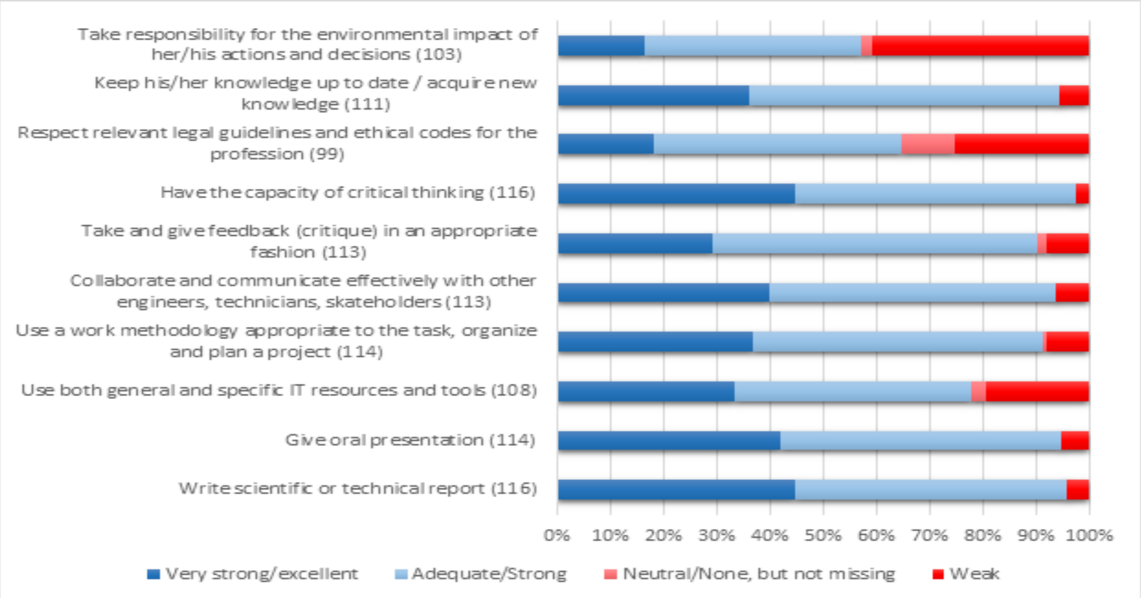

Fig.2. Respondents' perception of strengths and weaknesses - Three Master programmes.

In their qualitative replies, students offered further insights into what they felt were the strengths and the weaknesses of their education. Interestingly, several replies related to well designed programmes that provide an interdisciplinary overview of the field, as portrayed in these examples:

> *"The mix of possible courses from various different fields create the possibility to move in many different directions." (42)*

> *"I think [institution] is a superb place to grow as an adult, even more than as an engineer. I would encourage the intersection collaborations between sections uncompatible at first sight, about subject that matters for all." (110)*

Alongside the interdisciplinarity, the answers indicate that students highly value and appreciate internships and collaborations with real companies.

“I think it could be a very nice idea to push for more semester projects in collaboration with enterprises and more interventions from industrial experts to create awareness for the industrial challenges ahead. The mandatory internship is excellent to gain experience, but I think this advantage of gathering experience already as a student could be further enhanced and would make the [B] master even better.” (76)

Several opinions have pointed towards the value of the programme content that offers transversal skills, like those provided by the Social Sciences and Humanities Section (SHS), as given in this excerpt:

“How the real world works: to know what is 'maitre d'ouvrage, mandat, appel d'offre, etc...' SHS focuses on soft skills which are often MORE important than technical / hard skills, depending on the company we work at. Working as a consultant, my level in french / english, presentation, social competenties, teamwork are more important than the technical stuff…” (134)

Assessing the proportion of coded qualitative answers given by students, we noticed that most frequently they mentioned autonomy (45.9%), which was often regarded as a strength of the programme. Opposite to this, sustainability, ethics (each with a proportion of 18%), and law (13%) were often mentioned in a negative way, as something missing from the programme, as these examples show:

“More environnemental, ethical and legal knowledge.” (101)

“Environmental concerns, impact of the civil engineering industry, how to minimize environmental impacts, what to be careful with. I suggest not to add a course, as student could just not take it but to add this topic in the various courses” (131)

3.3 Students’ self-perceptions and impacts of COVID-19

Most of the comments related to how students experienced COVID-19 lockdown were neutral. There was a large proportion of answers (132) indicating that there was minimal or no effect of the lockdown with respect to their studies, and in some there were notions of how students adapted to the situation, reflecting on greater independence and autonomy. This was present in 28 comments, including this one:

“I had very little contact with my professors and it was sometimes difficult to be isolated in a foreign country alone. I had to rely on independence to complete the project. “(139)

However, outside of the knowledge and skills frameworks, there was a lot of content in qualitative answers related to students’ emotions. These comments were often related to the COVID-19 situation. Many of the perceived difficulties were connected to students’ stress related to finishing their studies, having to leave to their home countries, as well as having experienced negative consequences for their Master project, such as impossibility to do prototyping or being away from hardware. Some respondents reflected on different levels of teamwork quality in the COVID situation during their internship. They observed that zoom remote teamwork was more difficult than face-to-face (difficulty to speak simultaneously, more time consuming, less efficient, reduced interaction and collaboration with teammates), as well as hardship due to the lack of interaction and isolation during COVID.

Emotional aspects were coded in about a quarter of all the open-ended answers. In these comments, students described their difficulties of staying motivated and efficient during remote working, the lack of social contact, the feeling of loneliness (even depression in one comment). One respondent pointed with bitterness the impossibility of carrying out their PDM abroad, whereas another that was abroad for PDM described a feeling of being very isolated. One respondent described the sadness of ending the Master without celebration of this moment.

"I felt like nobody followed what I did, I was working alone on my project" (170)

Also, in 22 answers we found references to "self-esteem". In these comments, respondents often expressed doubts about their own ability to adapt to the professional world. These were not always strictly connected to the COVID-19 situation, but they reflected the ambivalence of their training, balanced between broadness of knowledge and specialization.

"It is difficult to express what I think of the master. It is great because on one hand, I have studied many different fields and that was very interesting. On the other hand I do not have the feeling to be fully prepared to work in any of those fields, even in my specialization in which I feel I have too broad and not specific enough knowledge." (105)

There were two other contributions in which students specifically suggested adding activities in the curriculum that would reinforce students' self-confidence, which could possibly improve their capacity to evaluate their own knowledge and skills, and feel more self-secure.

3.4 Discussion: how prepared do students feel?

Results showed that respondents feel well prepared in theoretical scientific fields such as Maths and Physics, and to less extent in Computer sciences/computational engineering and use of IT tools. Studying within the context of COVID may have reinforced the perception of need in this later domain. Opinions were divided regarding Chemistry, that may be explained by the various Master programmes that were included in the study. They perceived their ability for critical thinking and communication as strengths of their training.

On the other hand, results also showed that respondents seek mere preparation/experience in personal and professional skills, such as what participants call "real life work". Respondents are demanding for even more practice and interdisciplinarity in their training, and more preparation for teamwork. Results also showed that respondents felt less prepared regarding law and that responsibility skills are perceived as weaknesses of the training.

So, in answer to the initial question "How prepared do students feel for working effectively in engineering after finishing their Master programme?", we could state that from a theoretical perspective, they feel ready, but they feel they are lacking personal and professional skills that are essential in the industry.

This brings up the discussion: is the curriculum sufficiently up to date to face 21st century needs? Engineers have to be educated for facing challenges of sustainability and climate change, of automation technologies, and be trained for innovation, entrepreneurship and design thinking. They are expected to have both a systemic and interdisciplinary approach for dealing with ill-defined and complex interactions between technologies, integrating human and societal values, and designing innovative solutions in fast changing contexts. The engineering programmes of this study embraced some trends of emerging curriculum models, as described by Hadgraft and Kolmos, such as active-learning, integration of practice through internships and projects, and personalized learning through the choice of courses within the programme [10]. However, for dealing with complexity, the present study tends to confirm the students' expectations of more integrated project work within the curriculum. This is coherent with emerging trends towards more integrated curricula, such as the CDIO approach [5]. Hence, further explorations, including Alumni surveys, are much needed in order to understand how teachers and curriculum developers can enhance opportunities for students to gain adequate work-related skills adapted to the 21st century context.

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COURSES BASED ON COMPETITIONS HIGHLY MOTIVATE STUDENTS FOR RESEARCH-BASED LEARNING

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ABSTRACT

Specially designed research-based learning (RBL) modules are highly motivating, especially when they are based on competitions. We designed a project module at Technische Universität Berlin to motivate students from all fields to get involved in synthetic biology and evaluated the perceiption by our students and the marks they achieved in a final oral exam. During five years we experienced highly successful student groups that won prizes on the international student competitions iGEM and BIOMOD in Boston and San Francisco. The student teams organized themselves and invested strong efforts over long time periods to achieve their ambitious self

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chosen goals during the projects. The comparison between evaluation results and marks showed that the students achieved a high competence level.

We conclude that RBL modules which are coupled with competitions are highly motivating. Our experience shows that international student competitions like iGEM or BIOMOD represent an excellent basis for designing RBL courses in synthetic biology and biotechnology. Since the teams were interdisciplinary also students from informatics, engineering, physics, chemistry, mathematics and even arts were involved, successfully. The aim of the study is to present both 1) the methodological concept to set up similar competition and research based learning modules and 2) the outcome of our evaluation and the marks which are obtained by the students.

1 INTRODUCTION

1.1 Combined competition and research-based learning (RBL)

We believe training should comply with Humboldt's ideal, which we conceive as*: teaching without research is empty and research without teaching is blind*. In that sense we believe that learning is most motivating when it combines both, 1) the thirst for experiences and understanding and 2) the methodology of a researcher.

Therefore, we designed the student centered and competition based research module “iGEM-Synthetic Biology” where young students from all backgrounds with little or no research experience are provided with the intellectual and scientific resources to become confident, responsible, independent researchers of a group that targets a highly specialized field that needs a broad range of competencies.

Student-centered courses, projects and workshops that enable students to design their own research program, which can later be presented in a competition, are by nature highly motivating and of great didactic, scientific and societal value [2, 3].

RBL experienced a rise in it´s didactic awareness in the last 20 years [4, 5]. In our own RBL module “iGEM – Synthetic Biology” we observed an extraordinary motivation of the students and we believe that this is activated by the combination of RBL with a competition [6, 7] and an oral final exam that targets the basic teaching matter.

Generally, the following criteria motivate students to be highly active and drive them to achieve extraordinary results: (I) a democratic, student-centered structure, (II) a project of relevance targeting current societally important questions of e.g. sustainable waste treatment or energy production, (III) public science communication (as performed, e.g. during the *Long Night of the Sciences* and student-centered conferences, on a regular basis) and (IV) the participation in competitions. The motivation to achieve something really substantial, to obtain a product, that helps to save the world in their own point of view, is outstanding and is hardly achieved in other teaching formats [2, 3]. This especially accounts for a novel and fascinating research field like Synthetic Biology that constructs novel building blocks in biology [8], intending to find and understand new forms of life [9] which are unknown to date [10 - 12].

1.2 Research-based learning (RBL) from a cognitive science point of view

An extremely important question which needs to be addressed by universities is how to educate young students enabling them to solve real societal problems such as climate change or social cohesion. Knowledge and competence emerge from a development process, as psychological studies [13, 14] and error research [15, 16] show. The finally achieved competence levels are ordered hierarchically according to Bloom's taxonomy [17]. Each level requires exercise and self-reflection combined with the phantasy to drive basic concepts further enabling creative processes [18].

Therefore, RBL project courses provide a chance to reshape the teaching environment especially when developing new concepts, and potentially satisfy the need to achieve core competencies, which endow students with the capability to master problems occurring later in their professional life. These problem-related competences should gain higher priority in academic teaching and new didactic strategies need to be developed. This applies both to theoretical subjects [19, 20, 21], and experimental subjects (e.g. practical courses) [20, 22] linked to RBL [2, 3, 6, 7, 22-25].

1.3 Elements of digital teaching and presentation skills

Digitalization plays a major role in the communication of individual work or general science including the acquisition of and the search for knowledge. It enables a quick literature search, the administration and sharing of information and the collaborative documentation including the recording of actions and progress. Secondly, digitalization can support self-directed learning [26 - 28]. Thirdly, digitalization offers transfer possibilities between disciplines and institutions as well as towards the public when research outcome and learning content is shared in social networks, on blogs or via videos. Competence development that is urgently needed to handle future challenges include self-regulation issues [28 - 32], identification of learning strategies [33], rating of information quality and relevance and interest development [34, 35]. In this context, it is promising to record the students' current experiences and behavior in a timely manner in the respective actual situation, and, if necessary, to intervene in a controlling manner (ambulatory assessment) [36, 37].

In “iGEM-Synthetic Biology” the students particiate in international competitions like iGEM or BIOMOD [6,7], where they present their work with a talk, a website that needs to contain a complete documentation of their laboratory work and a three-minute video (for BIOMOD) that attractively covers the relevant steps of the project [38]. In addition the students organize the large project with project management tools like Trello® or Slack® to track their progress, distribute responsibilities and conduct project reviews. As the students are also judged by the efficience of their science communication they set up facebook, twitter and Instagram accounts to steady post news on their projects. In such sense RBL is naturally suitable to activate digital competences of the students if that is initiated at the beginning of the project.

Fig. 1. *The 2016/17 team "multibrane" outside and inside the lab.*

Presentation skills are part of the entire project as the students organize individual presentations in their seminars. By attending scientific meetings like the Forsch2017 conference at Humboldt University of Berlin, especially designed for student project presentations, or the urban and national "Long Night of the Sciences", where their work is presented to up to 3000 people (2019) in an open science communication format, science communication skills are developed further.

Finally, at the competition´s jamboree, the students present their results creatively on stage in form of a kind of theater play combined with a scientific talk (similar to a science slam).

2 CONCEPT AND METHODS OF "IGEM - SYNTHETIC BIOLOGY"

2.1 How to start?

We introduced "iGEM - Synthetic Biology" in 2014/15 and the module took place five times until 2018/19 with 10-15 participants for two semesters and three supervisors that invested an equivalent of 8 SWS (teachinghours per week and semester) all together. The students achieve an equivalent of 9 ECTS credits according to an overall effort of 270 working hours. The module teaches the basics of synthetic biology while students perform complex laboratory work to achieve their self developed project goal, they discuss their results with the public and present afterwards at an international competition (iGEM or BIOMOD [6, 7]).

At the beginning the supervisors distribute the task to all participants to present winner projects of former years and/or recent research papers (usually discussed by the winner teams) during the seminar talks. The time schedule of the seminar and the digital project management tools are established. All in all, the students refer to the current state of science but they are already try to think beyond – not necessarily with the focus on a deep scientific approach but in a broader sense of how to transfer recent scientific findings to more general or even different problems. This partially involves a kind of “science fiction”, however, it helps to find novel approaches. The supervisors seed to be visionary in that sense that they trigger the students’ ideas during the seminar.

Once a topic has been chosen, the participants formulate a hypothesis and a proposal for research, a realistic goal and concrete research methods. The students do online research and use their project management software and the web page for online documentation, project design, project tasks and documentation [2, 3, 20, 22, 23]. The Digital documentation also enables the supervisors for ambulatory assessment. From that content the student teams post on the internet (facebook [39], twitter [40], instagram [41]) and to develop the blog and video on the project.

2.2 How to design the final exam?

We decided to hold an oral final exam with each student to ensure that the basic teaching matter of the module is recognized and the work on their own project leads to a visible growth of professional competence. Therefore the competition is not the mandatory requirement to finalize the module but it is the final exam. Large numbers of questions of the students on the exam and the etaching matter and an excellent average performance during the final exams showed us that the students also wanted to perform in the final exam and not in the competition only. We even believe that these motivations to achieve both, a good rating in the competition and also in the final exam, are linked. A didactic study on the possible correlations of motivations and causes of achieved core competences might be still elusive. At the current point we can just contribute with the objective evaluation of the students performance during the final exam which is described in chpter 4 together with the evaluation of the module by the students themselves.

2.3 How to progress with the team?

Once the project idea is crystallized, the most important issue is to provide a framework for project implementation. Wet laboratory research in engineering biology is always difficult already at this level, even when simple protocols and procedures are followed. The research project is carried out as a team of usually 10-15 participants, who subdivide into different task groups. At the beginning of the project, the participants indicate which skills and which specialist knowledge they bring in, and which tasks they would like to work on. Ideally, there is one qualified expert per task group who takes over responsibility and shares his/her knowledge with the others in the group. The experiments carried out in the laboratory are first recorded in a laboratory book and then transferred into digital form on the project website. This also ensures open and transparent science and promotes the idea of OpenData and OpenAccess which are principles of the initiators of iGEM and BIOMOD.

2.4 Strengths and weaknesses

As outlined we believe that the main strength of the module that combines RBL with a competition and a final exam is an extraordinary high motivation to learn both, science communication and professional competences. However a disadvantage might be that the participation in the competition which was linked with a travel to San Francisco (BIOMOD) or Boston (iGEM) is a driving motivation and overshadows the need to learn the basic teaching matter. We addressed this by motivating the students to care themselves on the acquisition of financial support. The students were finally supported by companies (Bayer), working groups and cooperation partners as well as the Cluster of Excellence “UniSysCat” (funded by DFG) and the “Society of the Friends of TU Berlin e.V.”. In addition it is useful to clearify at the beginning that the participation in the competition is not to be sure but depends on the quality of the project progress and the individual engagement during the project. As both, iGEM and BIOMOD were conducted online during the Covid-19 pandemic a pure online participation in these competition would be an opportunity to shift the focus from expensive travels to performance in competitions and exams.

2.5 Happy end and beyond?

During the BIOMOD competition in San Francisco, the 2017 project “Multibrane” won a gold medal and the third place worldwide in the categories “best project” and “best video” [42]. During the final phase of the competition, the students spent several weeks working intensively every day in the laboratory and optimized their internet presence until late in the evening to realize the ultimate success at the BIOMOD competition.

It turned out that the students show a high motivation to work on their remarkably elaborate projects with great efforts in and around the laboratory (see Fig. 2). The module was awarded the prize for excellent teaching of the Society of Friends of the TU Berlin e.V. 2018 [43].

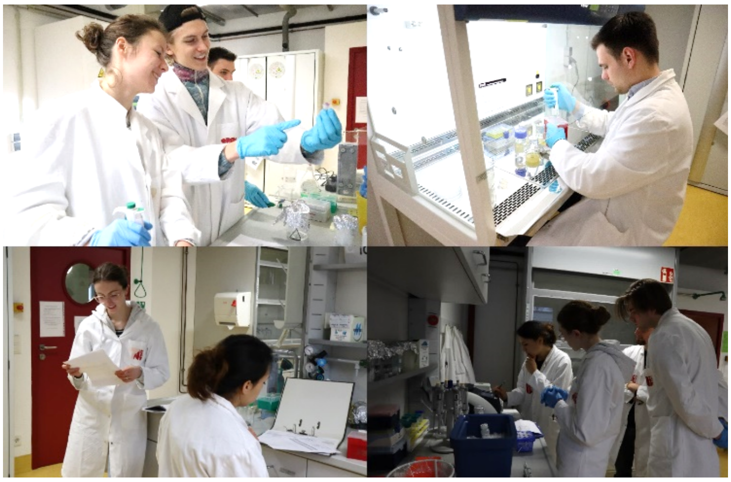

Fig. 2. *“iGEM – Synthetic Biology” students working in the laboratory at TUB (see acknowledgements). Reprinted with permission from [25]*

In 2019, TUB has included “iGEM – Synthetic Biology” into a large campaign initiated by the vice-president for teaching, Prof. Hans-Ulrich Heiß, with the special focus on RBL.

3 EXAMPLE PROJECTS

3.1 The 2015/2016 and 2016/2017 project "MultiBrane"

In 2017, the highly interdisciplinary student team "MultiBrane" with participating students from bachelor and master programs of biotechnology, chemistry, physics, informatics, biochemistry, mechanical engineering and arts as well as bachelor students from the orientation study program "MINT^{grün}" at TUB worked together and won the third place worldwide in the BIOMOD competition [44] (See Fig. 1). They designed a modular biological membrane designed with active fusion proteins for claring water from pollutants such as microplastics, antibiotics and heavy metals by binding suitable enzymes to the membrane [45 - 48] (See Fig. 3). They characterized their construct exhaustively by integrating the green fluorescent protein to apply fluorescence lifetime imaging microscopy which is especially suitable to characterize fluorescent hybrid systems [49 - 53].

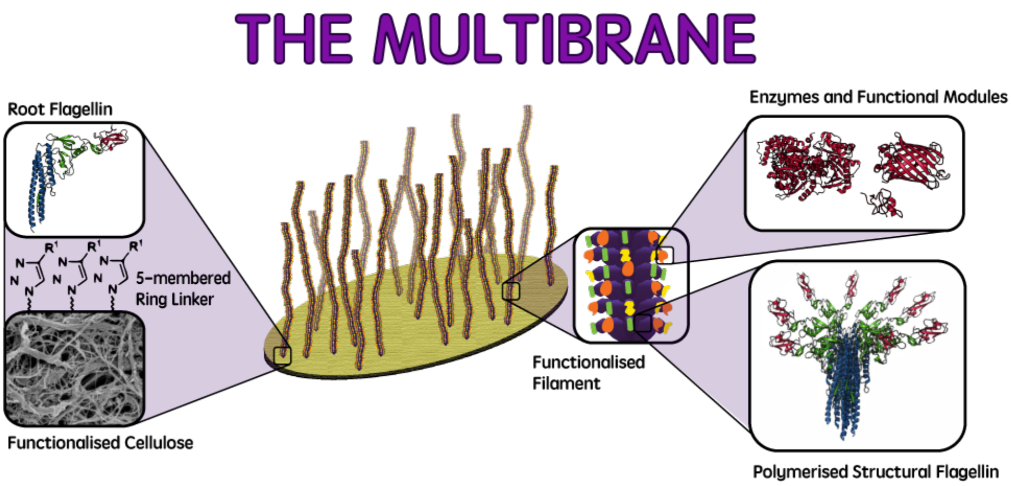

Fig. 3 Concept of the multibrane as developed by the 2016/17 Student team to cmbine different proteins for claring water from pollutants such as microplastics, antibiotics and heavy metals on a membrane of bacterial cellulose

3.2 The 2017/2018 and 2018/19 project "smart B.O.B."

In the semester 2017/18 the team was driven with the idea to replace fossil fuels and other environmentally harmful energy sources by renewable technologies involving genetically modified photosynthetic bacteria. As supervisors we suggested the students an actual approach proposed by Haas et al. [54]. The electrons released from photosynthesis should be fed into an electrical circuit. With different approaches, it was planned to optimize this process [55], i.e. by genetic engineering of a more efficient electron transport chain to the extracellular space [56] or to improve adhesion of the bacteria to the metal electrodes [49]. The final definition of the theme took quite a long time as the students proposed a large variety of visionary projects which were discussed in detail with the supervisors. So in 2018 we decided not to participate in the competition but shift the participation to the BIOMOD 2019 competition. The first idea was the development of a hierarchically structured fuel cell, where stable populations of two different species grow on nanostructured electrodes, with one species producing hydrogen driven by incident solar light, and another species directly generating an enhanced electrochemical reduction potential by heterotrophic growth in a hydrogen-rich atmosphere [57]. However, after studies of current literature on the complexity of synergistic growth and cooperative evolution in limited environments, the team decided to focus on the growth of a single organism only.

So the team "smart B.O.B." ("smart biologically-optimized battery") formed and developed the concept of a biological battery containing photosynthetic cyanobacteria able to generate electricity due to potential changes on macroscopic electrodes (see Fig. 4). In detail, according to the concept of an electrochemical workstation as e.g. technically proposed by the group of Adir [55], carbon membranes or a carbon mesh can be used as a conductive matrix to house electrochemically active bacteria that are well characterized and can therefore be genetically manipulated. Similar approaches of conductive and nutrient carrying matrices for bacterial growth have just recently been proposed as suitable reactors for biological batteries [55, 56, 58] (See Fig. 4).

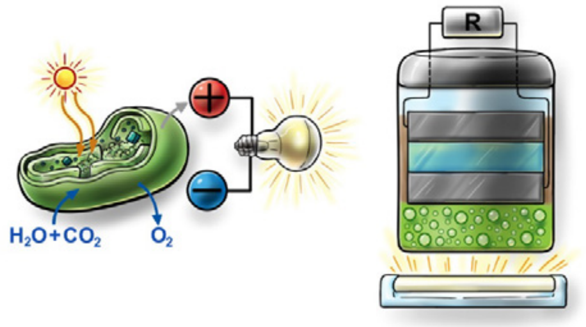

Fig. 4. *Left side: Basic idea of a biological battery driven by photoautotrophic cyanobacteria, right side: Simplified construction of an electrochemical growth cell based on commercially available "mud watts" [58]. Reprinted with permission from [25].*

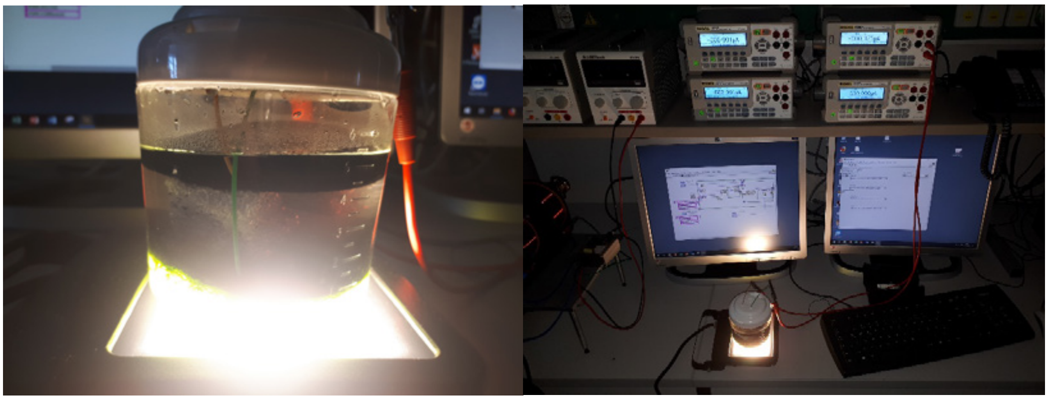

Fig. 5. *The growth cell under illumination and the setup suitable to monitor current and voltage during on-off periods of illumination.*

4 EVALUATION RESULTS AND ACHIEVED COMPETENCES

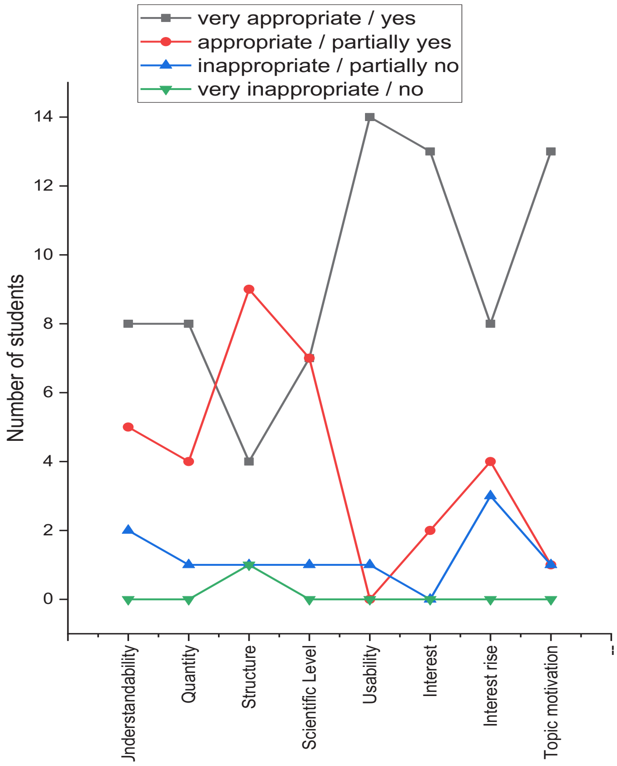

Fig. 6. *Part of the evaluation results 2017/18 (n=15).*

The project “iGEM - Synthetic Biology” has been repeatedly evaluated from different sides (TUB and *tuprojects* coordination) very positively. In particular, the lecture style and competence of the participiting experts as well as the teaching style of the lecturers who worked rather as team members than as teachers were rated in the highest possible category. Most importantly we were interested in students evaluation of their competence growth. It turned out that the module was estimated (ranging from very good = 1 to very bad = 4) with 1.6 in understandability of the study matter and scientific level. Ranging from 1 = very appropriate to 4 = very inappropriate the quantity of the teaching matter was rated 1.3 with a bit lower ranking of 1.9 for the structure of the module. Usability of the learned and Interest in the topic was extremely positively rated at 1.1 with motivation to get deeper into the matter ranking at 1.2. Interest rise during the module participation was lower with 1.7 but on a high level. So we conclude that the students judged their interest and the assumed usability and importance of the taught matter at highest level. They feel comfortable with the scientific level and the quantity and understandability of the matter even in such an interdisciplinary team which focusses on molecular biology. This is in contrast to the fact that the students worked even more in the laboratory and for the preparation of their blog, presentations and the teaching video as they would have needed to achieve the credit points of the module. The students are somehow missing the structure of the teaching module which might be caused by the nature of such a student centered teaching module.

All students finished the module with an oral exam and they were asked deep into the matter of synthetic biology. The 15 students in 2017/18 obtained marks between 1.0 (best mark in a range from 1.0 to 4.0) and 1.7. The average mark was 1.15 and the involved supervisors were regularily astonished by the deep knowledge obtained by the students during their time of participation ranging from 9 months up to 2 years (2 semesters (2x3 months with 3 months break inbetween) were mandatory).

From the students' side, the module was recommended to 100% for participation. Importantly, another point of the students' criticism was that they wanted even more interaction with experts from the working groups as they felt highly inspired by their competent input.

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IT'S A NEW ADVENTURE WITH EVERY NEW STUDENT: A CRITIQUE OF THE DISSERTATION SUPERVISION PROCESS

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ABSTRACT

Starting with the question *'How do MSc Dissertation Supervisors view their role?'*, this ongoing exploratory study focusing on supervisors' perceptions of their responsibility to develop students' study, professional, and analytical skills has been undertaken within a large engineering education department in the UK. An online survey was administered to a group of supervisors responsible for guiding graduate students through their full-time master's projects during the Covid-19 pandemic. The findings suggest that the majority of supervisors believe they have some responsibility for providing individual study skills support during the supervision process; although opinions differ with regards to the level of support that should be given. Changes to the supervision approach in response to Covid-19 are also identified and initial recommendations and suggestions for future research are shared.

1. INTRODUCTION

Set in a large engineering education department in a UK university, the research examines the question *'How do MSc Dissertation Supervisors view their role?'*. This short paper uses descriptive data to review the perspectives of project supervisors on their supervisory role to develop the study, professional, and analytical skills needed by students to successfully complete a master's level research project. This is significant since there is a lack of understanding about master's supervision [1]. Yet successful supervision is a key factor for student's achieving their degree and preparing for their career [2].

The master's level research project is a key element of master's study in the UK. Referring to the UK Quality Assurance Agency Characteristics Statement [3] for a Master's Degree, it clearly states that:

> "*they are usually predominantly composed of structured learning opportunities (are 'taught'). Frequently, at least a third of the course is devoted to a research project, leading to a dissertation /comparable research output or the production of other output such as an artefact, business plan, performance or musical composition"* (p6).

It proceeds to clarify that:

> *"They include research methods training, which may be provided in a range of different ways (for example, through content modules)"* (p6).

In the department there are slightly more than 1,200 full-time students from 15 diverse master's courses who complete the dissertation. The dissertation is 90 credit points for most students, and equates to half of the marks awarded for the master's degree. To support the students' skills development to complete a research project, students can attend a year-long blended learning module that focuses on study, professional, and analytical skills. This module is not compulsory at present, but strongly encouraged, as it is important for preparing students for academic success. In addition, students have a project supervisor, an academic or industry professional, who provides mentorship throughout the independent research project.

This work was conducted as part of a more holistic review of the master's project process and became increasingly relevant in light of the Covid-19 pandemic when support for students' during their studies became disrupted due to cohorts being dispersed globally. This short paper analyses the survey responses of 89 project supervisors about their perceived supervisory responsibilities for students' study, professional, and analytical skills development to complete the dissertation. Since this research is a work-in-progress, findings are not critiqued against literature as this will occur at a later stage. Initial recommendations and suggestions for further research are provided.

2. METHODOLOGY

To understand supervisors' expectations of their master's students' skills development and perceived responsibilities of supervision, a twenty question survey was sent to current supervisors during the Covid-19 pandemic in April 2020. The survey focused on four areas: students' skills development for the research project, the role of the supervisor, departmental processes, and impact of the first pandemic lockdown on supervision. An initial descriptive analysis of the data is presented here. Further development of the research will expand to include an analysis of supervisors' perceptions and practices for developing students' professional and analytical skills.

3. RESULTS

3.1 Supervisor Sample

A total of 89 professionals in academia and industry supervising master's students responded to the survey. Of the 89 participants, 38 were internal supervisors and 51 were external supervisors. The internal supervisors include members of the department or a different department within the university. External supervisors were divided into two groups: academic supervisors employed at a different HEI/FEI and 'others' that include supervisors that are employed in the business, industry, or public sector (excluding education), retired, or other. The sample breakdown is evidenced in Table 1. The study identified participants by supervisor position rather than other factors, such as gender or degree attainment, as the degree of closeness to the institution and higher education impact the extent of knowledge about available student support and expectations for student skills development. The multi-disciplinary portfolio of the master's programme is reflected in the diverse background of supervisors with experience in business and management, engineering, and social sciences.

Table 1. Breakdown of Sample Participants

Supervisor Position in University	*N*
Academic Supervisor (Internal – member of the department or university)	**38**
Academic Supervisor (External – employed at another HEI/FEI)	**20**
Other Supervisors (External)	**31**
Total	**89**

3.2 Supervisors' Perspectives of Students' Skills Development

A key finding is that a majority of academic supervisors, whether internal or external, perceive they have a minor to no responsibility to support their students' development of study skills, compared to other supervisors (external) who tend to perceive it as a major part of project supervsion. This is evidenced in a cross tabulation in Table 2. It is also notable that more external academic supervisors see study skills support and guidance as 'something [they] should only do in exceptional circumstances' or 'not [their] role' compared to the other groups.

Table 2. Cross tabulation of supervisors to perceived responsibility for providing 'study skills' support and guidance to individual students

"Providing study skills support and guidance to students is…" (% of responses per employment group)						
	A major part of project supervision	*A minor part of project supervision*	*Something that project supervisors should only do in exceptional circumstance*	*Not the project supervisor's role*	*Not sure*	
Academic Supervisors (Internal)	**38**	**56**	**-**	**6**	**-**	100%
Academic Supervisors (External)	**26**	**42**	**21**	**11**	**-**	100%
Other Supervisors (External)	**59**	**28**	**10**	**-**	**3**	100%

It may be that supervisors who are currently employed in higher education are more likely to see the responsibility of the department to provide support through the study, professional, and analytical skills module rather than perceive supervision as a complementary process for reinforcing skills progress. In contrast, 'other supervisors' currently outside of higher education may not be as aware to the departmental or university support for students' skills development.

More external academic supervisors (employed at a different HEI/FEI) perceived study skills support in exceptional circumstances or not part of their role may be due to their experience in their institution in which study skills and/or research methods training is credit-bearing and required. Hence external academic supervisors may have a different expectation on student skills development, particularly compared to internal supervisors, since the study, professional, and analytical skills module is unique compared to similar modules found in higher education institutions in that it is optional and not credit-bearing [4].

The difference between internal and external supervisors' perceived responsibility for students' skills development is also reflected in an open question asking supervisors to comment on the supervisory process. More external supervisors, typically those who are retired or are not employed at an HEI/FEI, recognised issues in students' skills, such as academic writing or information literacy. Also they commented more frequently on students' research competencies and/or the limitations of the non-compulsory study, professional, and analytical skills module. For example, one colleague suggested:

> *"Some of this year's [research methods] is unsuitable,*
> *causing students to switch off and game to get the*
> *exemplars so they can cut & paste because they*
> *do not understand."* (External Supervisor: Retired academic).

In contrast, internal supervisors tended to focus on the administrative processes that hinder or complicate supervision. For instance, one observed:

> *"[There is] too much dictate[d] by admin responsible*
> *for the management of the projects on supervisors"* (Internal Supervisor: In the department).

A responsibility of supervision is to evaluate students' academic skills and provide appropriate support and/or refer the student to a relevant service or resource for help [5]. Yet, in reflecting on the impact of Covid-19 in changing their approach to supervision, only 53% of supervisors signposted to the study, professional, and analytical skills module and encouraged their students to engage with it, and 31% of supervisors were 'providing enhanced levels of one-to-one academic support'. A lack of academic skills signposting and individual support during the pandemic can be a consequence of supervisors' changing workloads while adjusting to new working conditions in the pandemic. However, it is problematic as students' skill levels vary by educational and cultural background, so students benefit from encouragement to engage in the study, professional, and analytical skills module to support their academic development. Also, students may be more successful when given individual support, such as personal attention for improving critical writing.

4. DISCUSSION

This work in progress begins to shine a light on the possibility that supervisors often have different perceptions of what their responsibility is with regards to supporting students' study, professional and analytical skills development. Such inconsistencies in how supervisors view their role can lead to different levels of support being offered to different students on the same programme of study [6]. To resolve this matter the case-study organisation provides developmental opportunities and ongoing training for supervisors to ensure university processes are adhered to and colleagues are aware of their responsibilities. In addition to this, to promote consistency in the student experience, supervisors are encouraged to participate in internal and external peer networks to reflect upon and share good practice [7].

With such a large programme and with such a diverse range of supervisors, the challenge of ensuring a consistent level of expertise, approach and student experience is not easy to address. Referring back to the QAA Characteristics Statement [3], the following clause reinforces the importance of ensuring the supervision process is effective and consistent:

> *"Graduates of research master's are likely to be further characterised by their ability to study independently in the subject, and to use a range of techniques and research methods applicable to advanced scholarship in the subject"* (p4).

Bearing this in mind and looking forward, there are plans underway to bring the study, professional, and analytical skills module within the wider accredited and credit-bearing programme; meaning that the module will become compulsory for all students. This will benefit supervision by allocating teaching time to students' skills development and embedding within the curriculum the type of skills needed for students to succeed both in the taught and research components of their courses [8].

To adapt to the conditions of a global pandemic, supervision strategies that once worked required transformation to improve accessibility and utilise technology to enhance communication and feedback [9]. For example, signposting to study skills support during a once-a-month face-to-face meeting is impossible in a national lockdown. Instead, supervisors needed to increase their technology proficiency in order to forward emails or message their supervisees about upcoming developmental opportunities. Also, scheduling bimonthly meetings to increase the frequency of individual support to ensure students made progress on their project and received well-being support. Reflecting on strategies that supported students in their projects during Covid-19, such as new ways to record feedback, can help identify practices which enhance future supervision to the benefit of student learning and academic achievement. This is important as online supervision may need to continue given the variation of students' circumstances that impact their ability to attend any pre-pandemic styles of face-to-face supervision.

CONCLUSION

This short paper presents an initial investigation into the supervision of master's projects. Further research is needed to include the student perspective in regard to expectations of supervisors and perceived responsibility for skills development compared to the supervisors' perspectives presented here. In addition, research into the impact of departmental processes and institutional culture on the supervision process will enable a greater understanding of master's supervision.

In conclusion, project supervision represents a major part of colleagues' professional time and commitments. Whilst training generally assures adherence to organisational policies and practice, there is a need for much more work to be done in this area.

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INTROSPECTION INTO PORTUGUESE UNIVERSITIES ATTRACTIVENESS : A FOCUS ON INDUSTRIAL ENGINEERING AND MANAGEMENT STUDENTS

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ABSTRACT

Industrial Engineering and Management (IEM), combining management techniques with engineering background, was introduced in Portuguese universities at the beginning of '90. Currently, it occupies a high position in terms of students' preferences, when choosing their university. The main purpose of this paper is to investigate what are the factors influencing IEM students' choice of their universities in Portugal.

A quantitative survey was conducted (n=304) with the participation of ESTIEM (European Students of Industrial Engineering and Management), at Bachelor's and Master's levels, from five Portuguese universities (Porto, Minho, Aveiro, Coimbra and Lisbon). We carried out preliminary statistical analysis of the data.

The findings show that, when choosing a university to study at, the most important factor for students is the prestige of the institution. There are also other relevant factors, such as the city of the university, the companies' recognition and the employability rate. IEM students seem to be future oriented, as they give the highest importance to the job opportunities offered after graduation. However, they associate lower relevance on everyday factors of their academic experience, such as the evaluation methods, the support given by professors and the teaching methodologies utilized.

Findings from this study allow universities to have a better understanding about the most valued factors in the students' decision-making process for choosing their

university, as well as to adapt their recruitment strategy to this demand to attract good students for their programmes.

1 INTRODUCTION

Industrial Engineering and Management (IEM), combining management techniques with an engineering background, had an important evolution during the past three decades in Portuguese universities.

Nowadays, engineering degrees, and particularly IEM, have seen a rise in interest of Portuguese students. In the past three years, engineering degrees have occupied the podium positions, with the IEM degree of University of Porto always featuring in one of the first four places. In fact, in the academic year 2020/2021, only four out of ten of the top degrees were not from engineering, with IEM in University of Porto being the highest entrance grade with a requirement of 19.13 points out of 20.

IEM is also characterized as a degree with a particularly high employability in Portugal, as can be seen by the unemployment rates stated in Table 1, with data from 2019[1]. These low unemployment rates are coherent with the fact that IEM allows students to follow a plethora of career paths in diverse domains (such as quality management, production management, logistics, information systems, process modeling, management control, strategy and marketing, among others).

Furthermore, it is also relevant to mention the numerus clausus, whose data for 2020 for the Bachelor's, Master's and Integrated Master's[2] is also summarized in Table 1.

Table 1. Numerus clausus and unemployment rates for the IEM degrees in Portugal[3]

University	Aveiro	Coimbra		Lisbon		Minho	Porto
Type of IEM Degree	Integrated Master's	Bachelor's	Master's	Bachelor's	Master's	Integrated Master's	Integrated Master's
Numerus Clausus	74	54	45	69	30	59	93
Unemployment rate	2.3%	2.6%	3.9%	0.7%	0.4%	6.1%	2%

Considering the overall scenario of IEM in Portugal, it becomes very interesting to investigate the factors that lead students to their choice of university to pursue an IEM degree, as it can provide valuable insights to Portuguese universities. Their gain in terms of a better understanding of the most influential factors for the decision making of students can translate into direct actions towards them. University management can adapt both their marketing and recruitment strategies according to these factors, with the aim of attracting the best talent for their institutions.

In order to understand the influencing factors for student's first choice of university and their perception of their current university's attractiveness, a quantitative study was designed and conducted by students of ESTIEM (European Students of

[1] The unemployment rates utilized are from 2019, in order to avoid possible fluctuations due to the influence of the Covid-19 pandemic, so that conclusions could be made on the employability scenario of a regular year. These rates correspond to the amount of unemployed that graduated between 2015 and 2019, per total amount of graduates for those years. More information on the website: https://www.dgeec.mec.pt/np4/92/

[2] An Integrated Masters is a combination of Bachelor's and Master's degree in a continuous course.

[3] Data from the Direção-Geral de Estatísticas da Educação e Ciência (DGEEC) - General Center for Statistics of Education and Science.

Industrial Engineering and Management), a non-profit organization that connects students of IEM European-wide and has a strong representation inside Portuguese universities.

This study especially relevant in the Portuguese context, since it is the first to investigate the question of attractiveness in Portuguese universities, particularly in IEM degrees.

2 LITERATURE REVIEW

With the transformation of higher education to a highly competitive and globalized environment, there is a growing interest in research about students' choice of their universities. According to the conceptual model of Perna et al. [1], students' choice are influenced by the following four attributes: (1) habitus (demographic characteristics, social and cultural capital), (2) school and community context (availability of resources, type of resources, structural supports and barriers), (3) higher education context (institutional characteristics, location, marketing and recruitment) and (4) social, economic and social context. As highlighted by Han [2], students' university choice is a complex decision-making process based on the combination of numerous factors in interaction (for example the students' habitus and institutional characteristics).

For Maringe [3], there is a strong influence of future employment and career prospects in students' decision by applying a consumerist benefice-value approach considering their enrollment as a long-term investment. As highlighted by Conard and Conard [4], students give main importance to the academic reputation in their university choice process: they choose more likely an institution with a very good reputation in view of increasing their employability perspectives. In a recent work, Moulignier et al. [5] underlined the influence of diverse factors on French engineering students' preferences like institutional prestige, wide range of specialisation in engineering, extracurricular activities and excellent employability perspectives with access to high ranked job opportunities.

The work of Briggs [6], investigating students' choices in Scotland, identified three principal influence factors: academic reputation, distance from students' home and location. On the opposite side, the two least influential factors for students in this area were the information supplied by the university and its research reputation. The high influence of geographical factors was confirmed by Gibbons and Vignoles [7] who provided evidence that the distance between institution and students' home has a very high influence on students' decision (more particularly for students who have to stay at home for financial or cultural reasons). According to Sá et al. [8], Portuguese students' decision to leave their hometown related not only to the accessibility of University but also they have preferences over leisure activities.

3 METHODOLOGY

To answer the research question, an online quantitative study was designed in order to investigate what are the most influential factors for IEM students on their decision making process for choosing their university.

This study was designed and shared through five different Portuguese universities with an IEM degree - Universities of Aveiro, Coimbra, Lisbon, Minho and Porto. These are highly relevant universities in the Portuguese context and correspond to the ones in Portugal that have a student's organization associated with ESTIEM.

The respondents of the survey are all engineering students in the Industrial Engineering and Management degree of these universities, both from the Bachelor's and Master's degrees. The majority of the respondents (83%), were at the Bachelor level, with 22% of the respondents being in their first year. The data is well distributed between the five universities, with participation rates between 15.13%, and 26.6% as shown in Table 2.

Table 2. Percentage of respondents per university and study level

University	Aveiro		Coimbra		Lisbon		Minho		Porto	
% of respondents (BSc and MSc)	93%	7%	77%	23%	100%	0%	85%	15%	72%	28%
% of respondents (total)	15%		27%		17%		19%		22%	

The distribution between female and male respondents is 60% and 40%. The data was collected during a month (March 2021), through the local representatives of the student organizations, and handled anonymously.

The survey was divided in two main sections: one relative to students' first choice of university when applying for it and the other relative to their current university and what they consider attractive about it. For this study, four questions were considered. Relative to the first section, students were questioned about their first choice of university, having the chance to choose two other universities besides the ones analysed in this study, as well as to write other options, to make sure all possibilities were considered. Besides, they were also questioned about the influence of external factors on their choice. In this part, we used a five points Likert scale for the answers. Finally, in both sections of the survey there were closed multiple selection questions: respondents were asked to select a maximum of six factors out of fifteen that led them to their first choice of university, and a maximum of three factors out of six that make their current university degree attractive.

The principal limitation of the study is the fact that only engineering students of IEM from five Portuguese universities were surveyed. Although, when asked about their first choices, students still had the option to point out universities outside of the five universities chosen as the scope of this research. For several practical reasons, we decided to exclude these answers from our data analysis. Besides, it is also important to consider the limitations associated with the method utilized (self-reported opinion survey) and the fact that students were asked about a choice they made in previous years.

4 RESULTS AND DISCUSSION

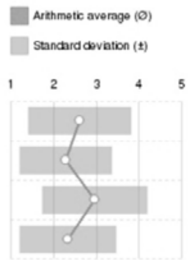
Oftentimes students have a certain university as their first choice, which does not necessarily correspond to the one they end up studying in. As so, it is important to analyze both the factors that lead to their first choice and the ones they consider to make their current university attractive.

4.1 Influencing factors for student's first choice of university

In order to study the influence of external factors that lead students to choose where to study, students were questioned about whether parents, friends, media and high school professors played a relevant role on their decision making. Our results, presented in Table 3, indicate that the respondents didn't consider either of them as influential on their university choice.

Table 3. External influences on student's first choice of university

	Totally disagree (1)		Disagree (2)		Neither agree or disagree (3)		Agree (4)		Totally agree (5)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
Influenced by Parents	67x	22.95	74x	25.34	69x	23.63	67x	22.95	15x	5.14	2.62	1.21
Influenced by Friends	83x	28.42	92x	31.51	72x	24.66	39x	13.36	6x	2.05	2.29	1.08
Influenced by the Media	44x	15.07	68x	23.29	56x	19.18	101x	34.59	23x	7.88	2.97	1.23
Influenced by High School Professors	85x	29.11	87x	29.79	67x	22.95	44x	15.07	9x	3.08	2.33	1.14



Regarding the factors related to the universities themselves, Figure 1 shows the overall results, where the prestige of the university is pointed as the most influential.

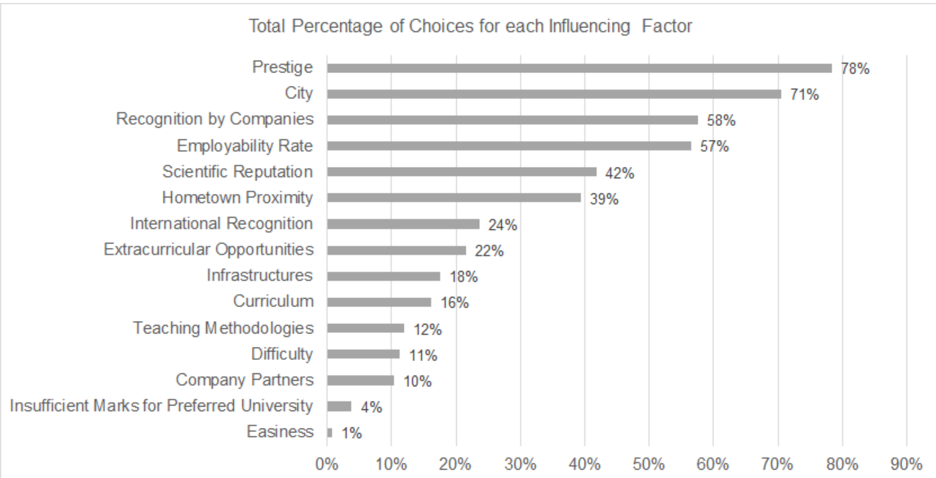


Fig. 1. Students' influencing factors for choosing their university

When analysing the results, the prestige of the institution is a major factor in all universities, which is in line with the study of Conard and Conard [4], pinpointing reputation as highly relevant.

The city of the university also affirms itself as a very relevant factor, especially in Coimbra, which can be justified by the fact that it is a renowned student city with a great academic spirit and traditions. Besides the actual location, it is important to consider that students oftentimes need to go out of their city to study, so hometown proximity was also a reviewed factor, particularly relevant to the students of Minho an Coimbra. This high relevance of distance from students' home and location of the university confirm also the results of Briggs [6] and Gibbons and Vignoles [7].

Looking in a more corporate perspective, recognition by companies and employability rate also affirm themselves as relevant factors. The first plays an important role especially in Lisbon and Porto, but the employability rate has a transversal relevance across all universities, with the exception of Coimbra, which is in line with the high employability rates for all IEM degrees in Portugal, seen before in Table 1.

However, not all results are similar across universities. For example, only students that have chosen Aveiro highlighted infractures as an influencing factor in their choice, and only the ones who chose Lisbon highlighted international recognition of the university as relevant, possibly due its location in the capital of the country and having more professors involved in collaborations at international level.

Overall, the least relevant factors of students' choice are the easiness/difficulty of the university, insufficiency of marks for attending a preferred one, the companies it has associated as partners and the teaching methodologies of the degree.

The percentages of choices per factor for each university, as well as the total percentage, are summarized in Table 4.

Table 4. Students' first choice attractiveness factors per university

	University						
First Choice Factor	**Aveiro**	**Coimbra**	**Lisbon**	**Minho**	**Porto**	**Mean**	**SD**
Prestige	15%	20%	17%	15%	17%	17%	2%
City	13%	25%	11%	14%	14%	15%	5%
Recognition by Companies	8%	4%	17%	12%	15%	11%	5%
Employability Rate	12%	5%	13%	12%	15%	11%	4%
Scientific Reputation	10%	6%	11%	6%	10%	9%	3%
Hometown Proximity	5%	13%	5%	15%	7%	9%	5%
International Recognition	2%	5%	11%	3%	4%	5%	4%
Extracurricular Opportunities	10%	8%	0%	8%	3%	6%	4%
Infrastructures	10%	3%	2%	4%	2%	4%	3%
Curriculum	4%	5%	3%	2%	4%	4%	1%
Teaching Methodologies	6%	1%	1%	6%	2%	3%	3%
Difficulty	0%	1%	5%	1%	3%	2%	2%
Company Partners	3%	2%	1%	4%	2%	2%	1%
Insufficient Marks for Preferred University	1%	4%	0%	0%	0%	1%	1%
Easiness	1%	0%	0%	0%	0%	0%	0%

Finally, the data of this study indicated that for numerous students there is a mismatch between the university they put as first choice and the one they are currently enrolled in. From the 255 students that stated their first choice, 56 were enrolled in a different one. There is a clear preference for University of Porto, being the first choice of 35% of the students, and corresponding to the preferred option of 33 out of the 56 mismatches between first choice and current university.

4.2 Attractiveness perception of the currently enrolled university

When questioned about what attracts them the most in their current degree, IEM students showed a notable preference in the job opportunities offered by the degree, as 40% of the respondents chose this factor as the most attractive. As indicated in

Table 5, this choice was identical among all Portuguese universities, with students from Porto and Lisbon distinguishingly preferring this factor over others. This is in line with the fact that Lisbon and Porto are the first and second biggest cities in Portugal, where the majority of the big companies are located, therefore having more job opportunities. Overall, this comes to show once again the bigger importance given to the opportunities that come after the degree, rather than the degree itself.

Table 5. Attractiveness of the current degree par university

	University						
Curent Degree Factor	**Aveiro**	**Coimbra**	**Lisbon**	**Minho**	**Porto**	**Mean**	**SD**
Job Market Opportunities	37%	38%	47%	31%	46%	40%	7%
Content Teached	19%	23%	26%	18%	24%	22%	3%
Companies Involvement in Subjects	17%	7%	16%	23%	12%	15%	6%
Professors' Support	13%	18%	9%	10%	10%	12%	3%
Teaching Methodologies	11%	10%	1%	13%	5%	8%	5%
Evaluation Methods	3%	4%	0%	4%	3%	3%	2%

Following job opportunities, the content of the courses and the involvement of companies in the subjects are the next two most chosen options, rating the importance given to the experience of the course as only slightly relevant. However, in the University of Minho, known for promoting the involvement of companies in their courses, students indicated that this was a quite attractive factor.

Professors' support, evaluation methods and teaching methodologies are the least influencingfactors, which again validate the idea that, in a general way, Portuguese IEM students are not really attracted by the actual experience of the course. Nevertheless, it isn't clear whether this is because their degree isn't a very pleasant experience to them or because this is simply not as relevant as their future careers.

5 CONCLUSION

In summary, this paper presents an analysis on the factors that influence IEM students' choice of university and perceived attractiveness of the one they are enrolled in. According to our findings, the most influential factor is the prestige of the University followed by the city of the institutions. Recognition by companies and employability rate are also very relevant, and in line with the context of IEM in Portugal. Concerning the attractiveness of their current university, there is an overall high relevance on the job market opportunities that students expect to access after their graduation.

The present findings provide a better understanding of students' values and motivations to choose their engineering degree as well as their appreciation of the current degree. These insights could give useful indication for universities to adapt of their recruitment and marketing strategies, and eventually even the strategic development of their IEM degree. As an example, it could be a valuable opportunity to develop a more active involvement of companies in the degree to improve their general recognition or reinforce the university reputation and image with specific and targeted marketing promotions

Further studies should enlarge the scope of this research, by understanding the attractiveness factors for Portuguese students of other engineering degrees, or by comparing the results for the IEM students in these Portuguese universities with others studying IEM in universities in other countries, in order to provide a larger European or international vision.

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RE-IMAGINING ENGINEERING EDUCATION IN SOUTH AFRICA

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ABSTRACT

The challenge presented by the global pandemic has brought into focus the need for curricula that stimulate an awareness of the complexity of society. Engineering graduates need to be more conscious of and have better access to contextual knowledge and expertise beyond the technical. As a way of providing such access, an ‘Engineer in Society’ course has been offered to third-year mechanical engineering students at the University of Cape Town.

The sudden shift from in-person to online learning in 2020 due to the Covid-19 exacerbated student differences and curtailed student engagement and participation. As restrictions ease in South Africa and physically-distanced meetings become possible, we draw on Mezirow’s theory of transformative learning to explore the impact of the course on how engineering students think about society. According to Mezirow, transformative learning takes place when the assumptions underpinning one’s frame of reference are changed. The study engaged with this by asking a twofold research question: How did students experience engagement within the course and what sorts of transformations did they experience?

We found qualitatively different ways in which students engaged with course content, engagement with peers and others, and engagement with the delivery modes of the

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course. Students experienced shifts or transformations in the understanding of their professional identity with the recognition of multiple possible engineering identities; professional responsibility in the form of awareness of active roles in relation to environmental and social issues; and epistemological shifts from abstract, decontextualised knowledge to practical, contextual knowledge.

1 INTRODUCTION

The argument for the inclusion of knowledge and skills for the development of engineering graduates who can engage with their role in relation to social responsibility has been well documented. Such knowledge and skills are often presented in courses and modules that draw on humanities, the social sciences, communication and management disciplines, and are either offered as electives or part of the core curriculum. These might be called 'non-technical' (Florman, 1997) courses, liberal arts courses or, in the South African context 'complementary studies'. Much debate has also been raised as to who should provide such offerings, with engineering academic staff being favoured over disciplinary experts.

Unlike other professions (such as law and medicine), engineers rarely have a direct relationship with society. Rather, Aslaksen (2015) suggests that the organisations within the industries that employ engineers mediate their relationship with society. However, registration as a professional engineer requires that individuals subscribe to a code of conduct that governs their practice and they can hence be held accountable for their conduct with respect to social, environmental and general ethical engagements. Engineering graduates therefore need to have a clear understanding of the complexity of their role within and their responsibility toward society. In different contexts, undergraduate engineering curricula have, in numerous ways, tried to incorporate non-technical content that introduces engineering students to social, political, environmental, economic and ethical issues with varied success.

What does it mean for us, as engineering educators, to build engineering capacity for effective interaction with society and develop graduate attributes appropriate for ethical economic development? Could we successfully re-imagine engineering education in South Africa and in doing so produce future-focussed graduates who can drive positive change? To initiate this ambitious aim, this paper specifically focuses on how students in a complementary studies course (entitled Engineer in Society) experience engagement and the extent to which their perspectives were transformed in the context of in-person and online learning. This study addresses the twofold research question: How did students experience engagement within the course and what sorts of transformations did they experience?

1.1 The context for the study

The University of Cape Town (UCT) is a research-intensive institution with a set of established undergraduate engineering programmes. As part of a comprehensive re-curriculation exercise in the Department of Mechanical Engineering, two of the authors were tasked with renewing complementary studies courses in the department. The long-standing courses that fulfilled this role were quite narrow and dealt with the topics of engineering professionalism, project management and the environment. With the intention of making the new offerings more holistic and relevant, two larger follow-on courses were developed. The first was a third-year course that was designed to be *outward-looking* in that it addressed issues relating to the role of the engineer in society (broadly speaking). The second course was to be offered in fourth year and was to be *inward-looking*, i.e. focusing on the role of the engineer within organisations and the business workplace.

The outward-looking course was named ‘Engineer in Society’ in reference to the seminal work by Mills (1946). This course was designed as a whole-year course worth 16 credits (designed to take the average student 160 hours to complete). It was offered for the first time in 2020 and is the focus of this paper. The inward-looking course was named ‘Engineer in Business’ and was a semester course but worth the same credits as Engineer in Society. This course is being offered for the first time in 2021.

1.2 The structure of the Engineer in Society course

It was decided to divide the content of the Engineer in Society course into four modules, each dealing with an aspect of society: human society, the biophysical environment, economic systems and political structures. One of the primary objectives of this course was to provide the opportunity for the students to engage with a plurality of perspectives and to develop a critical awareness of the role of engineering – and engineers – in society. This was facilitated by including field trips to sites of social and political importance, bringing in guest lecturers from industry and having regular group work sessions. The learning activities directed students towards reflection and discussion to deepen their thinking about complex issues in all realms of society.

The course was structured so that about 40% of students’ time was to be spent in lectures and tutorials. This was to include two 45-minute lectures a week with afternoon tutorial every two weeks. About 25% of students’ time was to be spent engaging with readings or video documentaries. Two field trips were planned which were to take 10% of the course time. The remainder of the time was to be dedicated to assessment activities such as reports, writing essays and taking tests. We thought it appropriate that the most important assessment was a capstone essay which required the students to reflect on the course and make explicit links between the modules.

1.3 The shift to online teaching and learning

The Covid-19 pandemic took hold in South Africa in mid-March of 2020. UCT decided to close for the mid-semester vacation one week early and this marked the end of in-person learning. As the country went into ‘lockdown’, the university prolonged the vacation and only opened again in mid-April for online learning. Given problems with access to technology and bandwidth for some students, UCT decided that lectures were to be presented asynchronously. There was no doubt that the move to the online environment exacerbated student differences (Czerniewicz, e.al. 2020) and curtailed student engagement and participation. Indeed, students tended to be – and still are to some extent – more physically isolated from one another and epistemologically insulated from perspectives outside an engineering curriculum that focuses on technical knowledge.

The shift to online mode impacted the structure of the course and the time that students spent on the various activities. The two 45-minute lectures were condensed into a single hour-long lecture (with PDF slides) that was released at the start of the week. In-person engagement was substituted by online forum discussions via the university's course management system. Other impacts were that the field trip in the latter part of the year had to be cancelled and guest speakers had to make online lecture videos where possible. These changes are described in more detail below.

2 CONCEPTUAL FRAMING

There are many perspectives that might be used to account for human experience in relation to others. For example, Christie (2005) emphasises how individual interests are in competition with – and often come at the expense of – a collective common good. Maistry (2014) goes further and suggests that the tension pervading higher education can be seen as capitalist market discourses in competition with social democratic citizenship discourses' (p. 57). In a higher education institution such as a university, the rhetoric aligned with capitalist market/neoliberal discourses places emphasis on, for example, institutional efficiency, rankings, test scores and work readiness of graduates and curricula that embrace skills and knowledge suitable for value creation in the form of profit. Courses that do not fit the mould of equipping graduates with technical knowledge and skills, such as complementary studies courses, are therefore afforded less legitimacy. Johnson, Lee and McGregor (1996) suggest that engineering knowledge contributes to this tension by setting up itself as a kind of 'captive discourse' that is intolerant of other forms of knowledge.

With regard to the student experience, the theoretical and analytical tools that we draw on provide a perspective on shifts in understanding as a consequence of engagement. Transformative learning theory (Mezirow, 1991) provides conceptual explanations for the shifts experienced as a consequence of learning. Mezirow (1991) points out that not all learning is transformative but when learning transforms, there is either change in beliefs or attitude, what Mezirow calls a meaning scheme, or our entire perspective can be transformed. According to Mezirow, every act of learning involves interpretation. Learning, in Mezirow's terms, would result in new or revised interpretations 'of the meaning of one's experience in order to guide future action' (1991, p. 12).

Sfard and Prusak (2005) take a different view of learning, characterising it as a culturally-shaped activity. They propose identity as the conceptual link between learning and its sociocultural context, with learning conceived of as 'closing the gap' between actual (e.g. engineering student) and designated (e.g. professional engineer) identities. The notion of learning as identity development is one that finds favour in a number of learning theories as it serves to account for a psycho-social view of learning, i.e. expanding the concept of learning to beyond the individual only and to account for the context or ways in which society influences that way individuals making meaning of their experiences as learning.

3 METHODOLOGY

3.1 Research design

This paper reports on the emergent findings of a larger research project that includes an investigation of the historical development of engineering in South Africa, student experiences of learning about South African society in the engineering curriculum, and recommendations for engagement with the engineering curriculum. For investigating the student experience, a qualitative research design was used to access in-depth perceptions of students' experiences of learning.

3.2 Data collection and analysis

Data was primarily drawn from semi-structured interviews using Microsoft Teams and was supported by data from two student course evaluations (see Table 1). All 117 students who were registered for the Engineer in Society course in 2020 were invited to participate in a 30-minute, online interview to reflect on their experience of the course. The author who was not involved in the teaching of the course conducted the interviews. Nineteen students responded and eighteen interviews were conducted. These students represented a purposive sample that included students from different schooling environments, demographics, nationality, gender, as well as a variety of achievement scores in course assessments.

Table 1: Data sources

Data source	No. of students participating (maximum 117)
Course evaluation, June 2020	28 students (24%)
Course evaluation, Nov 2020	29 students (25%)
Semi-structured interviews, June- July 2021	18 students (15%)

Data were analysed thematically using compare-and-contrast qualitative techniques. All the authors were involved in the analysis of the recorded interviews with at least two researchers reviewing each recording and transcription. The emergent themes identified by researchers were compared and final themes agreed upon.

4 FINDINGS

4.1. Engagement

Engagement with content

The formal course evaluations in the middle and at the end of the year suggested that most of the class were positively engaged. In the interviews, students also contrasted the course with regular undergraduate engineering courses that were described as 'involving calculations'. One student said that the course 'seemed different from your generic, just maths plug-and-chug courses so something different... "breath of fresh air" I guess you might call it' (Interview 7).

As expected, there were some negative comments about the course content, with students characterising it as ‘airy-fairy (Interview 6)’, a ‘Humanities-type course’ (Interview 8) or being akin to Life Orientation, a compulsory subject in secondary school in South Africa which tends to be derided because of its vague focus on life skills. Students who saw the course in this way were less engaged with the content. They described the lectures as ‘tedious’ and, even though they conceded that some of the content was new to them, characterised the course as being about general knowledge or ‘common knowledge’ (Interview 7), as one student put it.

Engagement with people

In line with the intentions of the course, we were pleased to see that students mentioned the value they found in learning from others. A number of students mentioned the afternoon visit to an area known as ‘District Six’ and its museum. This site is of political and social importance because its residents - about 60,000 of them - were were forcibly removed by the apartheid government in the 1970s when it was declared a ‘whites only’ area. This visit involved hearing stories from some of the former residents who grew up in District Six and witnessed the forced removals.

Students mentioned the important role this experience played in ‘opening their eyes’ to what apartheid was like and its lasting impact on South African society. Interestingly, one student highlighted how the visit actually gave her insight into the lives of her peers whose families were affected by the District Six removals. Indeed, learning from other students was seen to be a key ‘takeaway’ by some students (as the section below indicates). In this regard, the interviewees mentioned other students saying or posting things that made them reconsider their own point of view or other students recommending readings or videos that were relevant and interesting.

Another set of people that had a profound impact on students was the guest lecturers. One student mentioned that engagement with the guest lecturers really helped her to see that engineering is not ‘some untouchable industry’ but is made up of ordinary people:

> ...seeing the guest lecturers and seeing them as people… it really came to help me to understand that there has got to be a place where you are going to start and not everyone starts at the same pace (Interview 3).

Delivery of the course

Students’ perspectives on engagement were often linked to the mode of course delivery. Most students felt that they engaged better when the course was running in face-to-face or ‘in-person’ mode compared to when it was online. Activities such as tutorials (which often involved group work before the lockdown), field trips and class discussions were mentioned in this regard. One student suggested that the interactive nature of the course meant that it was especially affected by the pandemic:

> ...what spoiled the course is the fact that we moved to online learning and that kind of put a blow into power that the course had... this type of course is a very interactive course (Interview 5).

Interestingly, when students rated their involvement in the course in the formal course evaluation, they indicated little change before lockdown compared to afterwards. Furthermore, a student felt that her engagement actually improved in the online space. She said that she and her classmates felt quite shy in class and that discussions among them tended to be ‘surface-level’. But she explained that students tended to delve more deeply into issues when the course shifted online. This was in the context of students being required to post their opinions using a tool in the university online platform called *forums*: ‘...I think that everyone is much bolder if you have to type on the forums than raise your hand in class so I think I was very much engaged in the content post-Covid than before (Interview 1)’.

4.2 Transformations

Three themes emerged as transformations or shifts in perception as a consequence of participation in the course. They are described below.

Professional identity

This theme encompasses changes in perceptions of professional identity ranging from descriptions of how the course facilitated identification with the profession more closely – ‘I didn't know what it meant to be an engineer before the course’ (interview 3) – to identifying the type of engineer they wanted to be, illustrated by the student in interview 4: ‘The course showed me that you can be philanthropic in your work as an engineer’. The breadth of the course content and the engagement with the diversity of people and activities were experienced by some students as possibilities for aligning their personal goals with professional goals. This was evident from the student in interview 4, who noted that ‘the course is refreshing, [it] showed me that I can integrate my passions with work’. For other students, engagement with the course facilitated a shift from theoretical, technical engineering concepts to pragmatic considerations of what becoming a practicing engineer could mean: ‘I could now see the difference between being an engineer and applied maths’ (Interview 3). The course can therefore be seen as successful in closing the gap between actual (e.g. engineering student) and designated (e.g. professional engineer) identities (Sfard and Prusak, 2005).

Professional responsibility

Interviewees reported a deeper understanding of the relevance of context in the practice of engineering, especially in relation to various aspects of society. This resulted in students gaining a sense of confidence in the discipline they had chosen to study: ‘It gave me a greater sense of duty… reinforced why I like engineering’ (Interview 3). The sense of purpose in relation to the country was echoed in interview 5: ‘I am proud of the Faculty I am in because it shows how important it is to keep the country running smoothly’.

The sense of social responsibility was not shared by all interviewees, a criticism from a student was that they perceived the course to have a social justice orientation that did not consider that new graduates would be powerless to go against decisions made by their employers and their responsibility would be to their bosses: ‘...money rules the world and ...engineers are slaves to the industry” (Interview 8). This notion draws attention to the need to manage the tension between the capitalist market discourses and social democratic citizenship discourses as noted by Maistry (2014), given the reality of the graduates' initial forays into engineering industries.

Epistemological shifts

The course presented the opportunity for students to 'have an open space to develop opinions' (Interview 4), the recognition that opinions supported by robust argument was valued as a contribution was a shift from perceptions of knowledge as binary, i.e. either right or wrong:

> ...it was not something that I was able to experience in my other courses because we kind of take… naturally like an engineer would do, we kind of take what is said as the truth and there is no questioning it… So there is not much engagement in any of my other courses so it was a really nice experience to be able to… to question the lecturer, to question your classmates… (Interview 1)

The awareness of plural forms of knowledge can be illustrated by the comment the students in interview 1, in which s/he described how his/her way of thinking was changed through dialogue with classmates which allowed her to be more open-minded and considerate: '...being open to learning from anywhere, considering different perspectives, making the world your classroom'. Such engagement led to an interrogation of personal biases towards certain issues that the student wasn't aware of until discussions with peers through online forums.

5 DISCUSSION AND CONCLUSION

As reported in other studies, students' expectations were that with a non-technical course, they expected to do well without necessarily taking the course seriously. There were also students who struggled to engage with the course. On the other hand, there were students who really enjoyed the course, engaged with the content and embraced the learning opportunities the course provided. Both of these dispositions emerged strongly in the course evaluations and the interviews which suggests that the course had a polarising effect. Drawing on Johnston, Lee and McGregor (1996), it seemed that some students experienced a sort of 'epistemological conflict' as they encountered this course in the context of their third year of a predominantly technical degree. Exploring the deeper reasons for this is an ongoing interest in the broader project.

The few students who saw the course as illegitimate - very much the minority - also expressed that they did not learn very much. On the other hand, the students who engaged with the course tended to describe moments of transformative learning that suggests that their entire meaning scheme (Mezirow, 1991) was altered. This was particularly evident in the visit to District Six and - importantly - in their interactions with peers around the social issues involved. Drawing on Sfard and Prusak (2005), there is evidence that the cultural context shaped the development of conceptual understanding relating to engineering identity and the role of engineering in society. 'Cultural context' here does not only refer to the experience that students had on the field trip where they were exposed to the (romanticised) culture of the District Six that ceased to exist after the forced removals. Rather, it must be understood more broadly, even in terms of an online culture that can be enhanced to promote learning about self and others in a way that is not possible face to face.

The variety of modalities and opportunities was effective in facilitating active engagement, as students clearly favoured the class discussions, field trips and practitioner contributions. The contextualisation of engineering knowledge, in combination with opportunities for students to reflect on what engineering practice means for them allowed some students to re-interpret the meaning that they made of their experiences. While we hesitate to label such learning as transformative, we recognise that it should be explored further.

Going forward, we are challenged to try to find a way through student resistance to non-technical courses and design opportunities for learning that can contribute to transformative learning without risk of infection or transmission of the Covid-19 virus. At the same time, we recognise online learning can provide meaningful engagement. We are also cognizant of the need to manage the tension between characterisations of 'this is the way the world works in a capitalist economy' with social justice views of society.

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SHIFTING STUDENT PERCEPTION ON ONLINE AND IN-PERSON ENGINEERING LABORATORY SESSIONS DURING THE COVID-19 PANDEMIC

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ABSTRACT

During the academic year of 2020/21, because of the COVID-19 pandemic, universities were forced to make certain decisions about different types of classes and their nature. Depending on the ability of the university to ensure a safe environment, classes were held in person, or online. While most types of classes are easily transferred to an online environment, engineering laboratory sessions are not. This paper discusses the approach taken by the lecturers of the course „Fundamentals of electrical engineering" in professional study of electrical engineering at the Zagreb University of Applied Sciences, where students were able to choose between online and in-person laboratory sessions. The paper examines student choices and their gradual shift towards online sessions during the subsequent increase in cases in Croatia and following a series of earthquakes that hit Zagreb and the surrounding area at the time.

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1 INTRODUCTION

1.1 Laboratory sessions in an engineering course

For a student attending an engineering based study programme, laboratory sessions are unavoidable reality for most of the courses during the course of an academic year. The idea of these types of classes is to provide students with hands on experience with different types of equipment and practical examples that validate theoretical knowledge that was gained through instructions during the typical ex cathedra classes.

The objectives of these practical engineering laboratory sessions, among others, are [1]:

- familiarize students with instrumentation and tools for measurements necessary to observe certain occurrences of particular interest to the course subject matter
- teach students specific methodologies necessary for design and building certain parts and systems
- help students identify limitations of theoretical models
- foster a research based approach to practical problems
- develop the ability to collect and interpret data
- develop the ability to communicate about their findings, both orally and through the written word

Since Zagreb University of Applied Sciences is a "polytechnic" type of study programme, practical experience is one of its core principles and laboratory sessions are of utmost importance. The same can be said for the course that is studied in this paper, a first semester course called Fundamentals of Electrical Engineering. The course is worth 9 ECTS points and covers the most important topics necessary for a student to adopt to be able to successfully handle third and fourth semester courses.

In this specific course, students have five laboratory sessions during a 15 week semester. Each session is three academic hours long and the contents of the five exercises are:

- Ohm's law and Kirchhoff's laws
- transient state, RMS and mean value of a signal
- voltage and current analysis in RLC circuit with sine excitation
- voltage, current and power measurements
- resonance

Considering the fact that most of the students that enroll the course posses very limited experience with the necessary equipment, time spent in the laboratory surroundings is invaluable for them and for the teachers.

1.2 COVID-19 pandemic disruption

During the 2019/20 and 2020/21 academic years, a disruption happened, caused by the COVID-19 pandemic. The teaching and the learning process shifted for the most part online which meant that the usage of technology helped build a bridge between the teachers and students, who suddenly, for the most part, were not in the same room, as has been the case before. The bridge was formed by usage of streaming applications, presentation software, use of graphics tablets and other tools. This change has been the biggest challenge for the typical laboratory sessions.

This paper examines a shift in student perceptions on online and in-person engineering laboratory sessions during the COVID-19 pandemic in an engineering course named Fundamentals of Electrical Engineering at the Electrical Engineering department of the Zagreb University of Applied Sciences during the 2020/21 academic year and examines the possible rationale for student choices.

2 LABORATORY SESSIONS IMPLEMENTATION

2.1 Laboratory sessions during the pandemic

In early September of 2021, just before the start of the 2020/21 academic year, a decision was made by the Expert council of the Zagreb University of Applied Sciences by which all types of lectures, except for laboratory sessions and evaluations of knowledge were to be held online, while for the former, the decision of the type of implementation was left up to the teachers for every course separately. If the teachers decided to perform laboratory sessions or evaluations of knowledge in person, anti-epidemic and prevention measures had to be implemented.

After a brief discussion by the course lecturers, a decision was made for the laboratory sessions for the course Fundamentals of Electrical Engineering to be held in parallel; online and in-person. The students were given a choice between doing their lab work in person, or just following it online, trough prerecorded lectures from the lab, which resulted in practical laboratory sessions becoming demonstration exercises.

The lecturers felt that it was against anyone's interest to force one specific choice on the students and by doing so, possibly cause an infection or a local outbreak of COVID-19. Another reason for doing things in parallel was a sentiment that insisting on in-person laboratory sessions was impossible without an online alternative, simply because of the possibility of students inability to attend said in-person classes; either due to being a high-risk individual, or living with one, or getting infected during that time period.

As seen in *Table 1.*, 52.27 % of the students enrolled in the course chose to attend the in-person laboratory sessions, while the rest opted out and decided to attend the online versions.

Table 1. Initial poll results for the course Fundamentals of Electrical Engineering

Students enrolled in the course	In-person	Online
220	115	105

2.2 Anti-epidemic measures

In order to comply with anti-epidemic and prevention measures, which included a minimum distance of 2.5m between all students, the number of people in the laboratory had to be reduced to 6, from the previous 12 to 16. This meant an increase of number of groups in the lab during the week. Mask wearing was also mandatory. Also, in order to minimize potential contamination, after every group of students in the lab, all surfaces and the used equipment was sanitized. This all also led to the increased length of a laboratory session which was very problematic from an organizational point of view.

From an organisational standpoint, a course plan had to be made on an institutional level that would accommodate online and in-person classes done in parallel. In practice, a typical week was divided in two sections; one for online classes and one for in person. The number of days for each depended on the semester and number of students attending in-person classes.

One of the implemented measures was shifting everything unnecessary for the experiments themselves online. By doing so, a reduction in potential contact among temporary occupants of the labs was achieved. So, while typical laboratory sessions had a duration of three academic hours (135 minutes in total), by shifting pre-lab activity (homework relevant to the session and its evaluation) and laboratory report writing and evaluation online, which in turn meant they've become unproctored, a reduction of length for the sessions was done to two academic hours.

While pre-lab activity itself was unproctored even during the pre COVID-19 pandemic, a novelty was a sudden transition to online exams [2]. It was assessed that proctored online examinations after laboratory sessions could be done in various ways [3,4,5,6], but not without significant technical challenges facing lecturers and students in an already difficult situation and therefore, unproctored examination was chosen. After careful examination and research [7], this was implemented using a Learning management system (Moodle).

3 SHIFTING PERCEPTION

3.1 Data collection

Considering the students were given a choice to switch between the two types of laboratory sessions, a record of said choices had to be kept. Although the pre and post lab activities were shifted online and with that evaluations of student effort during the laboratory sessions were the same for students attending them in-person or online, a record of their choice was instrumental in organizing the in-person session. A fluctuating number of students translates to a fluctuating number of sessions and considering the additional work load on the lecturers, it was beneficial to know if enough students opted out of the in-person laboratory sessions to warrant a shuffle and reduction of available time slots in the lab during the semester. In short, a record has been kept for every individual and their choice and the possible change of said choice.

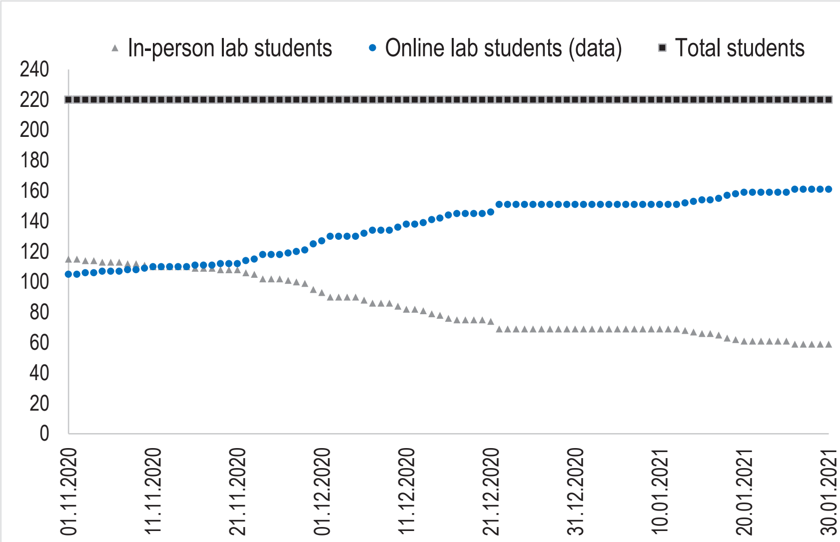

Fig. 1. Student choices through the semester

As seen on Fig.1., while a majority of students wanted to attend the laboratory sessions in-person at the start of the semester, after only 10 days, the numbers were right in the middle and after that a shift of perception towards online laboratory sessions gradually happened. This paper examines the role the COVID-19 pandemic had on said perception.

While the data collection for student choices were done in-house, the data on total cases in Croata was sourced from the "Our World in Data" website and can be publicly accessed on this link: https://ourworldindata.org/coronavirus/country/croatia

3.2 Data modelling

In order to properly study the possible connection between student choices and the COVID-19 pandemic, a Multi-Logistic Growth Model [8] was used to model the dynamic of infected inhabitants of Croatia and the dynamic of change in students opting for online laboratory sessions. The specific model with two successive life cycle intervals was chosen as it is a typical choice for modelling of spread of infectious diseases.

$$ML(t) = M_0 + \frac{M_1 - M_0}{1+\left(\frac{1}{u}-1\right)^{1-2(t-t_S)/\Delta t}} \quad (1).$$

Table 2. Multi-Logistic Growth Model parameters

Model parameters	Dynamic of infected inhabitants of Croatia	Dynamic of students opting for online laboratory sessions
M_0	30059	97
M_1	232387	159
t_s	-2.31	0
Δt	63.1	63.3

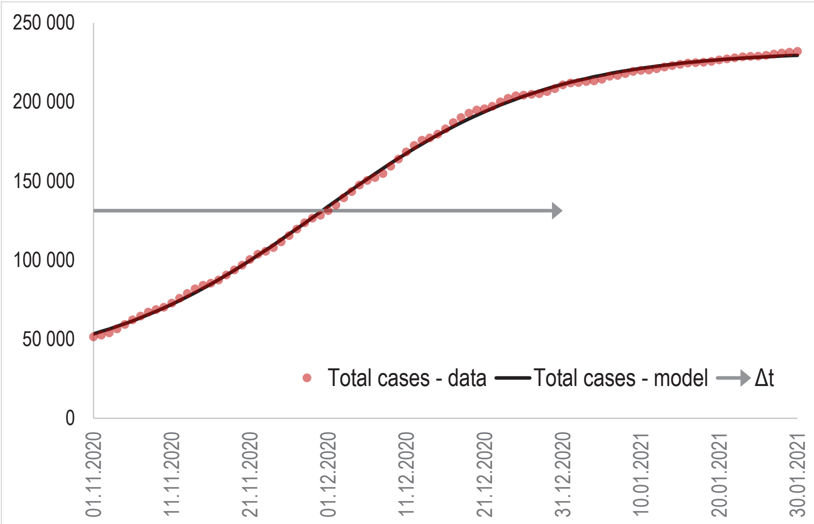

Fig. 2. Dynamic of infected inhabitants of Croatia

The t_s variable in the given in *Eq. (1)* represents the starting time of the model, while Δt represents the characteristic duration i.e. period needed for the diffusion to grow from $u^*(M_1-M_0)$ level to $(1-u)^*(M_1-M_0)$ level. u is a parameter that ranges from 0 to 1, but was set at 0.1 so that Δt in this case would represent time period needed for the diffusion to grow from 10% to 90%.

For the modelling of the dynamic of infected inhabitants of Croatia, the resulting optimal set of parameters M_0 and M_1 were calculated using the input data and the least squared method and can be seen in Table 2, specifically column 2. The same set of parameters was calculated using the same method for modelling the dynamic of change in students opting for online laboratory sessions and can also be seen in Table 2, specifically column 3. A visualisation of both models can be seen on Figures 2 and 3.

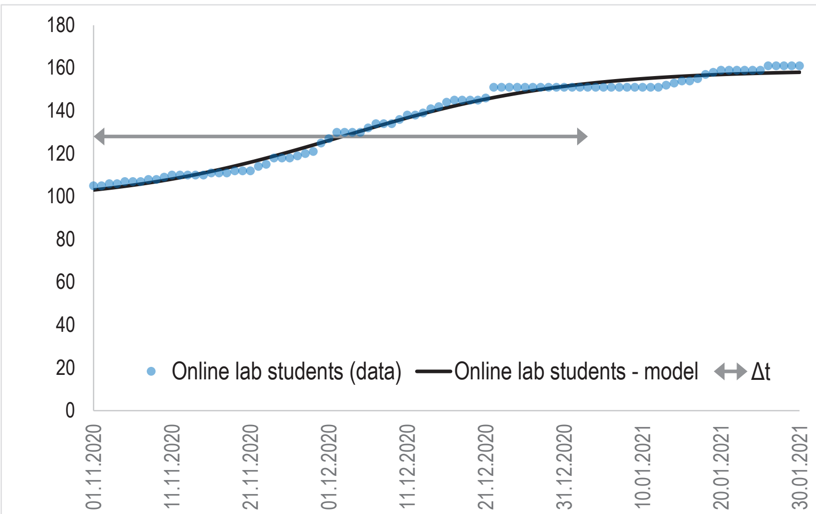

Fig. 3. Dynamic of students opting for online laboratory sessions

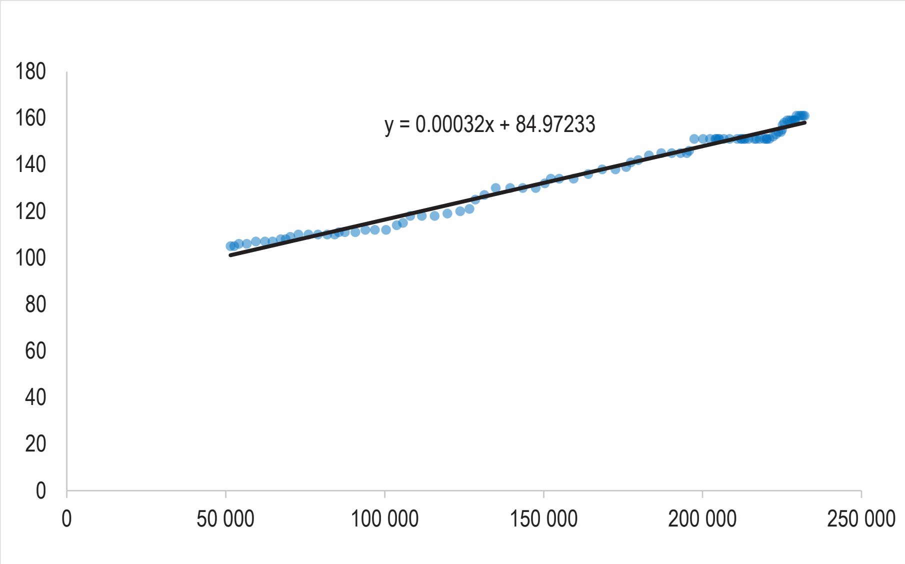

Fig. 4. Functional relationship between the number of infected inhabitants of Croatia and number of students opting for online laboratory sessions

3.3 Data interpretation

As seen in both cases, the model fits the data very well. The most significant connection between the two and a possible indicator of causality is approximately the same value of the *Δt* parameter, that represents the time period needed for the diffusion to grow from 10% to 90%, for both models. We further test this premise by studying the functional relationship between the number of infected inhabitants of Croatia and number of students opting for online laboratory sessions. As sen on Figure 4, a linear model can be applied, that can best be described by Eq. (2).

$$N_0(t) = 0.00032 * N_i(t) + 84.97 \qquad (2).$$

This premise could and should be investigated in future research with internal student polling on student motivation in making a switch from in-person laboratory sessions to online ones.

Another interesting data point was the difference in the t_s parameter between the models. As seen, the difference was 2.31 days, and could be possibly explained by the slow fluctuation of data of severity of the COVID-19 pandemic in Croatia to students and time to process the data and decide to opt out of in-person laboratory sessions. This is also a topic of possible future research and could be answered by internal student polling.

3.4 Future data points

When we take into consideration that data collection and analysis was done for a course that was held in the first semester of the 2020/21 academic year, certain questions are left unanswered that could be answered next semester. Would the trend of more and more students choosing online laboratory sessions instead of in-person ones continue with the continued rise of total number of infected inhabitants of Croatia? Considering the fact that three courses, which have the same student population as Fundamentals of Electrical Engineering, have also decided to let students choose their method of attending laboratory sessions, by studying that initial choice, we could have an indication towards an answer. As seen on Table 3, the decrease of students with a preference for in-person laboratory sessions is noticeable.

Table 3. Initial poll results for the summer semester courses

Course	In-person	Online
Electrical Measurements	52	168
Electronic components	36	184
Electricity and magnetism	53	167

4 CONCLUDING REMARKS AND FUTURE RESEARCH PERSPECTIVES

In this paper, we examine a balancing act that is laboratory sessions during COVID-19 pandemic. We articulate the importance of said sessions but also the difficult choices put in front of the lecturers, who had to decide on the form of the session while keeping in mind possible risks and ways of mitigating them. The main focus of the paper was in examining student preferences when faced with a choice between in-person and online laboratory sessions in a pandemic. Through modelling and fundamental analysis we believe that the main reason behind the shifting perception on online and in-person engineering laboratory sessions during the COVID-19 pandemic was the fear of a possible infection. A future research perspective is of course evaluating that premise through internal student polling after the end of the academic year and also data collection on subjects in the next semester and subsequential analysis.

Another interesting possible avenue of research is a comparison of future student success in courses that benefit from knowledge and skills acquired through laboratory session in one or more of courses mentioned in this paper. This would give us a unique opportunity to evaluate the difference in effectives of online and in-person engineering education. While there is some recent research done on inclusion of online pre-lab activities [9] [10] [11] and online homework [12] there is almost none on said subject.

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HOW TO UTILIZE TEST RESULTS EFFECTIVELY?

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Conference Key Areas: *Mathematics in engineering, Digital tools*
Keywords: *complex mathematical and grammatical test, engineering students*

ABSTRACT

There are numerous ways in which universities measure their first years' abilities essential to begin one of our courses. Institutions try to define processes, which projects successful progress or drop-out rates.

To create such tests is no easy task. In recent years, one of our research groups has developed complex mathematical and grammatical tests, which have been completed by more than a hundred students. In our experience, students are conditioned to a certain type of standardized test, since they can practice on the previous years' tests. Hence the results become distorted. However, we find that a greater knowledge is required for grammatical tests, thus the results tend to be more accurate. Standardized tests are much easier to predict.

First year engineers at BME have written several tests. The van Hiele test, which measures geometrical thinking, a university-required test that assesses their knowledge of calculus, and our afore-mentioned test. In our research we analyzed and compared the results. We could see that the students, who did well in our test, also did well in calculus. Furthermore, we found that there is a correlation between the results of mathematical and grammatical tests.

To summarize, with the results compared, we could see a clearer picture of the abilities of our freshmen. Which is incredibly important during a pandemic, where our contact with the students is limited.

1 INTRODUCTION

Students entering their university studies write entrance tests at many universities around the world, even though they have been admitted as part of an admissions process. Multiple tests can serve different purposes. Some of them examine the existence of the knowledge needed to complete a course, others try to find an answer to how successful the student will be in the future, whether there is a risk of dropping out. The latter is really high in the fields of Science Technology Engineering Mathematics (STEM) all around Europe, which causes a shortage of manpower, as the dynamic development of these fields requires an increasing number of engineers, computer scientists and scientists.

Marcell Nagy and Roland Molontay analyzed the data of the students of the Budapest University of Technology and Economics (21,547 people) using statistical learning methods to examine the strength of the admission points of the students in the Hungarian admission procedure. They prove that grades from high school have a strong predictive force, furthermore the general knowledge is more important than program-specific knowledge. They also find that the academic performance of the males is overpredicted, however, that of females is underpredicted by the university entrance score system [1].

1.1 Admission and testing of freshmen during pandemia

Due to a pandemic starting in China at the end of 2019, the students who had their admission in September 2020, closed their high school studies under changed circumstances. The last academic year of high school, the most important period in terms of repetition, synthesis of the learned material, and final exams, has already been spent in online education. In Hungary, only written final examinations were held, with the exception of a few subjects. There were no oral exams in mathematics, physics or computer science, although they were particularly relevant for further engineering studies at Budapest University of Technology and Economics.

In September 2020, the freshmen students began their studies in hybrid education, the large number of lectures were held online, while the practices were taught in attendance. After a few weeks, due to the aggravation of the epidemic situation, full education continued online. The so-called ‘Zero exam’ which is a necessary condition for fulfilling the object of calculation, was performed in such circumstances. This exam is compiled by the lecturers of the Institute of Mathematics of BME and is uniform in all faculties, the tasks are freely available for several years [2]. However, we find that these tests have traditionally performed well in the population we studied (first-year mechatronic and energetic students), with nearly no failed performers. The results of this measurement do not show a relationship with the success of completing the calculus subject, and they are not suitable for screening talented students. We suspect that those students, who are also outstanding in the field of engineering, learn relatively easily the type of the tasks of the zero exam, but only the existence of the most basic knowledge can be measured with this, even though the fulfilment of engineering subjects would require the ability to apply what has been learned in the subject of calculus. The knowledge acquired there, is safely applied in the problems that arise in the further engineering subjects. A zero exam- type survey does not aim to answer more complex questions (for example, how effective is the formation of groups if we want to implement differentiated education later). In this way, only the existence of basic skills and abilities is checked, and the excellent performance on it is not a guarantee for further excellence.

1.2 Motivation and goals

The question arises as to whether there is a way to learn more from the results of a survey at the beginning of the first year. If we intend to write this type of test, we should avoid being able to “be prepared in double-quick” knowing the tests of previous years and not to shock students with the poor results of an exam written in the first week, for whom mathematics will not play an important role in the future either. Such testing is designed with the intention of helping students at the university to continue on a career path that is as wide-ranging as possible according to their abilities. Our research team developed a test a few years ago, which is presented below, that includes a set of language tasks in addition to mathematics. Since then, we have completed the test with hundreds of first-year students of technical or economic fields of higher education. We have found that a new, modern competency test method has been developed that gives a prediction of the performance of first-year students at the time of their entry to the university with excellent accuracy and helps the identification of students who need more catch-up or talent management [3].

2 DATA AND METHODS

2.1 University selection procedure in Hungary

In Hungary, the university selection procedure is partly similar to that of other Central and Eastern European countries. Students complete a nationally uniform matriculation examination at the end of high school. The exam subjects are Hungarian language and literature, mathematics, history, a foreign language, and an elective subject. Each higher education institution defines the elective subjects for its selection procedure. In technical higher education, these subjects are typically physics, informatics or chemistry. The purpose of the matura exam is to check the existence of the required knowledge for the chosen university education program. Matura exam can be taken at an advanced or intermediate level in any subject. Each university determines the advanced level graduation subjects required for admission. From 2020, all students continuing higher education in Hungary are required to take at least one subject at an advanced level. The results of the matura exam are converted into points. A maximum of 200 points can be obtained from the graduation results, another 200 points are earned for grades from the last two years of high school. An additional up to 100 extra points can be obtained for advanced level matura exams relevant to university studies, for results achieved in study, art, and sports competitions, and for language exams. Like the Swedish model, students who perform well at graduation but have low scores from their high school studies can double their graduation points.

2.2 Investigated group

The students in our study population were admitted to two majors with the highest admission scores of the leading technical institution in Hungary. In 2020, the 433 points was for mechatronics, 349 points for energy engineering was the inclusion point limit [4]. The average admission score of the mechatronics in our study population is 459 points and 421.5 points for energy engineering students. A large proportion of students came from a high school where they studied mathematics or science subjects in a higher number of hours. This ratio is 51.6% (32 students) for energy engineering students and 51.1% (47 students) for mechatronic students. 59 (64.1%) of the mechatronics students and 41 (66.1%) of the energy engineering students graduated in advanced level from mathematics.

2.3 Description of the test

Language and mathematics are thought by many to be two very different areas. However, the situation cannot be so polarized. At a basic level, we can make many connections between language and mathematics. Our test is formed by two large parts (linguistic and mathematical), which also contain tasks that are unusual for Hungarian students, with the help of which students with knowledge deficits of certain types of tasks can be screened out.

The Hungarian language task series - related to mathematics - not only measured language knowledge, but also tried to explore the mechanisms of thinking. We used the elements learned in general and secondary education, but the tasks primarily required the application of learned knowledge.

The test took 70 minutes. It is also important that the student is able to complete the task in a timely manner, so the tests were designed to perform all tasks with only the expected speed. The test contains several examples, for which the solution takes longer time with using template methods, while a deeper understanding of the problem provides a much shorter path to success.

The test contained 14 multiple choice mathematical exercises, each with 4 possible answers from which only one was correct. The tests (basic and advanced) were divided into three blocks. The task types are shown in the table below.

Requested knowledge	Procedural skills	Difficulty (1-5)
Mechanical calculation skills	Operations with fractions	1
	Calculations related to absolute value	1
	Exponential Expressions	1
Combined mechanical calculation skills	Logarithms exponentials and square roots	2
Applying mechanical calculation skills in an unknown environment	Breaking into partial fractions	3
Application of learned functional knowledge	Calculations of the value set of a function	2
Slightly unusual application of learned functional knowledge	Knowledge of the substitution value of a function	3
Slightly unusual examination of learned knowledge	Calculations of polynomial roots	3
Basic relations	Logic, knowledge of relations	4

Slightly unusual application of learned knowledge under general conditions	Function transformation	4
Unusual environment	Proportional thinking	5
	Function graph - formula relationship	5
Difficult, complex, unusual	Parametric geometric problem	5

Table 1. Math test tasks by type and difficulty

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) 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.

The tasks of the language test cover a relatively wide range of procedural skills. In addition to the knowledge of grammatical elements, they affect several areas of linguistic abstraction: text correction, logical thinking, meaning identifications of text elements, interpretation of text structure, analogical thinking, rule recognition. The application of skill-level thinking mechanism (analysis, synthesis etc.) in the educational process, the incorporation of learned knowledge is closely related to the cultural and age characteristics of the relationship with the language.

Requested knowledge	**Procedural skills**	**Difficulty (1-5)**
a) text correction b) recognition of statements	a) Grammatical elements b) Comprehension	4
a) synonymy and b) circumscription	a) Lexical knowledge, passive vocabulary and b) Identification	4
Word recognition, basics of grammar, meaning identification (12 MC question)	Word development, synthesis, language skills, identification	3
word-syllable distinction (5 pcs)	Word development, syllables	2
meaning of verbs conjugation	semantics of verbs	5
Creation of word structures	analogy, linguistic abstraction	4
Word formation	synthesizing thinking	4
interpretation of foreign language elements	language analysis, systems theory	4
Style theory	comprehension, style knowledge	5
Interpretation of word element meaning	analytical ability	4

comprehension, sentence formation	comprehension, analysis of language elements	5
Comprehension of literary text, interpretation of style marks	comprehension of text, understanding of style	5
Text comprehension, logical connections	text value, reproducibility	5
Graph interpretation	visual ability, logical ability	3

Table 2. Language test tasks by type and difficulty

We measured the skill-level application of learned language, grammar, and mathematics. We set the measurement levels of Hungarian language and mathematical skills to each other (knowledge transfer, abstraction skills, etc.). We had to cross over to the usual school task schemes, we had to generate new task situations. We were looking for connection segments between language and mathematics that require similar or identical application of knowledge and ability. We placed skill-level knowledge in an unusual problem situation because we assumed higher thinking skills. Higher levels of text abstraction, rule recognition, language synthesis, difficult utilization of words, and meaning identification were mixed with simpler task problems.

3 RESULTS

3.1 Comparison of test results

Fig. 1 shows the results of each student. The earned points by solving comprehension problems are plotted as a function of the results reached in the mathematical part of the test. It is clearly visible that there are some students whose poor comprehension score is coupled with a good math test score. However, we did not find a student who had performed well in the comprehension part of the test but got poor results in mathematics. Being “elite” students, there were only two of them who performed poorly in both parts.

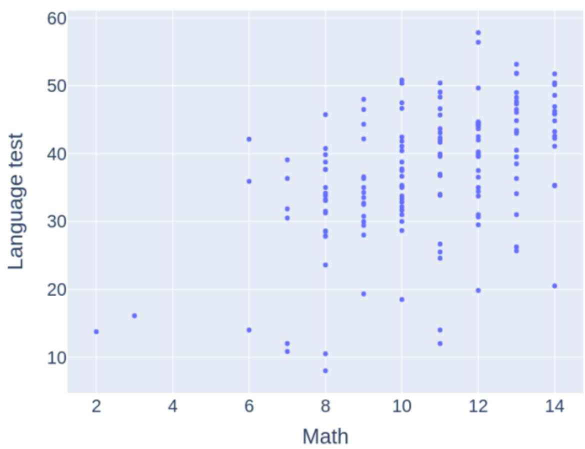

Fig. 1. Comparison of Math and Language test results

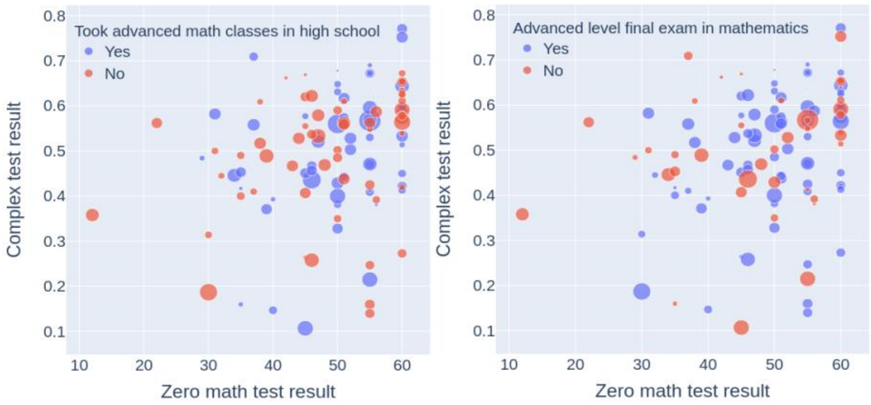

Fig. 2. Comparison of test results for students taking advanced level examination and attended advanced math classes

Figs. 2 shows the results reached on the language-mathematics test as a function of the results obtained on the zero math test. The blue dot indicates the ones who had a math final exam in an advanced level, while the orange dots correspond to the ones taking the final exam in the middle/normal level. The size of the dot is larger if more students have achieved the same result. The figure (B) below also shows the results obtained on the language-mathematics test as a function of the results reached on the zero math test. The blue dot now indicates those who were in math or science faculty, while the orange indicates the complement. The size of the dot is proportional to the length of the learning.

Note that both figures have a shape of an “upper triangle”, namely most of the students are located above the diagonal connecting the upper left corner of the rectangle to the lower right. This refers to the fact that the two figures are not different essentially.

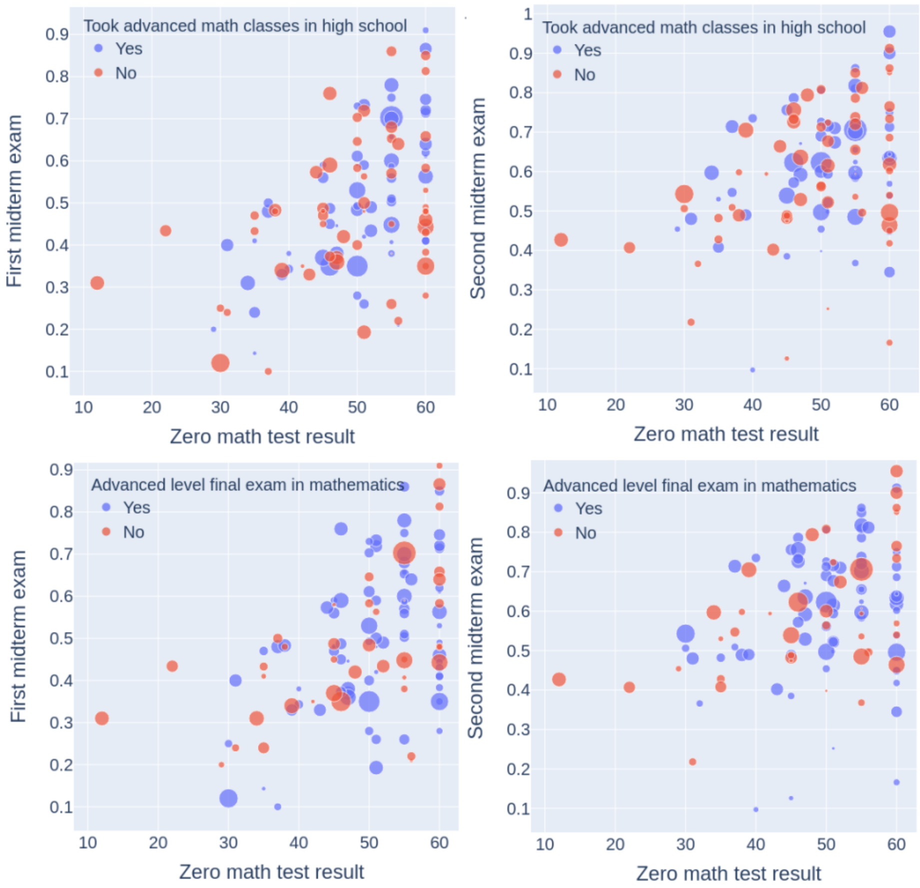

Fig. 3. Comparison of test results for students taking advanced level examination and attended advanced math classes

The zero math test is intended to check the existence of the level of knowledge required for the successful completion of the calculus course. If we examine the results of the two midterm exams written in the semester as a function of the score reached on the zero exam, in both cases, the points are rather below the diagonal connecting the lower left and upper right vertices of the rectangle which refers to the fact that the two measurements are not independent (Fig. 3). However, a good zero math test does not necessarily mean successful performance yet, but a weak zero math test is rarely followed by a good calculus result. The markings are similar to the previous figures.

Fig. 4 shows the results obtained in the complex test as a function of the mark obtained from the calculus subject, both in the linguistic and mathematical part. The obtained results are presented divided by the maxima. It is clear that the more unusual, novel task (language test) was more difficult for the students. It can also be seen from the figure that weaker scores resulted weaker calculus grades; this relationship was stronger in the case of the language test. The number of students having great results in math tests, although performing poorly in calculus courses is only a few, who obtained bad results in the language test.

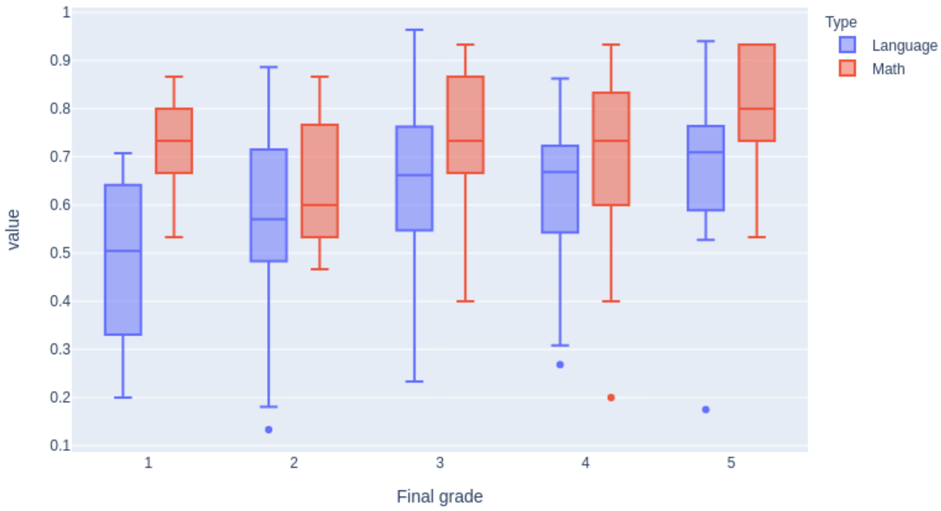

Fig. 4. Comparison of test results and the grade of Calculus 1

4 CONCLUSION

The multiple tests we use to measure first-year students provide us information from different aspects. The complex language-math test is more predictive than the one containing only math tasks, so it can be used effectively to measure first-year students. New types of impressions can shed light on connections which cannot be or only difficult to extract by other methods.

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HIGHER EDUCATION IN ENGINEERING – A FRAGMENTED PUZZLE OF BITS AND PIECES?

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Conference Key Areas: *Mathematics in engineering, Engineering in Schools*
Keywords: *Conceptual understanding, mathematical consequences, study pattern, abstract learning*

ABSTRACT

The author experiences big differences in the engineering students' ability to connect basic principles learnt in earlier courses with new concepts in a course on analogue electronics where the basic principles are the fundamentals to master the new knowledge, i.e. Ohm's law and Kirchoff's current and voltage law. Simple mathematical consequences such as dimension analysis and the meaning of the equal sign is ignored or simply not in their mind, and a reflection on the plausibility of the answer is seldom there. The students' seems to easily fall into a standard solution they remember and lack the ability to understand what actually the problem to solve is. From a survey including eleven 2nd and 3rd year students, in the span of failed exam several times to top students, it is clear that this is not only a problem for the students struggle to pass, but also from the higher performing students there are misconceptions on basic principles. This paper discusses issues on understanding and gained knowledge in the field of electrical circuits and electronics from a mathematical and conceptual view, their previous gained knowledge and the students' perception on how to study. The data comes from a test of exam questions with "check-up questions" on basic principles, a short survey on study pattern and selected interviews with five of the students from their performance on the test and/or their answers on the survey. The author suggests a model on how to highlight a new study pattern from basic principles and their future professional role.

1 INTRODUCTION

Since the 60’s the focus on more student-centered teaching methods with the aim to activate students way of learning has started to develop in higher education. Until then almost all teaching consisted of lectures. Even though storytelling is a powerful tool for learning, there are several methods that are at least equally as good for learning and have the benefits of engaging and motivating students to a larger extent; far from all enjoy storytelling as the best way to learn. The problem that now occurs is that regardless of methods chosen, the teachers act independently dependent on his or hers choice of planning, execution format and learning forum. Therefore, a program that consists of many courses often suffers from a lack of coherence between the chosen teaching methods and lack of communication between teachers on the program (since they are many and work independently, almost always unaware of each other). There are institutions started in the last 50 years, for example Aalborg University, that have committed to a fixed planning and teaching methodology, but they are more of an exception that confirms the rule.

For some problems you learn a method to come up with a solution, like following a receipe. These methods works perfectly for standardised problems where you reach the same goal through repetition. It can be a procedure on how to start up an arrangement, solve a quadratic equation on the form $ax^2 + bx + c = 0$ or simply cook grandma’s famous stew. The expected result is well known and even if it can be tricky to learn the correct routine for the final outcome, the procedure becomes a standard and you can repeat it nearly without conscious thinking after some iteration. Therefore, you move the thinking process from the conscious mind to the unconscious, like riding a bike; once you have learnt it you can do it for the rest of your life, as long as your physical status allows it. Another example on unconscious knowledge is learn how to play a music instrument: even though you give it upp for a couple of years, you can still play it once you decide to try again. You got it in your bones.

In mathematic based studies, depending on the individual, the ability to learn standardised solutions disappears sooner or later. For some the correct handling of a common-emitter (CE) step with a transistor or the solution of an ordinary differential equation up to a certain order is possible in the same way. Learning mathematic models in a professional view has no meaning unless you are a mathematician. The applications can get into your bones, but all who have studied electrical engineering know that just learn how to calculate a standard CE step is not by far enough to understand the complexity and function of a transistor as an amplifier from a random chosen electrical scheme. For a student in an engineering program it sooner or later becomes necessary to learn more than just standardized solutions on all the problems at hand to pass the courses and get the necessary understanding of the field. The models are simply not good enough to cover all situations you are supposed to know and learn, you need to learn by experience and from a more conceptual view to understand how it works in real life. If every engineering student had a genuine interest in their special subject, and gains knowledge from pure interest, it would be much more easy to educate them, but that is far from the reality.

Sooner or later an engineering student's knowledge has to reach a more conceptual level to learn and cope with the details. In electronics unwanted leaking current will appear, electrical fields from circuits, unknown capacitanses, noise, current density in conductors etc… These are components that rarely is a factor in the laboratory work, at least not in the fundamental courses, and are often neglected in the models we use. We focus on proving the models that are the basics for the principles of electronics because we cannot explain all the factors that occur when we explore outside the arranged environments that follows the simplified models. The complexity in just learning how to use components like the OP and the transistor in the simplest of circuits are high enough to confuse the brightest of students when they lack experience. The transistor, for example, works its magic because it does not follow Ohm's law. Still they must learn how to apply Ohm's and Kirchoff's laws to calculate the properties and behaviour of the circuits.

The author have experienced surprisingly low understanding of basic principles of electrical circuits such as Ohm's (1) and Kirchoff's laws (2) on an Electrical engineering program during a course in Analogue electronics for the second year. The course introduce two new components, the operational amplifier (OP) and the transistor, and a fundamental part of getting the knowledge is about using (1) and (2) to understand the function of the components. Despite focusing on how to present the concept of the new components, many students struggle to pass the course. From experience I have spotted three main paths of learning students trust in

1. Memorise solutions on all problems that is presented on lectures, in the textbook and from old exams.
2. Decide on and learn formulas for the different assignments and problems that are presented during the course.
3. Work out and learn by heart the standard methods used for the basic OP and transistor circuits presented in the course by solving a large number of problems.

The third option is done in many different ways: Ideally they solve the problems together in a study group and discuss their solutions. Unfortunately there are often solutions on each of the textbook problems available and some students take a shortcut here and do not struggle enough to reach the necessary understanding of the suggested solution. It becomes even worse when they try to solve it and after a short while consults the solution and then move on.

2 RESEARCH QUESTION

As seen further down, there is research on the complexity of learning electronics and electrics, but the author see a void for a more holisitic investigation on why the engineering students seemingly fail in understanding and apply basic concepts in electronics during their study period. It is easy to investigate difficulties in the more advanced application of transistor circuits and filters, to give a few examples.

Therefore, this inquiry is a initial survey that tries to pinpoint a reasonable explanation and a further research agenda on how the concepts can be more intuitive for the students when the electronics includes active circuits and further applications. For the study I aim to answer what are the actual tresholds the students experience and what conclusions can be drawn from their own opinion on how they learn and study.

3 METHODOLOGY

This inquiry is based on

- a quantitative comparison of the results from a test;
- the students own conception on how they study and learn; and
- five interviews with selected students,

a mixed methods approach is preferred [1]. The collected data covers both students' own view on study and learning as well as their results from the test, which gives the survey a narrative view from experience [2] complemented by the results from the test.

The students took a test with four exam questions (EQ) and additional questions for each EQ on basic circuit theory they ought to know from previous courses. They also had the opportunity to comment their solutions if they wanted. They described their way of learning and studying from proposed alternatives presented further down:

From the eleven students five were selected for a short interview based on their performance and opinion on how they study.

Therefore, the data collected consists of their solutions on their EQ and questions from previous courses, their opinion on how they study/learn the best, and the interviews.

4 LEARNING IN (ELECTRICAL) ENGINEERING

To promote deep learning and understanding in mathematics based subjects it is not the presence of a teacher that is the most important, but rather how to nurture the process amongst the students and increase their motivation and drive to reach the learning goals of the course [3]. The process of learning comes from an extensive knowledge on how to relate all the new content to a proper context, and also how it can,may or shall be used for further learning and knowledge [4, p. 192]. Learning electricity-related concepts is often confusing for various levels of learners [5] [6]. The difficulty in learning electricity, electronics, and electromagnetism concepts is attributed to their abstract nature, complexity, and microscopic features [7]. Some studies show that most difficulties experienced by learners of electricity-related concepts originate from certain abstract concepts that cannot be comprehended or associated with actual circuits [8]. The inability to see currents flowing through circuits in daily life and to comprehend abstract concepts leads to various misconceptions [9] related specifically to the understanding of current, voltage, and power consumption [10] [11] [12] [13]. Moreover, it is difficult to avoid these misconceptions through general instruction [8] [14] [15] [16]. Students do not seem to fully understand what a "signal" physically is. They also lack a functional understanding of a frequency-based representation of a filter [17]. From [4, p. 190f] we have that the classroom and the teacher is different from the everyday meaning of a room inside four walls and a person in that room guiding a group of learners: Teaching starts the day you decide to setup a program, and the learning environment shall be designed from how it best suits the study groups.

When we as novises approach new knowledge we rely on our experiensis and previous knowledge. From this standpoint we develop an approach based on our intuition and interpretation of the problems we are facing, our intuitive knowledge. From [18] we have that intutive knowledge is making sense of intellectual awareness. The most obvious problem with intuitive knowledge is when the intuition is wrong, i.e. from the basic principles it is hard to generalize a intuition that holds. Therefore, it is utmost important for the teacher to provide the students with tools (read learning environments) where they can better their intuition for the concept. For electronics its complicated since you cannot directly observe what happens, only consequences of the action. Together this calls for a larger possibility for misconceptions in electronics and we cannot simply rely on intuitive knowledge as an ingredient in the process; all concepts need to be explained and interpreted for each student.

5 RESULTS

5.1 The test

The students took the test three and a half months after the regular exam where the five reference persons got their passing grades, one passed (3), two of them passed with credit (4) and the other two passed with distinction (5). The other six had another opportunity two months later where three of them participated and failed. Two of the failed students are from the previous year. They are allowed to bring a calculator, the textbook, all their own notes produced during the course and a formula handbook of their own choice on the exam. The students were told that it would count as an ordinary exam if they passed. In the test there were two control questions from their previous courses on a basic level, see below.

Question 1 is a typical passive lowpass filter where they shall present the frequency response with a Bode plot. *Extra question:* Calculate the current through the capacitor (Simple Ohm’s law).

Question 2 is a basic CS amplifier (FET type of transistor). The correct calculated A_V was given and task was from a given U_{in} calculate the signal current through R_D where the output signal lies. All the signal parametres for the chosen transistor is presented, although they are not needed for the solution of the problem. So instead of the normal procedure to determine the amplification they shall calculate a signal current from a given input signal. *Extra question:* Calculate the dc current in one of the resistors connected to the Gate (A simple case of Kirchoff II and Ohm’s law).

Question 3 is a simple quiscent point calculation for a bjt where the only "trick" is that it is a CB amplifier, which has the same setup as the basic CE amplifier when deciding the quiescent point.

Question 4 is a basic AC OP amplifier circuit (inverted) where the drawing circuit is not in a standard format, but not complicated, just drawn with a different layout than they normally see them. They shall calculate the amplification $A_V(\omega) = \frac{U_{out}}{U_{in}}$ when $\omega \to \infty$ and $\omega \to 0$

There are lots of data that can be interpreted from their solutions, but the focus in this study is: Do they understand what to do, and Do they know how to solve the problem, and What are the typical errors?

Q1: All students start with setting up the general criteria for the transfer function. Seven of them present a correct transfer function, two of the higher graded students get lost in the algebra and therefore not reaching a correct transfer function on Bode's normal form. Three of the not passed students make calculation errors and get unreasonable answers without commenting them (for example I_C=10,8kA). Further from the not passed students the equal sign is incorrect used repeatedly. The passed students and one of the not passed set up Ohm's law for the current through the capacitor.

Q2: Three passed and one not passed understand what to do. Noone of them present the correct answer clearly showing lack of understanding of what voltage difference is. The students that goes wrong starts with calculating the quiescent point although it is not needed. The passed students calculate the correct dc current and two of not passed managed that as well.

Q3: Surprisingly many (all not passed but one and one that had passed) started their calculation from the key numbers normally used when dimensioning of the amplifier is done, i.e. a totally wrong approach. The one that passed then discovered the mistake and came up with the correct answer. It is obvious from this task that the non passed students have flaws in how to apply Ohm's and Kirchoff's laws.

Q4: Since the question is a standard setup for an inverting amplifier most of them were able to get the right expression for the relationship between the input signal and the output. Four of the students did not deliver a solution but three of them claimed lack of time as the reason, which made sense. One forgot the minus sign and a couple did not answer the question which was how the amplifier acts for the extreme values zero and infinity and presented their answer in a Bode plot.

In general: Students that have not passed make calculation errors or simply use the wrong method and get in many cases unreasonable answers without commenting on the reasonability. Structure, i.e. using the equal sign and analyse and use the dimensions right are common mistakes; more than once voltages were expressed as impedance. The ability to evaluate their answers are surprisingly low. Even passed students can answer with unreasonable numbers, but the real misconceptions were among the non passed ones: it is a big difference between 1,5A and 10kA, even though both are not possible after a simple consideration on voltage drop.

5.2 Their view of learning and studying

They got a number of propositions on how to study to choose from, see below. They were asked to determine what category represented them best, or formulate it in their own words.

- “By heart”: Memorise solutions on all the problems from the lectures and the textbook
- “Formulas”: Determine and learn formulas for the problems that are central for the course
- “Methods”: Abrasion of the standardized methods for the basic circuits from the course by solving a great number of problems
- “Planning”: Follow the course planning that the teacher presents to the letter.
- “Examstudy”: I study old exams and learn the solutions of the problems

Table 1 - students opinion on learning and study pattern

Student #	Description	By heart	Formulas	Methods	Planning	Examstudy
1	Not passed	Works	through	all the	material	
2	Not passed	-	1	3	4	1
3	Grade 3	5	2	1	3	4
4	Not passed	4	2	1	5	3
5	Grade 5	2	5	1	4	3
6	Grade 4	4	3	1	2	5
7	Grade 4	-	2	3	1	4
8	Grade 5	4	5	1	2	3
9	Not passed	-	1	2	-	-
10	Not passed	1	1	-	-	-
11	Not passed	2	4	3	5	1

As seen most of the students used more that one alternative, many of them used all the alternatives. The three students that have failed miserably a number of times has “Formulas” and “Examstudy” as their first choice. One who passed with distinction, student #5, failed the test and he puts a “4” in “Planning”, while the other “high graders” prioritise the “Planning”.

5.3 The interviews

Student #3, #4, #8, #9 and #10 was selected for interviews. The interviews was with open ended questions on how they experience the course and their gained knowledge and the result from the test.

#3 (Grade 3): The discussion quickly focused on whether solutions on problems are helpful or an obstacle for the students. His view and standpoint was that having solutions available is beneficial in the cases where you get stuck and the group cannot understand why they go wrong. His conclusion was that solutions on problems are beneficial as long as they are discussed within the study group until they reach a proper understanding and not just accept that there is a solution.

#4 (Not passed): This student performed very well on the test and described his study pattern that he first strive for a theoretical and fact based foundation from the start. Then he starts to solve a lot of problems to pinpoint where he has gaps of knowledge and returns to the textbook and lecture notes to fill the gaps.

#8 (Grade 5): He simply study after the planning and try to reach a proper under-standing of all the methods presented in the course. He has great success so far in his studies. Though not worked with electronics before, he has a parallel project for a private matter he works on.

#9 (Not passed): This is a student from a year before that have failed the exam five times, and did so this time as well. He writes everything down from each session with the teacher and claims that he solves every suggested problem in the textbook. From the interview it became clear that he has huge gaps in understanding the basics for electrical circuits and often presents the proposed solution from a ready made formula, often the right one, but seldom explained or drawn from the problem at hand. It is also clear that the understanding for quantities is simply not there; whether it is a voltage or current is not relevant for the formula at hand, just the outcome.

#10 (Not passed): He cannot accept his inability and shortcoming and starts immediately talking about stress and circumstances outside his studies that has affected him. When discussing the problems from the test it is obvious he is far from having the slightest idea on what the circuits are about; all approaches either come from formulas he memorized or a direct random guess.

6 SUMMARY

Although many students work continuously and in groups during the course, there are gaps in fundaments as algebra and basic circuit theory, and getting a grasp of the content. The worse they perform, the more narrow (and therefore bigger risc for choosing wrong solution pattern) the thinking around the problem becomes, and they associate to some standard solution they remember simply from the layout of the problem. The holistic view is from relatively small to non existent.

The top-down perspective right from the start: If you are to become an electrical engineer, you need to know what are you supposed master when you have the degree and take on a position within the field. By starting with courses in general electrical and electronics theory learning Ohm’s law, Kirchoff’s laws of current and voltage and circuit theory, it must be in the context of your professional role. Data implies poor outcome in just learning how to calculate voltages and currents in solvable exercises. It is the same for learning how to operate the operational amplifier or the transistor. Therefore, all electronics must be seen in a bigger picture to help nurture the students’ intuition on the concepts. Students already involved in practical electronics are rare from my experience. Therefore, the best you can do in the first part of a program, and following through the whole program, in electronics and/or electrics is connect the content from a professional’s perspective; presented as part of real life problems.

7 FURTHER WORK

A more extensive study on the course in Analogue electronics will be done included in the ordinary teaching sessions for next semester analysing all participating students from the data this study presents. The material for the course will be from a professional electrical engineer’s perspective where all learning goals are motivated and presented from the real world.

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MEASURING GEOMETRIC THINKING OF ENGINEERING STUDENTS WITH VAN HIELE TEST

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ABSTRACT

The van Hiele couple have developed a method of identifying different cognitive levels for geometric thinking. According to their theory, the goal of teaching is to reach these levels step-by-step. This is measured by the Usiskin test, which was created in the 1980s. It has been used all around the world, except at technical universities in Hungary. The test's results show whether a necessary level of logical thinking and reasoning for higher education has been reached and serve as a guide to forming groups in education for topic processing. People who are on different levels differ in their geometric thinking, which results in a person with a higher score, who won't accept the arguments of a person with a lower level of geometric thinking.

We completed the test with 130 freshmen with the following results: 68 of them were ranked at level five, 13 at level four, 39 at level three, 1 person reached level two, 7 people level one and 2 of them only reached level zero with permissive evaluation and a full roster. 62.3% were at least on the level of formal conclusions indicating a general level of mathematical thinking. These students tend to substantiate their statements, and are often able to prove them correctly. In our research, we analyzed the

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participants' test results and examined their scores in Calculus, having in mind how their results connect to their level of geometric thinking.

The importance of the van Hiele test is that it 'measures' logical reasoning.

1 INTRODUCTION

During the mathematical education of engineering students the non-Euclidean geometry is a neglected field. The structure of the calculus subjects is often based on examples that are closely applicable to real-life problems, thus resulting in proofs being relegated to the background in many cases compared to the mathematical education of scientific programs. Nevertheless, the volume of the curriculum and the pace of the semester cause difficulties for many engineering students after secondary school studies. Students coming to BME for mechatronics engineering and energy engineering programs are high-skilled students who have been admitted to the university with a high enrollment points and have been introduced to several details of the first semester calculus course in their secondary school studies. In case of these students, there is an opportunity to alleviate the constraints mentioned earlier and to introduce a curriculum requiring a higher level of abstraction.

1.1 Motivation and goals

This commitment is necessarily more difficult and requires more energy from an educational point of view. In order to successfully complete the educational goal along this path, it is necessary to classify the geometric thinking of the students into levels, as a prerequisite for achieving the goal is that the students are at an appropriate level in this regard.

Such a test, which assesses students, is also useful in the traditional method of teaching, as we can get a more complete picture of the students' thought process. In the present case, such a test helps us to get started, as it shows which methods of reasoning are expedient and which logical steps will most likely cause a problem in comprehension. In addition, in the case of a differentiated teaching method, it is worth treating students with the same level of thinking in homogeneous groups in order to increase the efficiency of communication between them. The Van Hiele theory and tests based on it are suitable for assessing students' levels of thinking.

Teacher-student communication plays a key role in successful education. It is not possible to reach a higher level of understanding if students are approached inappropriately. During the educational process, students should be educated from their individual level of understanding and the goal is to bring them to a higher level of understanding. If students' level of understanding is not assessed or teachers do not develop communication accordingly, the teaching process will fail in terms of developing the thinking process and problem-solving ability. In this case, no more than a transfer of factual material can take place. In contrast, if the level of comprehension has been properly assessed, there is room for improvement in small steps with proper communication.

1.2 The van Hiele test

Pierre van Hiele and Dina van Hiele-Geldorf developed a theory in 1957 suitable for understanding the process of geometric thinking. In their work, they developed five levels of understanding from the level of recognition to the level of formal logic. The different levels mean having the following ability:

Level 1: Candidates are able to recognize shapes. They are able to perceive the shapes based on their appearance, but they are not able to observe their details and properties. Without it, they are not yet able to understand the connections. For example, they recognize that the shape is square, but that it is a rectangle they are unable to determine.

Level 2: Candidates are able to identify shapes with their properties. For example, they know that a quadrangle whose angles are 90 degrees is a rectangle. They do not yet have the knowledge to understand the relation between a set of rectangles and squares.

Level 3: Candidates identify shapes by their definition. For example, they will be able to recognize that a square is also a rectangle. In addition, they understand simple proofs, are able to argue and take proof steps.

Level 4: Candidates are familiar with the meaning of the axiom system. They understand the difference between axioms and statements/definitions, but are not necessarily able to break down their proof into axioms. They can deduce evidence, but they don't feel they need to prove "seemingly obvious" claims. For example, if a third line is perpendicular to a line perpendicular to a line, then the parallelism of the first and third lines is felt to be obvious without proof.

Level 5: Candidates are able to think abstractly. They are able to work with other axiom systems, so they are able to use non-Euclidean geometry, such as Bolyai's hyperbolic geometry. This level is the highest in the Van Hiele system, usually only achievable by individuals with exceptional talent (in secondary school: mostly students taking special mathematics faculty, in higher education: mathematics, engineering students).

1.3 Place of geometry in Hungarian Math education

The most common test designed to measure the levels mentioned above was born in the 1980s. [1] Due to the structure of the Hungarian public education, it can be used very well to measure Hungarian students, so we used this as well. The goals formulated in the national core curriculum of public education in Hungary are discussed in detail in the framework curriculum. In Hungary, education is centralized - the national core curriculum defines it more loosely, while the framework curriculum defines the content of education more strictly. As a result, it can be expected that the map of geometric understanding in Hungary should be uniform.

Szabó and his colleagues examined the level of geometric understanding associated with the knowledge acquired in public education at a given age. [2] In their work, they found that each van Hiele level can be assigned to primary school and secondary school classes, respectively. The curriculum defined for the lower grades of primary school includes the recognition of triangles, squares, and rectangles, and their production by drawing freely or specifying properties. This can be assigned to level 1. For grades 5 and 6, students should be familiar with the illustrative concept of planes figures and polygons (triangles, squares). So for these classes, students have to reach level 2. They should then be able to group different shapes according to their properties, so they are expected to reach level 3 by the end of sixth grade. Later, at the end of grades 7 and 8, students should approach level 4 by being able to make statements based on their observations and they should have a need for proofs. Overall, students should reach the 3rd Van Hiele level during the 8 years of primary school and the 4th level by the end of secondary school according to the requirements of the national core curriculum.

The aim of our measurement was to examine the proportion of our students at the 4th level. If they sufficiently meet this prerequisite, the teaching of the calculus subject can be developed accordingly, since in this case we have the opportunity to teach our students knowledge that requires a higher level of abstraction. When explaining new material or proving statements, we can communicate in a way that suits their levels of thinking.

Given the content of the national core curriculum, it would be a legitimate expectation that there is nothing to prevent us from assuming the existence of level 4 even in engineering education. Thus, it becomes possible to understand and perform formal logical operations and conclusions regardless of the specific geometric interpretation. It should not be a problem to recognize the general laws of logic and to understand the connections between different axiom systems.

However, it is worrying that studies conducted in teacher education in Hungary have shown that there is a large gap between the theoretical expectations and the actual expectations. [2], [3] As a result, many students complete their secondary school studies with a lower level of understanding than level 4. Knowing these, we considered it necessary to carry out an assessment test that examines the thinking levels of students studying in elite programs in Hungarian technical higher education.

2 DATA AND METHODS

2.1 Structure of the test

The test created by Usisikin consists of 25 questions and measures 5 competing competencies. Each competency is designed to be measured by 5 questions. The questions are a test tasks and exactly one of the five possible answers is correct. They have 35 minutes to complete the tasks, regardless of age or previous education. Based on the test results, participants will either be classified into one of the Van Hiele levels or will be declared non-classifiable. The level of classified participants can be 0,1,2,3,4 or 5. During the classification 0 means the complete lack of competencies and 5 means the existence of the highest level of competence.

The abbreviated description is based on [1] and full definitions of the levels can be found here. According to Van Hiele theory, one can only possess a competency belonging to one level if one also possesses all the competencies preceding the level. For example, if someone met the criteria for Levels 1, 2, 3, and 4 during the test, their Van Hiele level is 4. However, if someone met the criteria for levels 1, 2, and 4, but not for level 3, they cannot be classified for any of the levels because they should have met level three for level four as well. (However, it can be said about the person that the Van Hiele level reaches two) From now on, such non-classifiable participants will be referred to as “not fit”. There are two methods for evaluating tests. According to the first method, the participants have a competence belonging to one level if at least three of the five tasks related to the given competence are solved correctly. (hereafter inclusive Van Hiele level). For the other method, this number is 4 (hereafter exclusive Van Hiele level).

2.2 Investigated group

The test was completed by 130 first-year students who are first-year mechatronics and energy engineering students.

2.3 Backgorund of the investigated group

The students who form the basis of our study were admitted to the two programs with the highest admission score in Hungary's leading technical institution. In the case of mechatronics engineering students, 59 people (64.1%) took their final exam at advanced level, while in the case of energy engineering students, 41 people (66.1%). The participating students all studied mathematics at an advanced level, which means they had at least 5 mathematics lessons a week in secondary school and their secondary school curriculum included differential and integral calculus.

3 RESULTS

3.1 Distribution of answers

The percentage distribution of answers to the test questions and the average time spent on the questions are shown in Table 1.

Table 1. The percentage distribution of the answers and the average time spent on each questions

No	Answ. A	Answ. B	Answ. C	Answ. D	Answ. E	No Answ.	Average time
1	0,00%	93,85%	0,77%	3,85%	0,77%	0,77%	0:00:14
2	0,00%	0,00%	0,77%	98,46%	0,00%	0,77%	0:00:15
3	0,00%	0,00%	96,92%	0,00%	2,31%	0,77%	0:00:13
4	0,00%	96,15%	0,00%	1,54%	1,54%	0,77%	0:00:14
5	0,77%	0,00%	6,15%	0,00%	92,31%	0,77%	0:00:21
6	1,54%	91,54%	3,08%	3,08%	0,00%	0,77%	0:00:50
7	5,38%	1,54%	1,54%	3,08%	84,62%	3,85%	0:00:59

8	80,00%	0,77%	2,31%	3,85%	12,31%	0,77%	0:00:47
9	0,00%	0,00%	97,69%	0,00%	1,54%	0,77%	0:00:31
10	5,38%	3,85%	6,15%	72,31%	11,54%	0,77%	0:01:31
11	0,00%	0,77%	96,92%	0,77%	0,77%	0,77%	0:00:35
12	0,00%	96,92%	1,54%	0,00%	0,77%	0,77%	0:01:02
13	96,15%	0,00%	0,00%	0,00%	3,08%	0,77%	0:00:14
14	86,92%	3,08%	0,00%	0,00%	9,23%	0,77%	0:00:40
15	3,85%	86,92%	0,77%	1,54%	6,15%	0,77%	0:00:56
16	7,69%	6,15%	52,31%	28,46%	4,62%	0,77%	0:02:10
17	6,92%	6,15%	80,00%	3,08%	3,08%	0,77%	0:01:12
18	7,69%	5,38%	1,54%	82,31%	2,31%	0,77%	0:01:16
19	17,69%	15,38%	21,54%	42,31%	1,54%	1,54%	0:00:55
20	41,54%	2,31%	7,69%	38,46%	9,23%	0,77%	0:02:05
21	3,85%	90,77%	1,54%	0,00%	3,08%	0,77%	0:01:32
22	14,62%	3,08%	5,38%	11,54%	64,62%	0,77%	0:01:23
23	19,23%	1,54%	3,08%	70,00%	5,38%	0,77%	0:01:05
24	3,08%	13,85%	7,69%	68,46%	6,15%	0,77%	0:01:04
25	0,00%	35,38%	0,77%	55,38%	6,92%	1,54%	0:01:38

The following bar chart shows the proportion of correct answers and the proportion of the most common incorrect answers.

Fig. 2. The proportion of correct and most common wrong answers

3.2 Possible explanation for most common wrong answers

Some explanation for typical wrong answers: Question 1: Which is a square? The fact that answer D was marked as correct in some cases may be the result of a misreading. The first syllable of the words square and quadrangle is the same in Hungarian. Question 4: Which is a square? Here, the choice of answer ‘E’ can be explained by the misreading mentioned earlier. Question 5: Which is a parallelogram? If only a few students, but a few made the mistake of not considering the rhombus as a parallelogram. In the case of question 7, the false answer should have been marked, but some must have inadvertently marked the first true statement. In the case of question 8, the only incorrect answer should have been indicated. Several students marked the answer ‘E’ that all statements were true. The only erroneous statement regarding the length of the diagonals was not noticed. For question 10, one had to choose from the statements about the deltoid determined by the intersections and centers of the circles, which statement was not always true. Although answer ‘E’ is not always true, the task was to choose between answers A, B, C, and D. In answering question 13, there were students who did not consider the square to be a rectangle. Question 14 seeks to answer the question of whether students correctly interpret the concept of a subset. Those who marked the answer 'E' as correct do not understand "All squares are rectangles, but not all rectangles are squares." types of statements. The statement in question 16 is true for any arbitrary triangle, it is likely that many were confused by this and therefore the answer ‘D’ was marked. However, based on the text of the problem, it can only be said that the statement is true for any right triangle. In Problems 17 and 18, a common mistake was made by several people who did not understand what the condition was, what the statement was, and what it meant to reverse a conditional statement. The aim of Problem 19 is to ask about the essential properties of the axiomatic structure. The task is really not easy and the many incorrect answers show that the students did not understand the essence of the axiomatic system. This is perhaps not so surprising, as this kind of rigorous structure is not strongly part of secondary school math education. Solving Problem 20 is easy for students who are familiar with non-Euclidean geometries, but difficult for others. Non-Euclidean geometries are not discussed in Hungarian public education. In Task 22, perhaps inadvertence is the reason why a few students marked the answer ‘A’. They did not pay attention to the fact that the sentence is about halving the angle. Constructing half angles is a primary school curriculum and it doesn’t usually cause problems for students. Question 23 is easily answered by those who have heard of hyperbolic geometry. This is not part of the curriculum in Hungarian secondary schools, although its existence is often mentioned. The Hungarian János Bolyai - whose first name is referred by J in the task - had important results in discovering this geometry. Question 24 also assumes a much more general approach to mathematics than that acquired by the majority of secondary school students. In question 25, the most common incorrect answer ‘B’ illustrates a typical error: we know that p implies q, from which several incorrectly concluded that p negates implies q negates.

3.3 Van Hiele levels

The table below shows the inclusive and exclusive Van Hiele levels of the students we examined.

Table 2. The inclusive and exclusive Van Hiele levels of the investigated group

inclusive Van Hiele			exclusive Van Hiele		
Van Hiele level	Number of students	Cumulative sum	Van Hiele level	Number of students	Cumulative sum
5	67	67	5	27	27
4	15	82	4	12	39
3	6	88	3	26	65
2	0	88	2	1	66
1	0	88	1	2	68
0	0	88	0	3	71
not fit	42	-	not fit	59	-

For students participating in the study, the average of the inclusive van Hiele levels was 4.693 and the standard deviation was 0.594. While the average of the exclusive van Hiele levels is 3.732. In this case, the standard deviation is 1.298. If we do not use the 'not fit' category, the inclusive and exclusive van Hiele levels are as follows.

Table 2. The inclusive and exclusive Van Hiele levels of the investigated group without "no answers"

inclusive Van Hiele			exclusive Van Hiele		
Van Hiele level	Number of students	Cumulative sum	Van Hiele level	Number of students	Cumulative sum
5	67	67	5	27	27
4	15	82	4	12	39
3	40	122	3	65	104
2	1	123	2	1	105
1	5	128	1	21	126
0	2	130	0	4	130

If all students who completed the test are graded, then the average of the inclusive van Hiele levels is 4.015 with a corresponding standard deviation of 1.207 and the average of the exclusive van Hiele levels is 3.085 with a corresponding standard deviation of 1.364.

It can be stated that using the 'not fit' category, the proportion of students who did not reach the level required by the Hungarian intermediate level graduation, calculated with the exclusive van Hiele levels, is below 5%. This is not necessarily due to student deficiencies. It is also possible that because this test had no stakes or consequences, some were frivolous in completing the test. In terms of inclusive van Hiele levels, all students reached at least the third level. If the 'not fit' category is not used, this ratio is close to 8% for inclusive van Hiele levels, while it is as high as 18% for exclusive van Hiele levels. Using inclusive van Hiele levels, 64% of students have at least the fourth van Hiele level. Using the exclusive van Hiele levels, the same rate is 32%.

4 DISCUSSION

In Hungarian secondary schools, education is organized around the preparation for the matura exam to be completed at the end of the studies. Szabó and his colleagues examined whether the matura exam's expectations were in line with the objectives set out in the national core curriculum. [2] It was found that the intermediate level matura exam requires no more than level 3. Thus, if the emphasis in the examinations is not on problem-solving ability but on performing routine tasks, it is not surprising that this will also play a greater role in education. Advanced matura exam tasks presuppose the existence of a higher level of geometric thinking.

5 CONCLUSION

With a minor exception in the Hungarian higher education system, the matura exam also plays the role of the university entrance examination. For this reason, there is a strong emphasis on preparing for the matura exam in secondary school. As a result, it is not surprising that students' level of thinking develops in line with the exam requirements. As the study was based on students studying in elite programs, the results are better than the domestic and international results published so far. These circumstances allow us to expand the traditional calculus curriculum and conduct the education of mechatronics and energy engineering students at a higher level of abstraction.

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CREATIVITY IN COMPUTING EDUCATION: A SYSTEMATIC REVIEW

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ABSTRACT

Creativity is an important skill for the 21st century, including for the computing industry, but it is not well understood how creativity is taught and evaluated in computing tertiary education. This study presents the results of a work-in-progress systematic review of creativity studies in computing published between the years 1990 and 2021, from two databases: IEEE and ACM. The databases were searched for publications defining creativity or discussing theories of creativity in Computer Science (CS), and/or conducting creativity training exercises and creativity experiments with undergraduate or postgraduate students or both. Focusing on instruments used in measuring creativity, how creativity has been measured and in which ways creativity is taught, our systematic literature review identified 26 key publications. Common methods for teaching and evaluating creativity are highlighted as relevant for educators identifying how they can build students' creativity skills. Limitations are discussed.

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1 INTRODUCTION

Creativity is one important generic skill that most employers prefer in their employees. Creativity being the origin of innovation is what employers are looking for, as they need innovation to stay competitive. Similarly, computer science is an important part of computing research and innovation, hence it is important that CS graduates are creative and employable in the industry for finding creative solutions to computer problems. Universities, therefore, must focus on ways to enhance students' creativity skills to meet the needs of employers in the ICT industry. Finding ways to teach creativity would be an ideal way of preparing computing students for industry. However, in the context of changing learning technologies, the process could be complex and time consuming. The definition of creativity, its importance, and ways of implementing creative learning techniques also vary for different professionals. However, the primary idea of being creative is to let the students explore their ideas and implement the ideas into reality. There is a need to find ways of implementing creative skills and behaviours in future professionals.

1.1 Background

In a 2020 report published by the World Economic Forum on the future of jobs, creativity was rated as the 5th top skill required globally as we move towards 2025 [1]. Specific to the field of ICT, academic studies have shown that creativity is an important skill for employees to possess. A study conducted on the perceptions of ICT students, lecturers and employers demonstrated that each group believed being creative and innovative was an important skill needed by ICT graduates [2]. A similar study conducted in Sri Lanka with university graduates, lecturers and employers from the field of ICT also found that each group perceived that individual creativity was a necessary skill to stand out in this competitive industry [3]. These outcomes demonstrate that creativity is a skill which is needed globally as we move into the 21st century, and that creativity is a key skill which is sought by employers in the ICT industry.

1.2 Motivation

There are various theories of creativity in the academic field and different explanations of creativity measures. Since creativity is becoming an important skill for future employability of computing students, we investigate the methods in which creativity has been previously taught in the Computer Science (CS) curriculum.

1.3 Contribution to the Literature

There is a lack of understanding about the diverse ways that creativity is taught in computing education globally. This study presents the results of a work-in-progress systematic literature review which explores creativity in computer education, including how creativity has been (i) defined, (ii) measured, and (iii) taught. Literature reviews about creativity in other fields such as psychopathology research have provided important insights about the field [24], and it is imperative that this level of understanding is also gained for the field of ICT.

In this study, the following research question was addressed:

- What metrics, methods or tools have educators used with the intention of increasing the creativity skills of computing students?

2 METHODOLOGY

This study implemented the systematic review method set out by Kitchenham [4]. The review is systematic because of the methods used in the survey of literature, inclusion and exclusion criteria set for the selection of papers, and the final selected papers that are clear and reproducible [5]. Working in a systematic way provides researchers with a process for writing literature reviews of the papers selected in a reproducible manner.

2.1 Search Strategy and Eligibility Criteria

The search was carried using the databases of IEEE and ACM, because these contain the key papers of computer science researchers and academics. The ACM also contains the curriculum documents for all CS degrees and courses. Initially, the search was also made within the Computer Science Education journal of Taylor & Francis online, however no relevant papers were found in the database from 1990-2021, and hence it was excluded. A scoping search was first conducted, to identify appropriate keywords and fields to be used in the primary search strings.

The Inclusion Criteria used for the search were:

- The study must focus on the study of creativity in the computer science field.
- The study must include an experiment/intervention conducted with undergraduate or postgraduate students.
- Publications must be from conference papers, journals, and book and in English.
- The search was restricted to publications between Jan 1, 1990 - April 12, 2021.

The Exclusion Criteria for the search were:

- The paper must contain full article.
- If the search resulted in article duplication (2 or more same article in the list), one of them is excluded.
- If the search resulted in a Proceeding's title only, it was excluded.
- The paper must not be a section of the session, book, article, magazine information or workshop information only.

For the IEEE database, the following search string was used:

((("Document Title":creativ*) AND ((("Document Title":"C.S.") OR ("Document Title":"computer science")) OR (("Document Title":"C.S.") OR ("Abstract":"C.S.")) OR (("Abstract":"computer science") OR ("Abstract":"C.S.")))))

For the ACM database, the following search string was used:

Title:(creativ*) AND (Title:(C.S.) OR Title:("computer science") OR Title:(" C.S. ") OR Abstract:(C.S.) OR Abstract:("computer science") OR Abstract:(" C.S. "))

The IEEE database search resulted in 42 publications which were either from conferences, journals, or books, while the ACM database research identified 141 publications. The paper screening was first done for article duplication, papers with abstract only or proceedings title only and book chapter or articles that were not available for download. 42 papers were excluded. The second screening was based on paper title, if it mentions creativity or not. 34 papers were excluded. The third and fourth screenings were done upon abstract and full article reading. The purpose was to look for interventions/experiments done for creativity in the paper. 26 papers were excluded from abstract reading, while 55 papers were excluded after full paper reading. All the above screening resulted in 26 papers for the final review, 10 from IEEE and 16 from ACM.

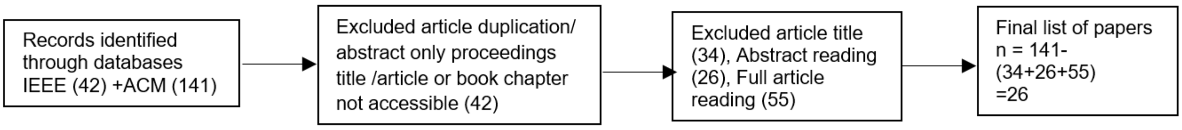

Figure 1: Review selection process.

3 RESULTS AND DISCUSSION

3.1 Where Studies Took Place

A total of 26 studies were included in the final review (ACM-16, IEEE-10). Based on the country, the studies were conducted in Australia (n=1), Finland (n=3), New Zealand (n=1), US (n=15), Uzbekistan (n=1), Brazil (n=1), Poland (n=1), Sri Lanka (n=1), Germany (n=1) Taiwan (n=1). **Fehler! Verweisquelle konnte nicht gefunden werden.** shows the final list of papers including the country where the research has been carried out.

3.2 Methods or Tools used by CS Educators for Increasing Creativity of Students

The common ways that have been used by educators in teaching creativity, and their reference numbers are:

- Course Lectures [26][13][25][32], Computational Creativity Exercises (CCEs) [27][24][22][21][23]; Case Studies [12][20]; Game Design Activities [20][14]; Robots [9][19][8]; and Brainstorming [14][8].

In order to teach creativity, several educators have implemented course lectures, activities, or workshops over a period of time that would help in enhancing creativity [26][13][6][15][16][22][23]. These courses are coordinated and synchronized with teaching assistants and students to realize the maximum benefit from a creative environment. Some studies also focused on creating an interdisciplinary professional learning environment in the classes where the students and educators can cooperate and encourage each other to be creative[6]. Amoussou et al. suggested that these instructors

Table 1: Summary of the CS Creativity Papers Reviewed

Ref.	Country	Document Title
[6]	USA	Assessing creativity practices in design
[7]	USA	Ways to learn and teach creativity and design in computing science
[8]	Finland	Creativity-Supporting Learning Environment-CSLE
[9]	Finland	Creativity and intrinsic motivation in computer science education-experimenting with robots
[10]	USA	Promoting creativity in the computer science design studio
[11]	Taiwan	The Influence of Interactive Art of Visual Music on the Creativity of Science and Engineering Students
[12]	Brazil	The importance of productive dialog in computer science students' creative thinking
[13]	USA	A pilot study on the impact of creative achievement on academic achievement in media oriented CS1
[14]	Germany	Creativity room 5555-evoking creativity in game design amongst CS students
[15]	Poland	Nature of Creativity in Computer Science Education. Designing Innovative Workshops
[16]	Finland	CLAP-teaching data structures in a creative way
[17]	USA	Integrating computational and creative thinking to improve learning and performance in CS1
[18]	USA	Improving learning of computational thinking using creative thinking exercises in CS-1 computer science courses
[19]	USA	Sparking creativity in computer science for interdisciplinary students
[20]	Australia	Creative geeks? facilitating the creative growth of computer science students using engaging environments
[21]	USA	Building Computational Creativity in an Online Course for Non-Majors
[22]	USA	Helping Engineering Students Learn in Introductory Computer Science (CS1) Using Computational Creativity Exercises (CCEs)
[23]	USA	Examining the Impact of Computational Creativity Exercises on College Computer Science Students' Learning, Achievement, Self-Efficacy and Creativity
[24]	USA	Computational Creativity Exercises: An Avenue for Promoting Learning in Computer Science
[25]	Uzbekistan	Development of Creativity of Learners in the Course” Innovative Educational Technology”
[26]	USA	Teaching creativity in computer science
[27]	USA	Learning through computational creativity
[28]	USA	Supporting Creativity and User Interaction in CS 1 Homework Assignments
[29]	USA	Teaching to foster critical and creative TH!NKing at North Carolina State University
[30]	Sri Lanka	Promoting creativity, innovation, and engineering excellence
[31]	New Zealand	Paperclips, Circles, and Six-Legged Spiders-An exploration of self-perceived and measured creativity among CS students

are succeeding in many factors that promote creativity [6]. Offering a studio-based teaching style or creativity room for game design activities can also provide students with a creative environment facilitating increasing creativity [14][20].

The use of robots in courses or game design is also one of the common interventions that CS educators are implementing in their course work to increase motivation and creativity levels of CS students. Apiola et al [9] arranged a workshop based on creativity-enhancing working methods where students participated in designing future robots for CS1 and CS2 courses. Based on this open teaching experiment, more ideas on how to integrate robots in the curricula supporting creativity and motivation were developed [9] .

Murimi Renita [19] at the Oklahoma Baptist University studied the effects of programming and robotics in fostering creativity in CS. Since robotics is an important tool for CS students and their interest in work, students in this study designed a creative product using robots during their student project course. It used a learning by discovery mechanism and students programmed the robot around a pursuit-evasion game termed ‘Zombie tag’. This sparked creativity in students to design a product to include a robotics project and laboratory in their course offerings was demonstrated to the educators [19]. Introducing project work in a course curriculum is a method widely used by educators for implementing creativity learning in their courses [33]. Gestwicki et al [7] suggested the conventional teaching method is limited to having students working only as per teacher's guidance thus inhibiting students' creativity and growth. Therefore, a change in the conventional teaching method is crucial. It is imperative to implement real world scenarios in classroom projects and activities and help students to work through a creative process and make them ready to tackle real world problems [34].

Brainstorming is a highly used method of educators to improve creativity in students cognitive processes by generating and evaluating ideas and innovations [8]. Brainstorming in CS courses is an important aspect of the creative game creation process where students are asked some questions promptly about creative environments or alternative solutions that they can purpose which evokes creativity in the students [14].

3.3 Ways that Creativity is Evaluated in Computing Education

Common metrics or tools used to measure creativity are:

- Survey [26][6][18][24][22][21][19][35] and Feedback [8][30]; Creative Achievement Questionnaire (CAQ) [13]; and Self-assessment [29][31]

Along with the courses that are designed to increase creativity in students, survey is one common metrics. Peteranetz et al [11] asked students to complete a web survey at the start of the semester long course and another survey at the end of the semester. The pre-course survey was about motivation scales and the post-course survey was about motivation and strategic engagement scales, the creative competency scales, the knowledge test, and the exercise evaluation. The common technique used is to include open ended survey questions such as 'How has CCE influenced your understanding?' and 'What suggestions do you have for improving the CCEs?' [22]. It is used to determine the basic concepts of methods and technologies that develop creativity [25].

It is also important to get feedback from the target audience on how they feel about the creativity exercise or course. Sometimes the feedback refers to the constructive feedback provided to the students helping them to keep on track. Other times feedback refers to the student feedback regarding the evolution of the project course. Alternatively, feedback is given by IT people to help students in their creative solutions for the IT industry [30]. One significant aspect of feedback is to understand the likes and dislikes of students about the creative method or tool, so that it can be modified or enhanced to be more important in the success of the course designed to improve their creativity [30].

A pilot study by Gestwicki et al [7] measured students' creative achievement using CAQs. The students' creative achievement here refers to the creative product made by the individual. CAQ comprise of 96 items divided into 3 parts: Self-assessment of their talent (13 areas) by the individual, concrete achievements in 10 domains of artistic and scientific endeavor (judged by experts) and free-response statements (3 questions) from individuals about how they think others perceives their creativity. The purpose of the study is to include creative activities in the courses for improving students' motivation [13].

Whalley et al [31] gave students a self-reporting questionnaire (SRQ) where they were asked to rate their creativity in 56 domains of creativity. The students were asked to make judgements on their own creativity in relation to other people having similar backgrounds to them. The purpose of this evaluation was to analyze how domain-specific the students' ratings of their creativity skills may be.

3.4 Instruments of Creativity Measure

It was found that while most papers focused on intervention or experimental methods used for increasing creativity of students and the metrics used to measure creativity, only a few papers have mentioned the instruments used in measuring creativity.

Common instruments that have been used for measuring creativity are:

- TTCT (Torrance Test of Creativity Thinking) [26][30]; Creativity Domain Questionnaire (CDQ) [31]; Abbreviated Torrance Test for Adults (ATTA) [11]; Critical Thinking Assessment Test (CAT) [29].

The Torrance Test of Creativity Thinking is one of the most popular ways of assessing creativity [26]. The test includes a divergent thinking test where participants are asked for several responses to a single prompt [26]. For instance, in an experiment by Whalley et al [31], the students were asked for the alternative and creative uses they can find for products such as paperclips and bowls. The researchers then analysed how creative the answers were. The Torrance test is designed to trigger this kind of divergent responses to some products, ideas, figural or vocal prompts [31]. The responses are analysed based on how creative and novel the ideas generated are.

Chang et al [31] used ATTA as a research measurement tool for pre-test and post-test research design in their research. ATTA is based on the principle of TTCT but requires less test time and is meant for adults (at least 18 years old). The students fill in the Study Preference Questionnaire as a pre-test study of ATTA, then experience visual music interactive artwork and later complete a post-test study of ATTA. In three phases, the experiment analysed current creativity performance of students, explored creativity with students of different backgrounds in the second phase and finally analysed the effect of virtual music interactive artwork in creativity of students [11].

Another instrument used to measure self-reported creativity is the CDQ. Participants provide ratings of their creativity across 56 domains of creativity. The rating of each domain is given by a seven-point Likert scale. How creative do you think you are in a specific domain as compared to other individuals with the same domain expertise? is what one CDQ asks to be answered by the participants. CDQ-R (CDQ-Revised) is a follow-on mechanism having the SRQ (Self Report Questionnaire) of 21 questions scaled on a six-point Likert scale [31]. The other instrument CAT was validated by researchers of Tennessee Tech University and the students in the experiment conducted by Vila-Parrish et al [29] took a pre and post course CAT test.

4 SUMMARY

In this systematic review, 26 papers were reviewed where all have followed one or more research methods to measure creativity. Most of the papers suggested various teaching methods that can be used by the educators to implement creative learning and enhance creativity skills in computing students. Having creative thinking ability will make students ready for professional jobs and will be beneficial for students, tutors, and the computing industry generally. From the studies to increase creativity skills in students, teaching faculties should be able to include a creative process in their course in any form of workshop, design, or projects. It might require more time for tutors initially, but the time and effort investment would be worthwhile to deliver a course successful in increasing creativity skills in computing education students.

4.1 Limitations and Future Work

This work-in-progress study is limited to 2 databases: IEEE and ACM. In future, this will incorporate 'Computing', 'Software Engineering' and 'Information Technology' also in our search criteria. This will increase the number of publications reviewed. Initial searches have identified this will include at least 145 publications from IEEE (up from 42 in this study) and 810 papers from ACM database (up from 141 in this study). This will provide a comprehensive understanding of creativity in the field of ICT education.

5 CONCLUSION

Even though creativity is a subjective topic and is difficult to measure, it is obvious from the papers reviewed that it is an important soft skill required in the professional world. To prepare students for the future, educators need to find ways to curate their courses from the traditional teaching methods to ones that can spark creativity in their students. With the increasing use of robotics and automation in today's daily life, it is essential that students are prepared to take real world and robotics challenges that may appear throughout their careers. Also, with the uptake of new modes of work, increasing numbers of students will need creativity skills to become successful entrepreneurs.

This systematic review paper provides several suggestions to educators on the methods that are being used to teach creativity, how creativity can be evaluated or measured, and which instruments could be useful in what context of measurement. The aim is to encourage more CS educators to plan for their course and implement innovative methods to teach creativity to their students. Creativity is becoming more and more important and hence it is essential for CS educators to teach and support the students in learning creativity as much as possible.

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USING THE ANDROID EMULATOR FOR THE PEPPER ROBOT FOR PROJECT WORK

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Keywords: *practical skills, remote term projects, emulation, learning process*

ABSTRACT

Excellence in teaching and learning requires that students acquire practical skills in addition to theoretical knowledge. For this purpose, many modules include term projects. In order to realize the practical projects in times of Covid-19, project topics have to be adapted so that students can work on them exclusively remotely. For classes that convey e.g. the principles of Human-Machine Interaction, one possibility is the use of the android-based emulator for the social robot Pepper. The emulator allows students to practically implement ideas for the Pepper robot without needing access to a laboratory. Thereby comparable options are conceivable for other subject areas. This paper presents a concept for remotely teaching and learning the principles of Human-Machine Interaction. The module is designed in such a way that the students realize their projects within the framework of User Centered Design. In addition to the technical implementation of the ideas using the Pepper Emulation, it is the students' task to determine the needs and requirements of the defined group of users on the basis of online questionnaires and online focus groups. The concept thus makes it possible to ensure a practical experience for students in times of Covid-19. However, the use of remote labs also offers many advantages for students, such as time and location autonomy, which is beneficial to the individualization of learning processes. In the presented paper, a guideline for the design of remote practical work is presented and advantages and disadvantages are discussed based on the experience of the conducted course.

1 INTRODUCTION

1.1 Application-oriented teaching and learning of competencies

Excellence in teaching and learning requires that students acquire practical skills in addition to theoretical knowledge. In recent years, the concept of problem based learning has become more and more prominent in engineering education. Problem based learning is a student-centered pedagogy that makes use of real-world problems as a challenge to enhance and promote student learning [1]. Compared to traditional teacher-centered approaches, problem based learning particularly promotes critical thinking skills, problem solving skills, cognitive skills and overall performance, which is highly desirable in engineering education. One way to integrate problem based learning in higher education are term projects.

Traditionally, term projects are designed to be carried out in university laboratories. Such practice-oriented projects are established in particular in the teaching of universities of applied sciences [2]. The laboratories provide the appropriate infrastructure for practical work. However, with the Covid-19 pandemic, teaching at universities was shifted from face-to-face to online formats, preventing project work from being conducted on-site. New concepts suitable for remote execution were required to continue to conduct practice-oriented, problem based learning challenges as part of courses.

Concepts for remote labs have first been used in the 90’s in the context of distance learning to opened up access to experiments to a larger group of students using the new possibilities of the internet [3]. Remote access was a key factor during the Covid-19 Pandemic and worldwide high quality concepts for distance learning were realized. One approach was to record laboratory experiences and put videos, quizzes and data online for students to engage with the material [4]. Others prepared take-home kits for students, gave remote access to real in-lab equipment or provided data to enable students to perform simulations of physical systems [5]. The authors of this study compared different approaches and showed that take-home kits (92 % positive rating) were the best replacement for in-lab activities followed by remote access (82 % positive rating). Using videos and quizzes as replacement was only enjoyed by 57 % of the students. When developing a remote concept, however, in addition to the preferences of students, the availability of resources and the feasibility of implementing the content in accordance with the module also play a decisive role.

1.2 Human-Machine Interaction

Human-Machine Interaction is a cross-disciplinary area (e.g., engineering, psychology, ergonomics, design) that deals with the theory, design, implementation, and evaluation of the ways that humans use and interact with machines [6]. A special form of human-machine interaction is human-robot interaction. Human-robot interaction is concerned with how physically human-like robots interact with humans in the social world and how social robots are perceived as social agents [7]. In order to understand the complexity and possibilities of this humanoid embodiment and to apply it to the needs of specific target groups, semester-long projects have been designed for the courses Human-Machine Interaction and Design of Anthropomorphic Machines of the Mechanical Engineering program at the Cologne University of Applied Sciences. The methodology will be presented in the next section.

This paper deals with the question of how semester-long problem-based learning challenges can be designed completely remotely. What are the advantages and disadvantages for both students and lecturers? What design recommendations can be made for future, post-covid courses?

2 METHODOLOGY

2.1 Objective and working environment

The given goal for the students was to develop an application for the Pepper robot for a specific application scenario. The students could choose between four different scenarios: Elementary school, entrance hall of the university, senior living communities and train station. Due to the Covid-19 pandemic, study courses took place online. Therefore, the working environment for the semester-long projects had to be accessible remotely aswell. For this reason, a programming environment was selected for the implementation of the projects, which is based on freely available software only. The courses had a scope of 5 ECTS credits. The course Human-Machine Interaction was attended by 45, the course Design of Anthropomorphic Machines by 65 students. They worked on the projects in groups of 3-5 people. For virtual collaboration, the teams were able to use the MS Teams collaboration platform. The grading of the modules was composed of 50% final presentation and 50% documentation of the projects.

2.2 Use of the User Centered Design Framework

Students were assigned to work on the semester-long projects within the User Centered Design framework [8]. An overview of the UCD and the recommended methodological approaches for the phases is given in Fig 1. The framework is highly suitable for developing user-centered products and was thus appropriate for the course Human-Machine Interaction and Design of Anthropomorphic Machines

In the research phase, the students' task was to develop a suitable persona for the application scenario. For this purpose, they were to conduct either interviews or a focus group to determine the needs and requirements of the defined group of users and develop the persona based on the findings.

In the design phase, conceptual and physical design had to be ideated. In the process, activities, actions and goals were developed that were tailored to the application scenario and the persona.

In the develop phase, the students were to implement the developed ideas with the Android Pepper emulator. The programming environment was based on Android Studio, the Pepper SDK as an Android Studio plugin and the Java library QiSDK. Students were able to install the software on their computer.

In the evaluation phase, the goal was to tests the applications using either (online) surveys, user tests or focus groups. The evaluation could be performed using video material. Based on the feedback, students were asked to give an outlook on which next steps they would recommend for the project. Students were further encouraged to incorporate evaluations into all phases of the UCD, but it was only mandatory after the develop phase.

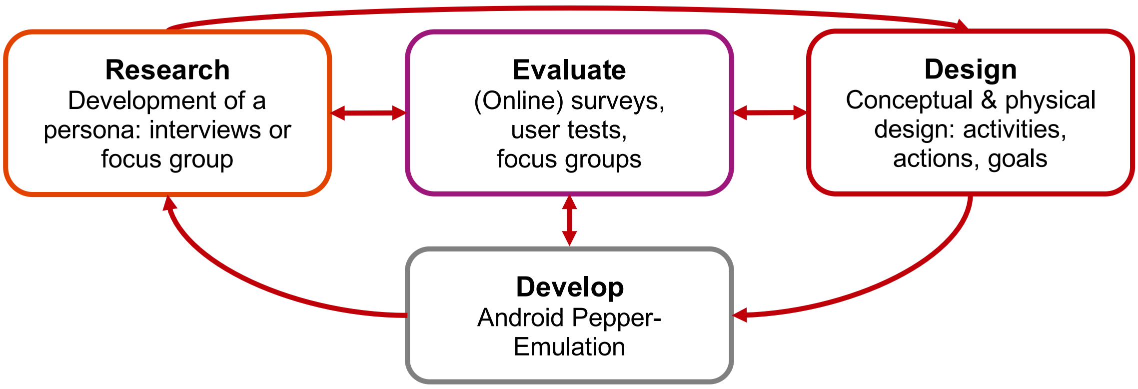

Fig. 1. Recommended methodological approaches for the individual phases of the UCD

The concept of UCD envisions multiple cycles of the process for optimal product development. Due to the time constraints of the semester-long projects, the students only performed one cycle. Based on the results of the evaluation phase, they had to provide an outlook on which steps would now be suitable for the further development of the project.

2.3 Procedure of the semester

At the beginning of the semester, the contents and objectives of the course were presented. The topics for the semester-long projects were also presented here. Based on the students' topic preferences, the groups were allocated. In the following four events, a winter or summer school took place, which familiarized the students with the programming environment in a targeted manner. Thus, the influence of previous experiences with programming which differed between students could be minimized. The following six events were divided into two sessions of 45 minutes each. In the first 45 minutes, students received input on relevant topics such as artificial intelligence, social agents, navigation and control, and computer vision. In the second 45 minutes, further exercises were carried out which supported the progress of the projects. Content-related and technical questions concerning the projects were discussed. In particular, students had the opportunity to receive assistance on problems related to the definition of the persona and the implementation of the envisioned applications. Students were only given the dates of the final presentations as deadlines for completing the projects. No milestones such as the completion of the persona were specified.

3 RESULTS

This paper presents a concept for the remote execution of a problem-based learning challenge in the context of semester-long projects to improve learning outcomes for the courses Human-Machine Interaction and Design of Anthropomorphic Machines. By going through the UCD process, students learned the importance of involving the relevant target group and gained hands-on experience implementing robotic applications. The understanding of the theoretical contents of the lecture could be deepened by the addition of remotely conducted semester-long projects. The groups were able to successfully set up the programming environment and implement viable applications for the Pepper robot. The Pepper robot and sample code is illustrated in Fig 2. The implementation of the applications promoted the application and deepening of programming knowledge. The concept thus makes it possible to ensure a practical experience for students in times of Covid-19. A guideline for the design of remote practical work is presented and the advantages and disadvantages of the concept as experienced are discussed in the following sections. Subsequently, effects on the learning process are discussed.

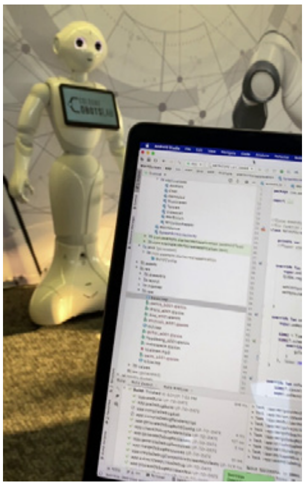

Fig. 2. Illustration of the Pepper robot and sample code

3.1 Guideline for the design of remote practical work

In this section a guideline for the design of remote practical work is presented. It is assumed that the subject of the lecture is given. In the next step, a suitable problem based challenge must be defined. The challenge should be based on real world problems. This makes the relevance of the challenge prominent, which has a positive effect on the motivation of students [9] [10] [11]. Particularly suitable are specific social challenges or distinct research questions from ongoing projects. Challenge selection must also take into account the scope of the semester-long project so that students are able to complete the assignment in the time frame provided. Based on the topic of the challenge, a suitable methodological framework must be given on the one hand, on the basis of which the students are to solve the challenge. Through the framework, the required methodical approach is made concrete and the solution process is guided and supported appropriately. On the other hand, a working environment must be defined, which is suitable for solving the challenge and which has to be accessible remotely for all students.

Fig. 3. Illustration of the guideline for the design of remote practical work

3.2 Advantages and disadvantages of using remote labs

The use of remote labs offers many advantages for students. By using the collaborative platform MS Teams, the students were able to organize the teamwork flexibly. Likewise, they were able to design the development of the applications for the Pepper robot independently of the opening hours of the university's laboratories. Through the use of freely accessible software, the students were able to work independently in terms of time and space.

However, several disadvantages of the concept were also experienced during the semester. In the research phase, the conduct of interviews or focus groups was limited. For example, for the scenarios train station or entrance hall university, it would have been desirable to conduct spontaneous interviews in the respective physical environment. Unfortunately, this was not possible due to the Covid-19 restrictions. In the development phase, the development of applications was limited due to the Pepper Android emulator. The emulator allows the development of dialogues and applications for the included tablet. But the robot's movements cannot be manipulated. In the evaluation phase, no real interactions with the Pepper robot could be tested. Although the emulator allows the development of new applications, the testing of these is limited. For example, requests can only be entered via text and aspects such as speech understanding cannot be captured remotely. To mitigate these disadvantages, test dates have been provided. The lecturers of the module implemented the developed code in the lab on the Pepper robot and the students were given the opportunity to experience their application via video call on the real robot.

3.3 Effects on the learning process

Problem based learning allows to compensate different previous knowledge between students and especially deficits within groups [12] [13]. The combination of problem-based learning with a remote way of working thus has many advantages for the individualization of learning processes. The design of remote labs allows students to organize the completion of projects according to individual preferences. In addition to the time allocation, the working environment in particular can be freely chosen.

The evaluation of the course showed that the students found the task interesting, practice-oriented and useful. In particular, it was positively noted that the application scenario of the Pepper robot could be freely selected and thus individual interests were taken into account. However, some of the students found the high degree of freedom in designing the application to be problematic and would have liked clearer guidelines for fulfilling the task.

Students were required to set up the programming environment on their own laptops. This allowed the students to invest more or less time in the implementation of the project work according to their respective level of knowledge without being bound by external capacities such as lab time. Some students had hardware problems, which is why alternative solutions had to be provided during the semester in the form of remote access to laboratory computers. The limited resources for remote access made it more challenging for some groups to complete the task. In future, the technical requirements should therefore be checked at the beginning of the semester in order to avoid delays and capacity bottlenecks.

The support from the lecturing team was provided flexibly. Students were able to ask for support throughout the project via the collaboration platform. Compared to face-to-face tutorials, this support was significantly more time-consuming. Problems were not only solved by the lecturing team, but students were able to support each other via the platform. The platform thus also encouraged peer learning.

However, the negative sides of the constraints imposed by the Covid-19 pandemic were also evident in relation to the learning process. Students were able to work remotely, but the living situation of many students does not provide the optimal working environment. Therefore, many students would prefer to work on projects on-site at the university premises. For the future, the use of hybrid concepts is recommended. The advantages of remote concepts, in particular the use of the emulator and the collaboration plattform, can be used and supplemented by suitable presence components.

4 SUMMARY

The presented concept demonstrates the chances to realize a successful remote learning process also for practical skills. Besides the selection of a valid problem based learning challenge, the selection of a suitable methodological framework and a suitable working environment is crucial. In post-pandemic times, remote elements should definitely continue to be used, as they can favourably influence the learning process. However, it can be assumed that the learning success of the students is positively influenced by face-to-face meetings through the direct interaction with peers and the efficient, parallel support in case of problems by the lecturers. Further analyses of students' learning conditions are necessary here.

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The Use of Metacognition to Develop Self-Regulated Learning Skills in Students of a Computer Programming Course

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Keywords: Self-Regulated Learning, Metacognition, Mentoring, Programming

ABSTRACT

In 2013, the Twente Educational Model (TOM) was introduced in the Bachelor programme of the University of Twente, aiming at increasing the motivation and improving the learning results of the students. TOM prescribed that the programmes should have 'integrated thematic modules' of 15EC. In one of these modules, software design and programming are offered to first-year 'Computer Science' (CS) and 'Business Information Technology' (BIT) students. Since most CS students had prior knowledge and experience in programming and/or were more intrinsically motivated to learn programming than BIT students, the BIT students performed generally much poorer than CS students. This paper discusses our efforts to improve the performance of BIT students by helping them become independent learners. To achieve this, we conceived a new pedagogical design to induce metacognition cycles integrated with a mentoring scheme. To help students self-assess themselves and provide structure to the mentoring scheme, we offered the students a study plan, which is a structured view of the syllabus. We broke the learning objectives down into smaller topics, which are units to be learned in one day, and we assigned three student-friendly rubrics to each topic (entry, intermediate, and target) allowing the students to grade their own proficiency level. Every two weeks, students had to self-assess their proficiency in the topics and discuss it with their assigned mentor. This paper shows that these actions have created an awareness of the learning process and consequently improved the students' motivation and end results.

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1 INTRODUCTION

In 2013, the Twente Educational Model (TOM) was introduced in the Bachelor programme of the University of Twente, aiming at increasing the motivation and improving the learning results of the students. In TOM, the curriculum of each programme is composed of so called *integrated thematic modules* of 15EC each, where some of these modules are shared amongst programmes for the sake of efficiency. One of these modules is the first year introduction to software design and implementation (programming), which was until recently shared between the Computer Science (CS) and Business Information Technology (BIT) students.

In this module, we noticed that the students with prior programming knowledge and skills in general performed better in the programming parts of the module than students without this prior knowledge, since the programming learning objectives of the module were quite ambitious. Initially, this difference in programming knowledge and skills was due to the lack of a standardised Computer Science / Information technology high school curriculum in the country of this university, so the programming literacy of the students was determined by how each school approached the subject and/or the hobbies pursued by these students. After 2016, the CS and BIT programmes started to also accept international students, so this difference in knowledge and skills became even more stringent.

Although the differentiating factor was their knowledge and skills, we noticed that BIT students in general performed much worse than CS students in the programming activities in terms of the passing rate (38% passed, compared to 55% of the CS students, in the 2019-2020 academic year). This can be justified by the lower intrinsic motivation of the BIT students, since if they were more motivated to study programming they would have selected the CS programme. This means that in order to solve this problem we need to do something about their motivation, by making programming more appealing and interesting for them. Due to a huge increase in the students inflow, in 2020 the module has been split into two, a BIT and a CS version, and we got an excellent opportunity to apply novel education approaches to solve this problem.

This paper discusses our efforts to improve the performance of the BIT in the programming activities of their introductory module in software design and programming. We achieved this by introducing a new pedagogical design to induce Metacognition cycles integrated with a mentoring scheme. In this effort, we aimed at improving the learning process without decreasing the ambition of the programming learning goals, by aiming at increasing retention and consequently obtaining a higher passing rate.

This paper is structured as follows: Section 2 introduces the methodology used in our work. Section 3 discusses the theoretical constructs that informed the design decisions taken on the intervention. Section 4 presents details of the intervention and their relation with the theoretical constructs of our theoretical framework. The intervention took place in the 2nd quarter of the academic year 2020-2021 and the results are discussed in the Section 5. Finally, Section 6 gives our conclusions and recommendations for future work.

2 METHODOLOGY

This article is part of a long-term Action Research (AR) project that aims to improve the performance of students of the 'Bachelors Information Technology' (B-BIT) Programme in the various courses of computer programming offered in the programme. In the AR project we define the community that will benefit from this research (students, faculty, and other roles related to the BIT Programme), their goals to be pursued following the needs and desires of this community and, in a practical way, we provide a longitudinal view of the results of this research. We follow the guidelines and procedure to perform the AR cycles according to [1] and [2].

In this project, we perform interventions either on the Pedagogical Design or on the Technological Support offered. We act like the 'designers' defined in [3]: *anyone who devises courses of action aimed at changing existing situations into preferred ones* (p.55). We design these interventions to last three months (a quarter), which is the duration of each course provided during an academic year. Therefore, these interventions contribute to a cross-sectional view of this research at a certain point in time. Because the interventions are based on artifacts (new pedagogical processes or new software), the ways we typically act to *change existing situations into preferred ones*, Design-Science Research (DSR) was chosen as a suitable method for the cross-sectional investigations of this research project, while the AR deals with the long-term goals of the community and the analysis of longitudinal data.

The cross-sectional investigation reported in this article is related to the Module Software Development (2nd quarter, 1st year, B-BIT). As observed in [4], DSR goes beyond merely designing and testing particular interventions. *The interventions must embody specific theoretical claims about the teaching and learning*. More than testing the artifact, the analysis of the intervention must feedback the theoretical body that informed the design of the intervention in the first place [5]. Was the artifact correctly designed, i.e. does it embody the theoretical claims it supports investigating? What are the updates, additions, corroborations, and revisions, that the analysis of the intervention done with the said artifact offers to the theoretical body that informed it beforehand?

The research problem (RP) indicated by the community to which this Action Research project was designed is (RP1) *the low performance of BIT students in the various programming courses offered in the Programme*. While we expect to make several interventions in the next years aiming at improving the performance of our students, we chose to start by addressing this research problem by helping students becoming more 'independent-learners'. From the faculty point of view, we expect students to progressively learn more topics on their own.

In order to solve the research problem, we aimed at answering two research questions that help us better understand the problem and how to address it: (RQ1) *How do students use and perceive the periodical review of their proficiency in the topics taught in the course?* This question aims at understanding whether the approach is well-received by students and also investigate any possible phenomenon related to it, like *do students correctly self-assess their level of proficiency? Do they overestimate or underestimate their levels of proficiency? How does it compare to the grades they obtained?* (RQ2) *How did students perform this year in comparison with previous editions?* The analysis of the intervention counts on data collected from the course itself, like test and project grades, reports and essays submitted by students, submissions of weekly exercises together with the feedback and correction. We also consider qualitative data gathered from participants like interviews and surveys done with students, mentors and teachers.

3 THEORETICAL FOUNDATION

Learning computer programming is complex and has been approached in several ways by researchers in computer programming education. In particular Cognitive Load Theory (CLT) has been used to improve the design of instructional material [6][7][8], especially for introductory courses [9][10][11], while Self-Regulated Learning (SRL) and Metacognition theories have approached the monitoring of the learning process as a way to support it [12][13][14]. Cognitive Load Theory (CLT) explains that problem solving tasks (like computer programming) have a way higher cognitive load [15], and learning them depends on previous experience and how developed are their metacognition skills, which are necessary to regulate learning processes that are often lengthy and complex. [16][17].

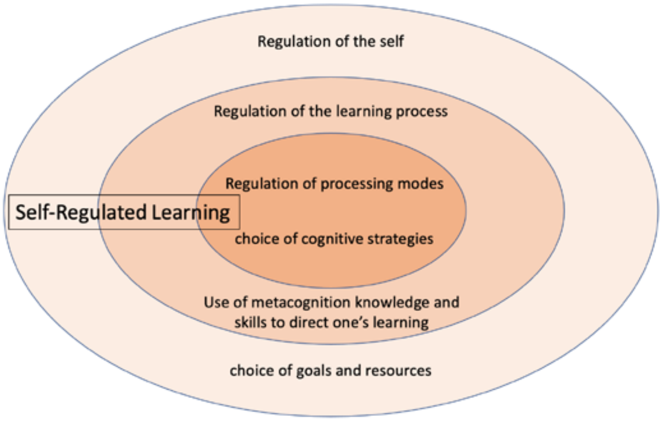

Figure 1: The three-layered model of Self-Regulated Learning (adapted from [18]).

Figure 1 shows the SRL model of Boekaerts [18], which organizes the 'Regulation of the Learning Process' as an intermediary layer. Metacognition has been used to help regulate the learning process, while also offering benefits to the innermost layer by supporting cognitive strategies [16].

3.1 SRL and Metacognition

Research on SRL and Metacognition has provided evidence that monitoring the cognitive process, which happens in the metacognition cycles, positively affects cognitive processes [13] [19]. The same effect is sought with the improvement of instructional material following advice from CLT. However, while CLT aims at reducing the cognitive load or making it easier to manage, Metacognition focuses on paving the road to learn and monitoring the learning progress. In that sense, it is worth highlight the work of Glogger-Frey *et al.* [20], in which they present findings that the self-regulated group presented better results than the group that received direct instruction - after some practice - although the guidance provided to the instructed group led to lower extraneous load. This is often sought in CLT research as a way to improve the quality of the instructional design. The Metacognition approach requires that the students have enough practice time for their results to surpass those that received a well-designed direct instruction. Well-designed instructions bring faster results and tangible benefits, like the reduction of the extraneous load. The downside of only offering well-designed instructions in the computer science field is that this field requires professionals to learn and adapt quickly to new technologies. Well-designed instructions are often not present to support this need for constant learning and adaptation. However, as pointed out by Kunh and Dean [21], *Metacognition is what enables a student who has been taught a particular strategy in a particular problem context to retrieve and deploy that strategy in a similar but new context*. The schema transfer-ability benefits of Metacognition makes it suitable for equipping the students to learn not only the topic at hand but also to improve their performance in future studying endeavors.

Havenga *et al.* [13] argue that a possible reason for the lower performance of students in computer programming may be that 'students mainly focus on the *product* of programming, namely on computer programs, rather than on the *process* of programming' (p.3). Using Metacognition to improve programming learning seems to be convenient because programming consists of formalizing the process used to solve a problem [19](p.2) [12][14].

3.2 Metacognition Cycles

The model proposed by Flavell in [22] is described as an interplay among our metacognitive knowledge, metacognitive experiences, goals or tasks, and actions or strategies. The metacognitive knowledge can relate to three domains: Person, Task, and Strategy. Knowledge on the Person domain refers to knowing the one's weaknesses and strengths (knowledge about the self or the other), while the knowledge on the Task is regarded to the characteristics of the learning effort (topics that are easier, topics that requires practice, etc.), and the knowledge about the Strategy relates to how to tackle a certain learning endeavor. One example of the three variables at interplay can be illustrated as "*you believe that you (unlike your brother) should use strategy A (rather than strategy B) in task X (as contrasted with task Y)*" [22](p.6)

4 INTERVENTION

To tackle the low-performance problem of the B-BIT students, we decided to invest in pedagogical designs that emancipate students, helping them be more independent learners, hence the choice for SRL and Metacognition. To support the development of SRL skills in our students, we planned a structured intervention with the following points:

a. Support students' reflection with a structured syllabus (*Personal Learning Records*).

b. Create a mentoring system to support students to reflect/prospect.

c. Create checkpoint meetings one-on-one (mentor/mentee) based on the self-assessment.

The three aforementioned measures are tightly connected to the establishment of a 'culture of reflection.' While students receive the task to self-assess their knowledge every other week (item a), this self-assessment serves as a conversation starter for the bi-weekly meeting among mentors and mentees (item c), also mandatory. The goal of the mentor in the checkpoint meeting is to *support the mentee's reflection and offer extra material and guidance to prospect a new week of studies* (item b), mainly when the target level of proficiency is not achieved in the current week. It is crucial here that the mentors are experienced Teaching Assistants (TAs), not teachers. We chose to have TAs as mentors for two reasons, namely the shorter *social distance* of students and TAs and to foster community building. First, TAs are more experienced students and, therefore, they understand the needs of 1st-year students, which makes them suitable to help teachers understand and adapt to students' needs. Second, our mentoring system states that a 2nd-year student acts as a Jr. Mentor paired with a 3rd-year student, who acts as a Head Mentor. This helps us foster community building and last-longing commitment with the learning of programming. We select TAs that are both technically skilled and willing to share their expertise with the mentees. However, although they are keen on the activity, they need guidance to mentor. So, the Personal Learning Records offer the basis for starting the conversation with the mentees and focusing on each week's learning goals. This intervention resulted in a new flow for the course, as illustrated in Fig. 2.

Every week, the students have a list of challenges based on the topics taught in the lectures of the current week. These are also the same topics for the self-assessment of the week. The students must submit their exercises to an online grading system, that we configured with special scripts for applying automated tests and automatic grading based on the tests (included, but not limited, to Unit Tests [1]). Once a student has submitted the exercises, the mentors can give inline feedback on any part of the submitted code. The goal is to give support in case the code fails to achieve the threshold of points to get signed-off. The weekly exercises must be submitted by the student and signed-off by the mentor up to the Monday

[1] Unit Testing is a software testing technique in which individual units of code are tested to assess if they fit the specification [23]. In Object-Oriented Programming languages, like Java, this unit of code is a class.

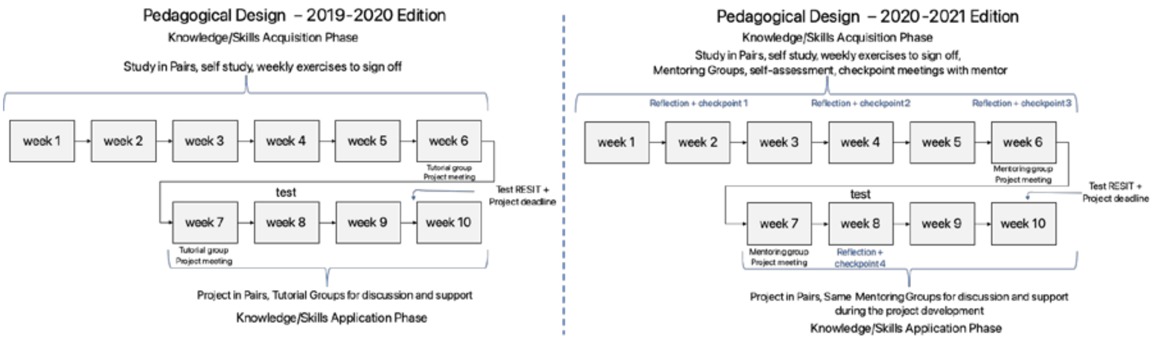

Figure 2: The new course flow featuring the bi-weekly checkpoint meetings.

of the following week.

Because the mentors sign-off the exercises, they have a good opportunity to check if the self-assessments done by their mentees are accurate. They are asked to provide the same assessment to each of their mentees, so that the teacher can see the discrepancy between the self-attributed level of proficiency and that attributed by the mentor.

4.1 The Personal Learning Records

The structured self-assessment is done with the support of the Personal Learning Records: an intricate combination of online connected Google Spreadsheets that are shared among the students (≈130 students), mentors (13) and teachers (3). The dashboard with the self-assessment and mentor-assessment is illustrated in Fig. 3. The green color indicates that the student self-assessed her proficiency that level. The yellow bar (right below) represents the mentor's assessment of their mentee's proficiency based on the weekly challenges they signed off. The structured syllabus is composed of Learning Objectives that can be learned in approximately one day of study. Each week has approximately 5-6 topics to be learned.
This dashboard view of Fig. 3 is visible only to the teachers, who can select other mentors/mentees on the top of the spreadsheet. Mentors have a similar spreadsheet that lists only their mentees, while mentees can only see their own data. In addition, teachers have access to some aggregated data, like a chart showing the proportion of students that self-assessed their proficiency in each topic. This chart makes it visible to the teacher the topics that students had difficulty to learn, allowing for some supportive actions (like Q&A sessions) during the course.

5 RESULTS

We used an ethnographic approach for collecting the data to investigate the research questions presented in Section 2. We observed and collected spontaneous comments and reactions of students and mentors during the course, analyzed reports, essays, and grades. Our first goal is to understand how students perceive the proposed self-assessment model (RQ1). This understanding is critical to avoid a misperception between those proposing the model (teachers) and those playing the roles in the model (students and mentor)[2]. Additionally, we monitor the effects of the interventions with performance indicators that the community considers necessary, as the pass rate in the current and future programming courses and the quality of the projects delivered by the students (RQ2).

The pass rate radically changed from last year to the current. While in 2019-2020 academic

[2]An adaptation of Michel de Certeau in 'The Practice of Everyday Life' [24] to our context: *what a teacher considers as a support activity may be perceived simply as extra work by the students.*

Personal Learning Records		Mentor	Student	Checkpoint
				Checkpoint 4
LO Code	**Learning Objective**	**Entry**	**Intermediate**	**Target**
P0001	Java Programming Fundamentals	I can describe what is a program and I can state the difference between a process (program) and a thread. I can explain what is the Java Virtual Machine and how it works.	I can develop small programs in Java, even though I may eventually make syntax mistakes.	I can examine a given piece of Java code, break it down into smaller parts and make inferences about the way it works.
P0101	Java Syntax Fundamentals	I am able to list the main syntax' rules. Given a piece of code, I can identify: blocks of code, classes, functions/methods, variable declaration, constants.	I can examine a given code and solve simple syntax errors, like: punctuation, case-sensitiveness related issues, correct opening and closing of curly brackets ({}), etc..	I can develop small programs using correct Java Syntax if I have at least the support of an IDE like Eclipse.
P0102	Variables and Constants in Java	I can explain how to declare and use variables and constants of primitive types in Java (int, double, char, String boolean).	I can explain the specificities of the String type, I know how to properly compare the value of 2 String vars. I can explain and apply the concepts of autoboxing and unboxing.	I can create non-primitive types in Java, i.e., I can develop a class with multiple properties (inner variables).
P0103	Conditionals	I can explain what are and how to use the different conditional structures (IF and Switch) in at least one programming language.	I can explain what is the logic used to build the conditional structure of a given piece of code and differentiate lazy and eager evaluations.	I can develop small pieces of code using conditional structures (IF and Switch) of Java language.
P0104	Blocks and Subroutines	I can explain what is a block of code and I can recognize the different blocks and their hierarchies in a given piece of code.	I can indicate whether or not to create a new subroutine or arrange/re-arrange (refactoring) a code into smaller subroutines using Java language.	I develop subroutines fluently, creating methods for my classes that maximize the reuse of code and improve their maintainability.
P0105	Repetition Structures (loops)	I can explain what are the main repetition structures of Java language (while loop, do-while loop, for-loop) and the syntax of each one.	I can develop small pieces of code in Java (like finding a value in a list), and I can identify which repetition structures best suits the problem at hand.	I can develop more sophisticated loops, like iterating over a collection of objects using optimised for-loop, combine Loops and Generics, etc.
P0106	Exception Handling Fundamentals	I can explain what are Java Exceptions and explain the syntax of a try..catch block on a Java code.	-- intentionally empty --	I can develop Java code to handle Exceptions using try-catch blocks.

Figure 3: Dashboard with learning objectives and friendly rubrics for each level.

year we had a pass rate for the BIT group of 38% (compared to 55% of CS students in the same year), in the 2020-2021 academic year the pass rate of the BIT group almost doubled and reached 68%. We didn't focus exclusively on the pass rate, but on a combination of key performance indicators that include also the quality of their projects and their performance in future programming courses, to understand the long-term effects of developing their Metacognition skills. Therefore, a complete view of their performance must be taken from a longitudinal analysis on the results of the upcoming years. The current result, however, motivates us to continue improving the approach of using Metacognition with mentoring in our courses.

Regarding, student's perceptions, most students were very enthusiastic about the approach. We ran a survey at the end of the course and we had 42 (out of 90) respondents. We asked whether we should keep or remove the self-assessment routine for the next years and 93% (n=42) stated that we should keep it. They perceived the activity as supportive because they were receiving weekly feedback on their assignments and advice on how to improve their proficiency in various topics, for example, to prepare for the exams. We believe the association of the mentoring system with the self-assessment may have had a positive influence in attitude of the students towards the checkpoint meetings, since according to the rules, they could only schedule a checkpoint meeting after updating their Personal Learning Records for the week. Figure 4 illustrates their evaluation of the self-assessment routine.
They recognized the benefits of structuring their reflection in topics and of their checkpoint meetings with the mentor. The following comments from students, answered in the open questions of the survey, illustrate this perception.

> *I think it is good because it gives structure. You know when you will work on what. It is also easy to discuss with your mentor what you find difficult and what you don't. Then the mentor can also easily share his thoughts about your progress. Without the learning journey I don't think the mentor meeting would go as well. This introduces talking topics.* [Student #28]

> *I liked that it gave me a clear overview of all the topics and the different levels I could study it.*

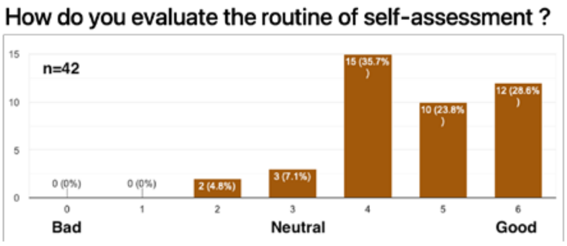

Figure 4: Students had a positive reaction to the self-assessment routine.

> *It calmed me down to realize that with trying hard for the weekly assignments, I was already on a pretty good level for the test. I definitely advise you to keep it!*. [Student #17]

However, not all students saw it the same way. The most disciplined ones and the ones with best performance may have seen this as unnecessary, at least partially. The following comments were provided by students with a high-performance (belonging to the top 5 grades):

> *For people who have self-discipline I think it does not make a big difference. But for people who need extra motivation I think it is a good idea* [Student #02]

> *I didn't find much use for it as most of the topics were already rather familiar to me and it didn't seem worth it to track of what I already knew.* [Student #04]

> (...) *the truth for Academic Skills part? 'Cause the only think I used the PLR for is getting topics for the exam preparation.* [Student #03]

The approach of using structured self-assessment combined with mentoring was indeed designed to support the development of Metacognition skills, mainly in the students with low performance. While we had a partial attendance to the survey, it's quite illustrative that only the students with high performance said the routine didn't seem necessary to them. These are students that did not need much support from mentors and, because of that, some of them skipped the self-assessment and the checkpoint meetings. This may have contributed to their perception of the self-assessment not being useful. Even for these students, the structured syllabus used in the self-assessment helped them organize their studies for the exams. Their reflections bring us the challenge of reviewing the approach to keep these students as engaged as the others, to further develop their Metacognition skills.

6 FINAL REMARKS

In this paper, we presented our approach to support the development of Metacognition skills in students who presented a lower performance in previous years, namely the students of the B-BIT Programme. We analyzed the students' perception of the approach and the pass rate as a first step to assess the effects of our intervention. Students were very optimistic about the approach and the course received the highest grade (since the beginning of the yearly inquiry) in the anonymous course evaluation form, which is ran by the quality assurance team of our university. The pass rate increased dramatically and now is similar to those of the CS students. The enthusiastic feedback sent by the students, both on our surveys and the independent one, and the improved pass rate have motivated us to continue developing the approach.

Regarding our RQ1, we still have no conclusive data regarding the questions *Do students correctly self-assess their level of proficiency? Do they overestimate or underestimate their levels of proficiency? How does it compare to the grades they obtained?*. We did ask them to predict their performance, but we used a qualitative scale and realized later that the multicultural environment brings different meanings of what defines good grades. Given that the course is challenging, for most students a 5.5 grade is a good grade (it is the minimum required to pass the course). However, for other students, the goal is to achieve the maximum grade. We will solve this in future editions of the course.

Our approach is not specifically designed for teaching computer programming. However, this course is by far the most challenging in which we used this approach and we believe it provided a unique point of view for the effects of a structured reflection. We repeatedly see the different points-of-view students have about the approach, namely the top-performers versus the low-performers. For the latter, this approach helps structure the studies and focus the attention, while the former tends to perceive it as tedious extra work.

Currently, we are collecting data on their Metacognition skills (and the pass rate) in the most advanced programming courses. The goal is to understand the long-term effects of developing their Metacognition skills on their learning performance. Our future work, includes fine-tuning the approach by adding better software support and more frequent self-assessment. Because of the lack of a proper automated system to support the self-assessment, we could only collect and aggregate data every two weeks. To address this, the Personal Learning Records system is currently being developed as a mobile application to be used in the next edition of the course, aiming at allowing students to self-assess at any time.

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DEFINING INTENDED LEARNING OUTCOMES (ILO'S) OF INTER-PROGRAM CBL TOWARDS ACHIEVING CONSTRUCTIVE ALIGNMENT IN THE CONTEXT OF ISBEP

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ABSTRACT

We present a framework that connects identified competence areas with Indented Learning Outcomes (ILO's). Such a framework is likely to be useful for the design of inter-program Challenge-Based Learning (CBL) in engineering education. The framework was developed out of a need to increase the constructive alignment (CA) of ILO's, learning/teaching activities, and assessment of the Innovation Space Bachelor End Project (ISBEP); an inter-program CBL initiative at Eindhoven University of Technology (TU/e). The framework was developed based on a co-creation session, and set up around the definition of ILO's as departing point to reach CA. We contribute a comprehensive framework listing the ILO's associated with inter-program CBL at the third-year, bachelor level, and identify three categories related to design and research processes, professional skills, and professional identity and self-directed learning. Furthermore, we illustrate our findings with practices from ISBEP, highlighting the influence of ILO's on our efforts to reach alignment. Finally, we discuss the implications for CBL design, propose future work, and draw attention to possible limitations in the use of the framework.

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1 INTRODUCTION

Kim is a third-year biomedical engineering student at Eindhoven University of Technology (TU/e). Kim is about to graduate, and to do so has joined the innovation Space Bachelor End Project (ISBEP). ISBEP an alternative for students who wish to graduate in an interdisciplinary team. Kim's team is composed of a biomedical engineer, a mechanical engineer, and an industrial designer. For the last five months, Kim and her team have worked on an open-ended challenge brought in by a local hospital (the challenge owner). Throughout the project, Kim's team has interacted with ISBEP coaches, who overlooked the interdisciplinary aspects of the project; academic coaches, who oversaw the disciplinary development of students; and the challenge owner, who provided valuable input, and resources for the project.

Kim's project is coming to an end. The team is proud of their results. For Kim, ISBEP has been a formative experience. Through the interdisciplinary project, Kim has developed her professional skills, such as the ability to communicate with other disciplines. The project has allowed Kim to dive into topics of relevance to her discipline. Kim feels confident about her performance and professional growth.

Unfortunately, Kim's assessment does not develop in the way she expects. Kim is assessed following the criteria and procedures of a traditional (individual, non-challenge based) final bachelor project. Members of the examination committee do not fully understand the breath of Kim's learning. Her academic coach intervenes and provides some context for the assessment. After long deliberations, and providing further evidence, Kim's project is approved. Kim's graduation is bitter-sweet. Kim believes her assessment should better reflect the learning outcomes of her project.

1.1 CBL at TU/e, the context of ISBEP

The above illustrates the experience of a graduating student from ISBEP. ISBEP is a Challenge-Based Learning (CBL) initiative, set up and coordinated by TU/e innovation Space. CBL is currently a central topic at TU/e, which sees this approach as effective in developing student's broader skills and content knowledge [2]. ISBEP is characterized by interdisciplinary teamwork and the collaboration with multiple stakeholders, such as challenge owners, ISBEP coaches and academic coaches. Furthermore, ISBEP students work on open-ended challenges, brought in by real-word parties, such as companies and research groups. These, and other characteristics have been deemed descriptive of Challenge-Based education, by among others, [3]–[6]. ISBEP is high stakes because students' performance during the project determines the completion of their bachelor program.

1.2 Challenge of ISBEP as inter-program

A key characteristic of ISBEP is that it is *inter-program*. We define inter-program CBL as education where two or more educational programs (i.e., with distinct learning goals, criteria, and regulations for assessment) collaborate/interact to setup CBL experiences. This characteristic is well reflected in Kim's experience with ISBEP. The varying regulations on assessment from the different involved programs created *unclarity about the assessment procedures and criteria*. This and other challenges associated with inter-program CBL have been previously reported [7]. Among others, the *discrepancy between perceived learning outcomes and assessment criteria,* is highlighted as an important challenge of inter-program CBL. The large number of stakeholders (e.g., students, program directors, academic coaches, ISBEP coaches) plays a key role in the effective design/implementation of *constructively aligned* inter-program CBL. Achieving alignment across the instruction [8], the authors conclude, is key in achieving effective student-centred education.

This paper follows up on [7] and elaborates on the efforts followed to increase the constructive alignment of Intended Learning Outcomes (ILO's), assessment, and learning/teaching activities of ISBEP. The efforts are part of a longitudinal research project, whose aim is to arrive at assessment practices (formative and summative) that align well with inter-program CBL. Particularly, the paper presents a framework for inter-program CBL design in engineering education, using ISBEP as a case. The framework focuses on ILO’s as a departing point for design, contributing a comprehensive list of ILO’s at the third-year (engineering) bachelor level.

The remaining of this paper is structured as follows. First, we provide the theoretical framework guiding our research efforts. Subsequently, we elaborate on our methods and we present the framework (i.e., results). We conclude with a discussion on the framework, implications for practice and future work.

2 THEORETICAL FRAMEWORK

2.1 Constructive Alignment

Constructive Alignment (CA; [1]) is a well stablished student-centered approach to educational design. The approach is outcomes-based, which means that the definition of ILO’s precedes the design of learning/teaching activities and assessment practices in a course or curriculum innovation. A guiding principle of CA is that ILO’s drive the actions (i.e., learning/teaching activities) that are expected to construct knowledge for students. Assessment is a tool aligned to ILO’s, which help judge whether the intended learning has been achieved. Similar frameworks that highlight the importance of ILO’s as departing point to educational design are the Integrated Design Approach [9], and the Curriculum Spider Web [10]. CA has been previously used in the context of higher engineering education, among others by [11].

2.2 Defining ILO’s as basis for educational design

ILO’s can be defined at the institutional (e.g., across programs), program (e.g., a student’s trajectory within a domain) or course level (e.g., a module or project) [1]. A main attribute of ILO’s is that they allow students to understand what is expected of them, as and how to demonstrate their learning [12]. In competency-based education (such as that at TU/e), ILO’s are linked to competency areas, such as “scientific discipline”, “scientific approach” or “communication”, and encompass the knowledge, skills and attitudes students are expected to develop [13]. The Academic Competences and Quality assurance (ACQA) framework, for example, presents a comprehensive list of competencies and associated ILO’s [14].

ILO's indicate how the content/topic of learning is to be addressed, and its context. In defining ILO's, Biggs & Tang [1] advise distinguishing between declarative knowledge (e.g., disciplines-specific topic) and functioning knowledge (i.e., applied knowledge). ILO's are written in terms of verbs, which express what students can do with the content/topic of learning, and at what level. For example, "identify", "analyze", "reflect", all denote different levels with varying complexities. Hence, it is advised to establish the intended level of understanding/performance expected from students. For instance, the performance expected at the first-year bachelor program versus the master level differs significantly. Existing models used to denote such levels include Bloom's taxonomy (see e.g., [15]), and the SOLO taxonomy [16].

Following the definition of ILO's, teaching/learning activities and assessment are defined. In CA, "knowledge is constructed through the activities of the learner" ([8], pg. 9). For example, through coaching sessions (i.e., teaching/learning activities), students engage with the verb "reflect". Coaching sessions act as a catalyst for learning; students are stimulated to think of their (learning) goals, current performance, effectiveness of their strategies, and to set new goals/strategies [17]. Assessment practices are expected to align with ILO's and learning activities when they inform students about the intended learning and how to attain it [1]. The literature on assessment is wide and presenting an overview of it is outside the scope of this paper. Important to highlight are the two commonly acknowledged types of assessment [18]: *Formative* (i.e., assessment for leaning, such as feedback) and *Summative* (i.e., assessment of learning, such as checking that students have met certain criteria). Under the CA framework, concepts such as *fit-for-purpose* assessment (see programmatic assessment, [19]) gain relevance. Here, the idea is to select assessment in relation to the purpose of the learning activity (i.e., ILO's). ILO's, learning/teaching activities and assessment are aligned to maximize learning.

2.3 ILO's in CBL

CBL is attributed to the development of both disciplinary knowledge and professional skills [6]. In relation to broad professional skills, reported outcomes include communication, collaboration, organization, stimulated by the work on real-life cases (and scenarios), and the interaction with multiple stakeholders [4], [6], [20]. Furthermore, by engaging in CBL, students learn to 'identify, formulate and manage complex problems in a creative and critical manner' [6]. CBL is said to promote self-directed learning and to help students embrace uncertainty [20]. Similarly, in a study exploring the perceived learning gains of engineering students, van Uum & Pepin [21] report five strands of learning associated to CBL: *Disciplinary conceptual and procedural knowledge* (i.e., subject matter knowledge), *General cognitive learning* (e.g., forming ideas & setting goals; designing, implementing & operating); *Affect, thought, and learning* (e.g., taking initiative, motivation, lifelong learning; taking into account the societal context); *Entrepreneurial learning* (i.e., communication & collaboration with stakeholders); and *Teamwork and communication*.

While the above information provides insights into the intended learning associated with CBL, the learning goals for CBL and similar educational environments (i.e., promoting the learning of 21st century skills) remain vague [22]. This need has been highlighted for similar learning environments, such as sustainable learning [23]. Information on ILO’s for CBL remain scattered, and the link between ILO’s, assessment and learning activities is rarely addressed. In this paper we contribute to this need by exploring the ILO’s for inter-program CBL, using ISBEP as a case study. As ISBEP is a third year, final bachelor project, it sheds light into the intended learning for students at the highest engineering bachelor level, in a context where the development of content knowledge and broad professional skills are both key. Furthermore, we explore ILO’s in relation to their associated learning/teaching activities, as a first step in increasing the CA within ISBEP. Our aim is to provide information relevant for the design/implementation of constructively aligned CBL.

3 METHODOLOGY

Our research interests were addressed by means of a co-creative workshop [24], to bring in the varying views of relevant stakeholders in the design and implementation of ISBEP throughout TU/e. The goal of the session was to arrive to new ILO’s for ISBEP, which serve as a basis for its constructively aligned redesign.

3.1 Participants and setup

The session lasted two hours and was set up as a combination of plenary and breakout sessions. Discussions in the plenary and breakout rooms were guided by facilitators. Three questions guided these discussions: 1) What do students learn by engaging in CBL?; 2) How do the ILO's for CBL relate to those of TU/e’s Bachelor College?, and 3) What should the Intended Learning Outcomes of ISBEP be? The questions acted as a funnel, from general to specific, starting with general learning associated to CBL, and ending with learning specific to ISBEP.

Two platforms were used during the sessions: MS Teams and Miro. MS Teams was used for audio/video communication and to video-record the sessions. Miro is an online collaboration tool that allows remote and active participation. Boards were created in Miro with the guiding questions to stimulate the discussion between participants. Outcomes of the session were captured by means of digital post-its.

To stimulate alignment across the institution [8], different stakeholders, including, students, educators, final project coordinators, program directors, policy advisors, and administration staff were invited to take part in the activity. Invitations were sent via email. An initial list of possible participants, representative of the various views/expertise within the university was made. However, the invitation was open, and invitees were encouraged to extend the invitation to other colleagues. This resulted in 28 participants (out of 61 invitees; 7 facilitators, 6 students, 5 educators, 5 educational researchers, 3 educational strategists, 2 administration officers), divided across 6 teams. Team were allocated making sure varying views were represented in each team. All participants agreed to taking part in the research voluntarily and consented to the use of the collected data for research purposes.

3.2 Data Analysis

We followed a thematic-analysis approach to data analysis [25]. First, data were processed; videos and post-its were reviewed, allowing the main researchers to familiarize with the data. When post-its where not self-explanatory, they were revised and fine-tuned based on the audio/video information. Next, data/post-its were reviewed, identifying themes descriptive of the different ideas discussed during the session. For example, post-its reading “think out of the box”, “ideating”, and “solving”, were grouped in the theme “thinking creatively”. This inductive analysis was followed for all post-its and questions, leading to the identification of a first potential list of learning areas and competencies linked to ISBEP. These results were triangulated by two separate researchers, increasing the validity and reliability of the analysis. The independent results were discussed and used for the final development of ILO’s and framework, and fine-tuned through several iterative sessions with the ISBEP team.

4 RESULTS

172 post-its were generated, of which 58, clustered in 14 themes, were associated with the question “*What should the Intended Learning Outcomes of ISBEP be?* (See Appendix A; basis for results). Table 4.1 depicts the framework of ILO’s for ISBEP (i.e., inter-program CBL, third-year bachelor level). The framework lists 10 ILO’s (i.e., knowledge, skills, and attitudes), related to 3 areas of learning (i.e., design and research process, professional skills, and professional identity); and 7 competence areas. Furthermore, we provide examples of learning/teaching activities from practice within ISBEP, to illustrate the first steps increasing CA based on defined ILO’s.

ILO1 relates to the competency “defining problems” within the complexity of the open challenge. In ISBEP, students navigate the challenge during the first weeks of the project. Students *identify* the interdisciplinary problem to be addressed, as well as their individual contributions (i.e., disciplinary components). Exploratory sessions with different stakeholders (e.g., challenge owners) support this ILO. Information gathered in this activity serves as input to write down an interdisciplinary problem statement.

ILO2 relates to the competency “need finding”. Students *identify* the varying needs of stakeholders (e.g., challenge owners, academic coaches), and *integrate* them in a viable solution. A learning activity supporting the development of this competency are the several alignment meetings with stakeholders. This activity stimulates students to think in terms of project goals, ask questions in relation to their development (individual/interdisciplinary project), allowing them to fine-tune the problem statement/scope (as the project matures).

ILO3 and ILO4 relate to the competency “systems thinking”. While ILO3 focuses on *identifying, assessing* relevant theories from their own (i.e. individual) disciplines, ILO4 focuses on *applying* those knowledge in the project, and *integrating* them into a viable (interdisciplinary) solution. “Systems thinking” thus relates to the interconnectedness of disciplinary contributions and identifying the boundaries of the project. In terms of learning activities, discussions with experts, and workshops on system mapping, provide students with the necessary tools to attain these goals.

Table 1. Framework of ILO's for ISBEP and Associated Learning Activities

Area of learning	Competence Area	Intended Learning Outcomes (ILO's) for ISBEP	Associated Learning Activities
Design & Research Process	**Defining problems**	**1.** *Identify* the interdisciplinary problem that needs to be solved, and the disciplinary components.	• Exploratory sessions with stakeholders (e.g., challenge owners, academic coaches). • Alignment meetings with stakeholders throughout the project. • Problem analysis and statement in group discussion supported by coaching.
	Need finding	**2.** *Identify* the needs of different stakeholders, and *integrate* them in the viable solution.	• Exploratory sessions with stakeholders (e.g., challenge owners, academic coaches). • Alignment meetings with stakeholders throughout the project. • Workshop on mapping tools/models (i.e., map of stakeholders; systems mapping).
	Systems thinking	**3.** *Identify* relevant theories from their own discipline, assess their relevance.	• Sessions with academic coaches on disciplinary aspects of the project. • Collaborative discussion groups (students from same discipline). • Discussion with (disciplinary) experts on topics relevant to the projects.
		4. *Apply* the knowledge from different disciplines in a project & *integrating* them into a viable solution.	• Workshop on mapping tools/models (i.e., map of stakeholders; systems mapping). • Alignment meetings with stakeholders throughout the project.
	Prototyping	**5.** *Integrating* the individual components (i.e., individual contributions) into a working/experiential prototype.	• Peer-to-peer feedback sessions on how to prototype solutions. • Workshop on prototyping. • Mid-term project market. • Final presentations.
Professional Skills	**Interdisciplinary Collaboration**	**6.** Be able to *identify* the roles & contributions within a team.	• "Roles & goals" session. • Coaching sessions. • Retrospective sessions (self-reflection, peer- feedback).
		7. *Demonstrate* the ability to communicate and collaborate with people from other disciplines while working on a real-world case.	• Pitching exercises. • Workshop on interdisciplinary communication. • Retrospective sessions (self-reflection, peer- feedback). • Alignment meetings with stakeholders throughout the project.
	Organizing & Planning	**8.** *Manage* a situation where there is no clear answer to their problem.	• Coaching sessions on process. • Alignment meetings with stakeholders throughout the project.
Professional Identity & Self-directed learning	**Reflecting on learning**	**9.** *Reflect* on the role that they have played in the interdisciplinary team, and its impact on professional identity.	• Retrospective sessions (self-reflection, peer- feedback). • Final presentations. • Writing reflection.
	Understanding the position as a type of engineer in relation to the societal context/challenge	***10.*** *Demonstrate* an awareness of what their personal contribution can be to the societal challenge.	• Writing reflection.

ILO5 relates to the competency "prototyping", where students *integrate* the individual contributions into a working/experiential prototype. For ISBEP, this is an important deliverable at project completion. A prototype can be a mock-up, video, or other media that allows stakeholders to experience the solution. Students are encouraged to present their mock-ups or ideas for prototyping during the midterm presentation and justify their decisions. This allows for formative feedback from key stakeholders and peers, to further fine-tune their plans/strategies.

ILO6 and ILO7 relate to the competence "interdisciplinary collaboration". ILO6 centers on students' capacity to *identify* the roles/contributions of members in the interdisciplinary team (i.e., professional skills, e.g., leading). A learning activity supporting this ILO is the "roles & goals" session, where students are encouraged to discuss their personal development goals. This session is guided by (ISBEP) coaches. ILO7, on the other hand, centres on students *demonstrating* the ability to communicate and collaborate with people from other disciplines. The development of this skill is supported through a workshop on interdisciplinary communication.

ILO8 addresses the competence "organizing and planning". The competence relates to students engaging in the abstract open-ended challenge (no predefined set of goals/outcomes), and students' competence in *managing* said situation. The learning activity most directly linked to this ILO are the weekly sessions with ISBEP coaches, which help students reflect and set new directions/strategies for the project.

Finally, ILO9 and ILO10 concern the competence "reflecting on learning" and "Understanding the position as a type of engineer". Particularly, students *reflect* on the role they played in the interdisciplinary team, and its impact their professional identity. Moreover, they *demonstrate* an awareness of what their personal contribution can be to the societal context/challenge. "Retrospective sessions" (i.e., where students discuss as a team what went well, what should be improved) support this learning.

5 DISCUSSION

This study investigated Intended Learning Outcomes in inter-program CBL. Overall, the ILO's show alignment with previously learning associated with CBL (e.g., [4], [6], [20]). The framework points to the development of both disciplinary knowledge and broad professional skills as key in this context. The domain of disciplinary knowledge stands out as particularly important in the third year, high stakes, bachelor level, but framed in relation to the interdisciplinarity. We choose to link this to the competency "systems thinking", as it relates not only to the identification of relevant theories from own discipline, but also to their integration in the interdisciplinary project/solution.

Competencies related to the design and research process (i.e., defining problems, need finding, systems thinking, prototyping) remain a central part of the ILO's associated with ISBEP. The development of the broad professional skills relates particularly to the process, facilitated by the openness of the challenge, the interaction with stakeholders, and the hands-on approach characteristics of CBL. In our context, these ILO's were perceived as characteristic of ISBEP, and generally lacking in the regular BEP (i.e., non-CBL alternative). Similarly, professional identity is an area not generally addressed in the regular BEP, as these projects are framed within the disciplines. When finalizing ISBEP, graduates are expected to have a better account on their identity as an engineer in relation to other engineers, as they have a better insight into their role in the challenge. This is not assessed in current practice but highlights the competences an individual has gained throughout their development in the Bachelor Program, and more explicit for this group of students.

The followed approach allowed for a rich discussion on the ILO's associated with CBL at TU/e. The workshop highlighted the varying views on learning, particularly in the inter-program CBL context. The workshop was valuable as a first step in reaching alignment across the institution [8], and highlighted the need for open and constructive communication in the design/ implementation of inter-program CBL. Our advice in designing similar initiatives is to co-define/create CBL with different stakeholders, and to involve students in this process whenever possible.

An important question is whether the defined intended learning aligns well with the expected level of students engaging in CBL. In our case, some resulting ILO's were not always aligned with the intended learning of TU/e' Bachelor College. When comparing our resulting ILO's to the ACQA framework [14], for example, working on complex, 'real-world' challenges is linked to the knowledge, skills and attitudes of students at master level. This points to the need to look at students 'intended learning through CBL at a curricular level.

An important limitation of our work is that the findings are highly linked to our institutional culture and vision on education. While the framework can serve as inspiration for discussing the intended learning of new CBL initiatives, the institution's vision on education ought to be considered. This may also be reflected in the learning activities and assessment practices chosen to support the learning of students. A second limitation is that the present paper does not reflect the depth and breadth of the process of defining ILO's; particularly in inter-program CBL. Defining ILO's is an iterative process that requires the involvement of the different programs. This process goes beyond our reported method, and requires organization of evaluative meetings with program directors, final bachelor project coordinators, among others. These efforts are directed towards evaluating the list of ILO's (i.e., clarity, validity, overlap) but also, furthering the alignment across the institution.

Finally, the current framework focuses on the definition on ILO's as starting point for educational design towards CA. The framework links learning activities from ISBEP to exemplify how this alignment can be reached. These learning activities, however, ought to be validated. Furthermore, the present framework does not cover assessment, which is a key component in reaching alignment. Our next steps thus focus on assessment. Particularly, on defining performance indicators that strengthen the link between ILO's, learning activities and assessment practices. This could, among others, result in the development of new assessment tools (e.g., rubrics) which can guide development of students. Our goal is to design a learning experience for students, such as Kim, which is perceived as valuable and coherent by students and educators alike, along the three elements of CA.

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APPENDIX A: OVERVIEW OF CODES AND GROUPS

	"What should the Intended Learning Outcomes of ISBEP be?		
Themes/grouping	**Number or associated post-its**	**Examples post-its (Repeated post-its omitted for clarity purposes)**	**Link to Intended Learning Outcomes (ILO's) ISBEP**
Analysing an open-ended challenge and defining a relevant problem & Contextualizing Problems/solutions	2	Identify problems in a context, to be able to define a complex problem.	ILO1,
Appling disciplinary knowledge to real-world challenges	6	How to do applied research, putting theory into practice, learn by doing, application of theory, working in real-life cases, challenge.	ILO 3, ILO4
Demonstrating command of disciplinary knowledge	4	Learning to perform research, able to argue at scientific level about design choices, shows a good understanding of his/her own discipline and beyond.	ILO3, ILO4
Following a Systems approach to problem analysis/solving	2	Systems approach to complex problems, students learn the whole process/start with the challenge and ends with solution.	ILO1, ILO2, ILO3, ILO4.
Integrating ideas (from different disciplines) into a solution	3	Integrate-part solutions, connecting knowledge of multiple areas, prototype the solution/know how to test the solution from different perspectives.	ILO2, ILO 5
Thinking Creatively	7	Think big, think outside the box, design/create, solve problems.	ILO1, ILO2, ILO3, ILO4, ILO5.
Working/Collaborating interdisciplinarily	7	Collaborate, multidisciplinary learning, connect to various disciplines, working together, collaborative learning, how to design in a team, develop multidisciplinary learning skills.	ILO6, ILO7.
Acquiring communication skills for the interdisciplinary project	3	Effectively communicate with people from other disciplines, experience and learn soft skills.	ILO6, ILO7.
Dealing with uncertainty & managing a project	5	Deal with uncertainty, able to steer their (learning) process under guidance, execute plans, learning how to take ownership.	ILO8.
Self-directed learning	8	Learning how to learn, learning to be in control of own learning, acquiring the skill of life-long learning, define own learning path.	ILO9, ILO10.
Reflecting	3	reflect on learning process/outcomes, processing feedback, reflect on the role of engineers in solving the problems of society.	ILO9, ILO10.
Developing professional identity	4	Finding out what you like to do, identify and follow own interests and preferences, develop your professional identity.	ILO10
Developing a solution of societal relevance	4	Contributing to society, contribute to real-world challenges.	IL010
TOTAL Post-its	58		

ENGINEERING EDUCATION RESEARCH IN THE NORDIC COUNTRIES: SCIENTOMETRIC INSIGHTS INTO PUBLICATION AND CAREER PATTERNS.

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***Conference Key Areas**: Niche & Novel*
***Keywords**: scientometrics, citation analysis, Nordic countries, engineering education research*

ABSTRACT

This study analyses 3237 publications from 76 Nordic authors and provides data on the percentage of these that are educationally focused and how this in turn impacts the authors' h-index. We also calculated how early in their career they published their first educational paper.

The results provide insights into the comparative evolution of engineering education research (EER) in these countries and identify both points in common and differences in the research publication trends in the four countries. Authors from Denmark, Sweden and Finland published more educational publications than non-educational throughout their careers. Apart from Denmark, the h-index of these Nordic researchers tended to be driven by non-EER publications. Researchers in our sample, apart from those in Norway, began publishing in engineering education (EE) early in their publishing careers.

1 INTRODUCTION

1.1 Background

Over the last decade there has been a growing interest in the evolution of engineering education research (EER) and a variety of approaches have been adopted to study this process. Froyd and Lohman [1] used criteria for defining the field of science education research [2] to point out that while engineering education has been seen as an area of interest for educators since the end of the 19th century, over the last two decades there have been significant indicators of a transition to an interdisciplinary, more scholarly field of scientific inquiry into engineering education. Borrego and Bernhard [3] have compared Northern and Central European approaches to EER with those of the U.S. using a framework from the European *didaktik* tradition, which focuses on answering the w-questions of education. Borrego and Olds [4] employed an analysis of National Science Foundation funded projects as a way of characterizing development in EER in the US while Williams and Alias [5] used a scientometric approach to track the evolution of EER in Malaysia.

Neto and Williams [6] analysed historical studies of the European Journal of Engineering Education (EJEE) to provide insights on the European context. Other studies looked at specific European national contexts [7, 8, 9, 10].

Strobel and colleagues at Purdue University applied bibliometric analyse to gauge the presence of interdisciplinarity in EER [11] and the growth of loose networks within the EER community [12].

1.2 Motivation

The above studies used human-curated approaches, and this limited them to analysing relatively small data sets. More recently with increased access to computer-processing power there has been growing interest in employing machine-curated analysis as this permits scientometric analysis of large volumes of data [13,14, 15, 16].

A 2018 study by Edstrom et al. [8] presented a global analysis of 160 publications from the four Nordic countries between 2000 and 2014. Their findings suggested that Nordic authors had been publishing steadily over the four years without signs of a clear evolution during the period.

The present study takes a more in-depth look at EER evolution in the four Nordic countries by employing a computer-facilitated analysis to identify the Nordic-affiliated authors in 12 leading journals in the period 2018-2019 and then analysing their total research output throughout their careers in both educational and non-educational publications. Our study analyses a sample of 3237 publications from 76 Nordic authors and provides data on the percentage of their publications that are educationally focused and how this in turn impacts their h-index. We also calculated how early in their career they published their first educational paper.

2 METHODOLOGY

This study adopted a quantitative scientometric approach to build an understanding of the characteristics of researchers who are affiliated to higher education institutions in Denmark, Finland, Norway or Sweden and are active in the field of EER.

2.1 Data Sources

Data were gathered from the Scopus API (http://api.elsevier.com and http://www.scopus.com) during January-February 2021 using the pybliometrics Python library [17]. A list of engineering education researchers who were affiliated to institutions in Denmark, Finland, Norway or Sweden was required. To build this list, twelve research journals relevant to the field of engineering education were consulted; these are shown in Table 1. In total, 76 authors were sourced from the four countries.

Following this, details for each author were retrieved from Scopus, including their complete list of publications. For subsequent analysis, only articles, conference papers, reviews, book, and book chapters were included. Other types of publication such as editorials, notes, letters, or erratum were excluded.

Table 1: Engineering education journals where authors were sourced from (note it was possible that authors may have published in multiple journals)

Journal	Acronym	Denmark Authors	Finland Authors	Norway Authors	Sweden Authors
Advances in Engineering Education	AEE	0	0	0	0
Australasian Journal of Engineering Education	AJEE	0	0	0	0
European Journal of Engineering Education	EJEE	7	14	4	20
Global Journal of Engineering Education	GJEE	0	1	0	0
IEEE Transactions on Education	IEEE ToE	2	1	0	1
International Journal of Electrical Engineering Education	IJEEE	0	1	0	0
International Journal of Engineering Education	IJEE	4	2	3	9
International Journal of Engineering Pedagogy	IJEP	0	2	0	0
International Journal of Mechanical Engineering Education	IJMEE	0	0	1	0
Journal of Engineering Education	JEE	0	0	0	0
Journal of Engineering Education Transformations	JEET	3	0	0	0
Journal of Professional Issues in Engineering Education and Practice (now Journal of Civil Engineering Education)	JPIEEP	0	0	1	0
Total (duplicate authors removed)		**16**	**21**	**9**	**30**

For each publication, the document title, author keywords, document publication year, source title (e.g., JEE), document type (e.g., article), source type (e.g., journal), publisher, subject category, citation count (note that this can change over time; this is a limitation of the study), and DOI was recorded. A total of 3,237 publications until the end of December 2020 were recorded for the 76 authors.

2.2 Data Analysis

Each publication was categorised as being either educationally focused or non-educationally focused. This allowed information (e.g. citations, h-index) about an author's educational and non-educational publications to be established. Each publication was retrieved from the Scopus API (represented as a Scopus AbstractRetrieval object - see [14]), and the following data fields were searched; document title, source (journal) title, author keywords, subject category, publisher.

After an initial scoping search, the following keyword terms were adopted; 'education', 'student', 'university', 'college', 'ASEE', 'SEFI', 'AAEE'. A publication was deemed to be educational if any of the data fields contained any of the search terms. This method was validated using a random sample of 150 publications.

For each of the 76 authors, several details were then established. This included:

- the number of years the author had been publishing, and how long they had been publishing educational papers
- the percentage of publications which were educationally focussed
- the number of citations on educational and non-educational publications
- the author's overall h-index, h-index of their educational publications, h-index of their non-educational publications
- the distribution of the publications by document type including articles, conference papers, book chapters, books, and reviews.

Tests of statistical significance and correlations were evaluated using SPSSv26.

3 RESULTS AND DISCUSSION

3.1 Publication breakdown

Overall, on a country-wide basis, 449 publications were from Danish authors (362 educational, 87 non-educational), 1281 publications were from Finnish authors (294 educational, 987 non-educational), 405 publications were from Norwegian authors (96 educational, 309 non-educational), and 1102 publications were from Swedish authors (482 educational, 620 non-educational). Figures 1 and 2 show the distribution for the number of publications per author, and the number of citations for each author's publications.

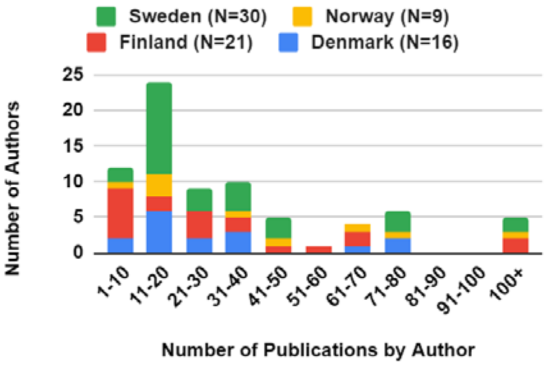

Figure 1: Total number of publications per author

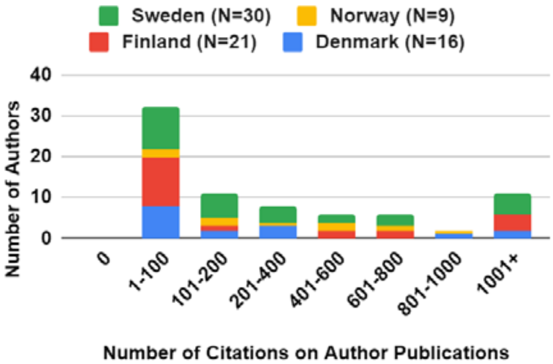

Figure 2: Total number of citations per author

3.2 Average percentage of publications which are of each document type

Table 2: The mean percentage of authors' publications which are educationally focused for each document type, per country

Country	Type of Document	Article	Book	Chapter (Book)	Conference Paper	Review	Total
Denmark	Educational	31.2%	0.5%	6.3%	38.0%	1.5%	**77.5%**
	Non-educational	12.1%	0.0%	3.3%	6.4%	0.7%	**22.5%**
Finland	Educational	33.1%	0.0%	1.4%	30.5%	0.1%	**65.0%**
	Non-educational	13.4%	0.0%	2.0%	18.6%	0.9%	**35.0%**
Norway	Educational	22.4%	0.0%	4.5%	9.4%	0.8%	**37.1%**
	Non-educational	22.3%	0.0%	3.0%	37.1%	0.5%	**62.9%**
Sweden	Educational	29.6%	0.6%	1.4%	32.8%	0.6%	**64.9%**
	Non-educational	18.1%	0.0%	0.7%	15.2%	1.1%	**35.1%**

Authors from Denmark (77.5%), Sweden (64.9%) and Finland (65.0%) published more educational publications than non-educational, while authors from Norway (37.1%) published more non-educational publications than educational publications Table 2). The mean number of educational and non-educational publications for each country was then compared for statistical significance, using the one-way ANOVA test of significance. This demonstrated there was no statistical significance for the four countries between the mean number of educational publications and mean number of non-educational publications. This may be due to the small sample sizes of the groups.

Authors from each of the four countries tended to publish a similar amount of journal articles and conference papers, on average. For example, Swedish authors have a publication record which comprises 47.7% articles, and 48% conference papers on average, while Finnish authors have a publication record which comprises 44.7% articles and 46.5% conference papers. There are similar statistics for Denmark (43.4 articles, 44.4 conference papers) and Norway (44.7% articles, 46.5% conference papers). This demonstrates that authors from each of the four countries tend to have a similar distribution of publications when considering document type.

3.3 Average percentage of citations which occur for each document type

Whereas authors from each country tended to publish about 45-49% of their publications as articles and conference papers (Table 2), the publications which received citations were not as evenly distributed (Table 3). Regardless of whether total publications, educational publications, or non-educational publication categories are considered, articles consistently had a higher number of citations compared to conference papers.

Table 3: The mean percentage of authors' citations which occur on each publication type

Country	Type of Document	Article	Book	Chapter (Book)	Conference Paper	Review	Total
Denmark	Educational	59.4%	0.9%	3.6%	14.1%	2.1%	**80.1%**
	Non-educational	12.8%	0.0%	1.6%	4.7%	0.8%	**19.9%**
Finland	Educational	39.8%	0.0%	0.5%	28.4%	0.0%	**68.7%**
	Non-educational	17.3%	0.0%	0.2%	12.6%	1.1%	**31.3%**
Norway	Educational	20.2%	0.0%	0.1%	3.8%	0.3%	**24.4%**
	Non-educational	45.1%	0.0%	2.1%	25.3%	3.1%	**75.6%**
Sweden	Educational	35.6%	5.2%	0.1%	16.3%	1.5%	**58.7%**
	Non-educational	25.6%	0.0%	0.6%	12.0%	3.0%	**41.3%**

Table 4: Comparison between mean percentage of publications which are educational, and mean percentage of citations which occur on educational publications

Authors from each country	Mean % of publications which are educational	Mean % of citations on educational publications	Mean % of publications which are non-educational	Mean % of citations on non-educational publications
Denmark (N=16)	77.5	80.1	22.5	19.9
Finland (N=21)	65.0	68.7	35.0	31.3
Norway (N=9)	37.1	24.4	62.9	75.6
Sweden (N=30)	64.9	58.7	35.1	41.3

Table 4 presents a comparison between the mean percentage of publications from each country which are educational, and the mean percentage of citations which occur on educational publications. As shown, the ratio of educational publications and citations on education publications are similar for Denmark (2.6% difference) and Finland (3.7% difference), but somewhat different for Norway (12.7% difference) and Sweden (6.2% difference).

3.4 h-index

Figure 3 demonstrates that the h-index of authors from Denmark is primarily driven by educational publications, while the h-index of authors from Norway is primarily driven by non-educational publications. Swedish authors benefit slightly more from educational than non-educational publications. Educational and non-educational publications have nearly an identical impact on the h-index of authors from Finland. Considering the 76 combined authors from all four countries, the correlation between overall h-index and educational h-index was statistically significant (Pearson correlation coefficient=0.341, p<0.01), but the correlation between overall h-index and non-educational h-index was notably stronger (Pearson correlation coefficient=0.879, p<0.01).

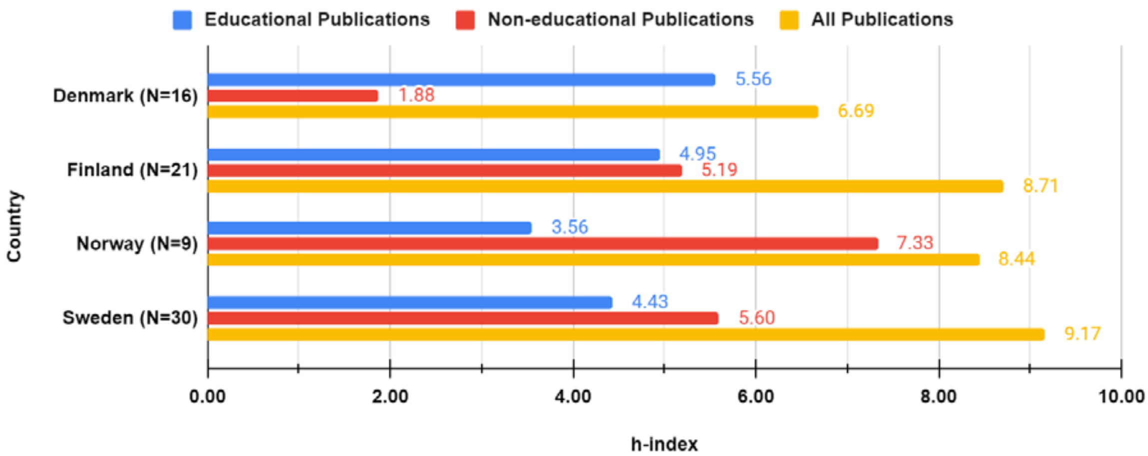

Figure 3: Mean h-index for each author per country for (i) all publications, (ii) educational publications, and (iii) non-educational publications

3.5 Evolution of Publication Careers

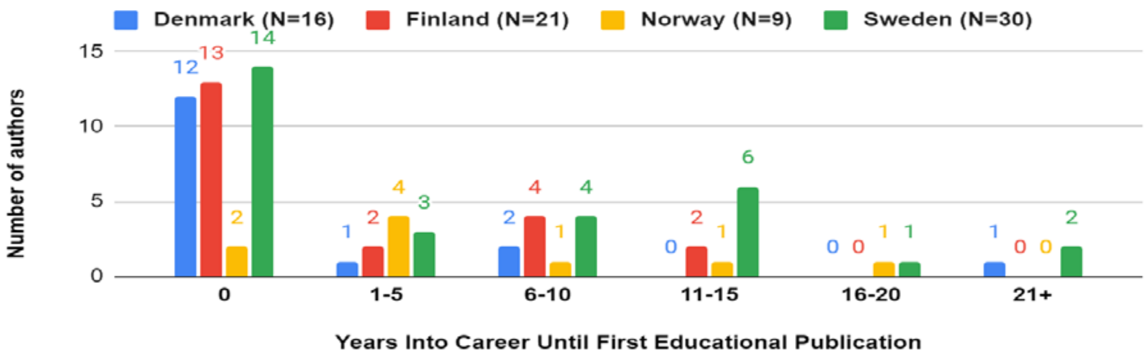

Figure 4: Mean number of years into a researcher's career before an educational publication is published

Figure 4 shows that many EE researchers start their careers publishing educational research. Between the four countries, 41 out of 76 (54%) authors published their first educational publication during their first year of producing research publications. The mean duration of time until producing an educational publication was 4.53 years, but the median was 0 years (because over half of the authors published educational papers at the start of their career). This contrasts with research showing that Australian EE authors tend to publish their first educational publication after 7 years (both mean and median were about 7 years) [15] and in Portugal and Spain it is typically after 6 years [17].

4 SUMMARY

Our findings represent a snapshot of EE researchers in the Nordic countries who published in any of 12 EER journals in the 2018-2019.

Less Norwegian authors appear in our sample than those from the other three countries. This could suggest that EE research is more of a priority in Denmark, Sweden and Finland than in Norway; this interpretation is supported by the data showing that the EE researchers from the former 3 countries published more in the field of EE than other in other fields throughout their career whereas for the Norwegian authors the opposite was the case.

EE authors from all 4 countries had broadly equal publication output for conferences and journals which suggests that presenting and discussing research in conferences is seen as important in the Nordic countries. Journal articles, however, were more likely to gather citations than conference papers.

The h-index of authors from Denmark is primarily driven by educational publications, that of authors from Norway is primarily driven by non-educational publications while for Sweden and Finland the respective impact of the fields of inquiry were more evenly balanced.

Apart from Norway, researchers in our sample began publishing in EE early in their publishing careers. We found this surprising as data from other countries showed that researchers typically began publishing in EE some years after they had published in specialist engineering fields.

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TOMORROW'S CHALLENGES FOR TODAY'S STUDENTS:

CHALLENGE-BASED LEARNING AND INTERDISCIPLINARITY

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ABSTRACT

TU/e innovation Space offers an environment for students to work in interdisciplinary teams on societal problems. These problems ask for development of a shared language for interdisciplinary collaboration and to facilitate learning processes. Little is known about design characteristics for these problems, and what is needed to support interdisciplinarity in student teams. The educational concept Challenge-based learning (CBL) uses authentic societal problems ('challenges') to urge student learning. The main research question for this case study is: What design characteristics of innovation Space challenges support interdisciplinary student collaboration? Data collection consisted of analysis of learning materials, interviews with teachers and students, student surveys about motivation and collaborative learning in four courses and two honour’s tracks. The results show how teachers ask for competence development in supporting students, especially in assessing and integrating discipline knowledge. Students reported high motivation combined with anxiety for open and complex challenges. Over time this anxiety decreases, as students develop knowledge to solve the challenge. Students also reported a need for a clear mapping of learning goals to activities and assessment. For students it appeared often unclear how and on what criteria they are assessed. Yet, students also reported support in developing ownership, self-directed learning, and collaborative learning. This study confirms existing literature that emphasises difficulties in students developing rigorous discipline

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knowledge in CBL and interdisciplinary assessment. This study increases our understanding of challenge design and how interdisciplinarity can be situated in this design. It offers starting points for research on motivation and collaborative learning in CBL.

1 INTRODUCTION

1.1 Challenge-based learning in higher engineering education

Today, many universities are embracing the concept of ‘challenge-based learning’ (CBL), to better prepare students to contribute to societal challenges. CBL is an interdisciplinary experience where learning takes places through identification, analysis, and collaborative design of a sustainable and responsive solution to a real world – authentic - sociotechnical problem [1]. These authentic problems, also known as 'challenges' are seen as self-directed work scenarios in which students engage [2]. The goal of these challenges is to learn how to define and address the problem and to learn what it takes to work towards a solution, rather than to solve the problem itself. The final deliverable can be tangible or a proposal for a solution to the challenge [3].

At Eindhoven University of Technology in the Netherlands (TU/e) CBL has been introduced in a bottom-up approach by allowing teachers to experiment with a variety of implementations. The result is diversity in characteristics of CBL between courses and departments, giving a local colour to CBL. Many of these experiments are conducted in the context of the award-winning TU/e innovation Space. TU/e innovation Space offers an environment that encourages and facilitates students to work in interdisciplinary teams on challenges that directly impact our world [4].

The working definition for interdisciplinarity in education science that studies of Interdisciplinary Engineering Education (IEE) seem to agree on is that interaction between fields of expertise requires some level of integration between those fields to count as "interdisciplinary" [5]. Interdisciplinary interactions can be considered as attempts to address societal challenges by integrating heterogeneous knowledge bases and knowledge-making practices, whether these are gathered under the institutional cover of a discipline or not. Sometimes integration is facilitated through students striving to incorporate foreign methods and knowledge into their own practices, and sometimes collaboratively through interdisciplinary student teams. Generally individuals operate in interdisciplinary teams and learn from others' perspectives and produce work in an integrative process that would not have been possible in a mono-disciplinary setting [6]. The end result is that team members develop a shared language for collaboration and interdisciplinarity to facilitate learning processes [7]. This language should be shared among stakeholders, including students, teachers, and industry or NGO’s.

However, little is known about characteristics that make societal challenges suitable as assignment, and what should be done to support interdisciplinarity in CBL, including how to structure challenges and whether or how to control the space of possible approaches to a challenge students should consider. Furthermore, current courses and projects appear insufficient in their support of interdisciplinarity as part of the student learning process, as intended in the TU/e innovation Space educational vision/philosophy. This paper aims to address this lack of knowledge by investigating support for interdisciplinarity in CBL-assignments in TU/e innovation

Space courses and projects. We do so by exploring innovation Space challenges with the purpose to find a shared language that supports interdisciplinarity in engineering education.

The core research question is: *what characteristics of innovation Space challenges support interdisciplinarity and student participation in those challenges?*

This research question can be divided into sub questions:

- How does interdisciplinarity emerge in innovation Space projects and courses?
- How can challenges in innovation Space projects and courses be characterised?
- What motivates students to undertake CBL activities?

Given the aim of this paper, we focus on collaboration and integration as operationalization of interdisciplinarity [7], and open-ended versus structured as operationalization of challenges [8].

2 METHODOLOGY

2.1 approach and included courses

To understand which characteristics of challenges support interdisciplinarity in CBL, an evaluative case study method was chosen. Evaluative case studies can be defined as enquiries into an educational programme, system, project, or event to determine its worthwhileness, as judged by researchers, and to convey this to interested audiences [9]. The context for the current case study is an extensive educational innovation initiative focused on development, implementation, and evaluation of CBL at a Dutch university of technology.

The included courses aimed at implementing CBL in interdisciplinary teams, with students working on assignments in close interaction with high-tech companies and societal organizations. They combined the design and engineering of a product, service, or system with new business development. Defining and refining of a problem and ideas for a solution simultaneously and iteratively through analysis, synthesis, and reflection processes were important elements of these courses.

Students needed to iteratively experiment on ideas through visualization, prototyping and testing until a feasible problem-solution fit emerged. This means that students had to communicate with experts, potential clients, and end users as part of the validation process. Students were in charge of their own project and encouraged to think out-of-the-box to develop a feasible and valuable solution.

2.2 Data collection

Data collection consisted of learning materials, three interviews with individual teachers and coaches, four focus group interviews with three to four students each, surveys about student motivation and collaborative learning (N = 67), and course-evaluations of five TU/e innovation Space courses, including two honour's tracks.

2.3 Instruments and analysis

In addition to analysis of course materials and student evaluations, semi-structured interviews with teachers and coaches were held. These interviews focused on how teachers and coaches approached interdisciplinarity in student teams in their course, and how they supported and assessed the learning process. Focus group interviews with students focused on how they perceived the design of the course, the degree of interdisciplinary interaction, and the support of their learning process.

Analysis of interview results was guided by sensitising concepts (interdisciplinarity, integration, collaboration, structured vs open-ended, group-learning, anxiety and motivation) that were derived from the theoretical background. These concepts were used to categorise answers from interviews, focus group and open-ended questions. The categorisation was validated by the authors, by continuous discussion and evaluation. To increase the reliability of this qualitative analysis, the authors collaborated closely in the process. Points of debate and uncertainty were discussed until consensus was reached.

Motivation and group learning were measured with the nine-item version of the intrinsic motivation inventory [10], and the dimensions of social learning framework [11][12].

3 RESULTS

3.1 Interdisciplinarity in CBL Courses

Collaboration

Interdisciplinarity is analysed here as the ways in which collaboration and integration are required and scaffolded. In general the five included courses show a high level of support for collaboration, for example because teams are composed on an "interdisciplinary basis" (courses 1 and 2) at the start of each course. Furthermore, the learning goals and assessment show how students develop the ability to contribute and work in a team: “Develop skills in cross functional communication and cooperation” (course 2). Most often these learning goals are assessed with individual reflection (e.g., the honors tracks) or peer-review tasks (course 2). Issues of team-performance, organization, and direction are most often addressed in weekly team meetings with the coach (honors tracks, courses 1 and 2) or workshops (course 1).

Existing literature shows how engineering students are in need of clear signposting and scaffolding, especially for open-ended and complex assignments [7]. Team development in the included courses is scaffolded through multiple (non-summative) instruments, such as mini-pitches, weekly team-member scores, and Agile project plans per week.

Integration

The results show how teachers to a certain extent experience implementing interdisciplinarity in their course or project as problematic. Teachers also reported a need for competence development in supporting students, especially in assessing and integrating discipline knowledge. For most of the courses this is reflected in learning goals addressing problem-solving instruments and targets that are largely given by one disciplinary framework. Still, students were encouraged to be open and creative, and assess each other's value. But in only one course specific workshops were addressed to interdisciplinary team building. In one of the honour's tracks, the course coordinator required students not to work as islands. Students should understand each other's work but not to a high depth, however, they needed to be able to explain to each other what they were doing – their intent and plans.

The criteria for learning goals on integration in the included courses show difficulty in measuring the level of integration. For example, in course 1, assessment criteria for integration evaluated students in terms of how well they "Identified, envisioned and promoted explicitly the role and contributions of different engineering disciplines. Demonstrated and explained convincingly how knowledge and skills from all different fields were considered in the designed system." This puts weight on the engineering disciplines; however, it stays unclear what is meant with 'explicitly' and 'convincingly'. Still, it does demand that students with more than one engineering group think about the role of their different technical fields in the project.

Integration is sometimes defined in learning goals as "synthesis". For example: students will "Develop a problem-driven, creative and integrative design, resulting in an original and validated prototype that balances desirability, feasibility and viability." (course 1). It is thus expected that the prototype will at least score well on each of those three categories. However, none of these goals or criteria give any real solid meaning to what could be meant by integration here, except the ability to produce a design which scores jointly well on viability, feasibility and desirability.

That said, an interdisciplinary project outcome is expected to emerge by virtue of this set-up, even if it is not a form of interdisciplinarity necessarily governed by the bachelor degrees of the students. Further, although interdisciplinarity is not a learning goal in any of the included courses, students were required to make sense of concepts relevant to the challenge, from their own disciplinary perspectives. This is overall a kind of integrative task.

3.2 Type of challenges

Open-ended vs structured

In three of the courses the challenges appeared open-ended. However, the targets students were meant to hit are mostly described with disciplinary frameworks, and thus structured rather than strictly open-ended. For example, in course 1 a framework of technical feasibility, business viability and customer desirability meant that students did not have complete freedom with respect to how they could frame their approach. Technical feasibility weights towards an engineering-based assessment, and business viability towards a business-science based assessment. Customer desirability leaves options for students to bring in different perspectives from fields like psychology. Each three were separately built into the learning goal "Analysis" as distinct requirements. "Analysis" requires students to be able to analyse their problem from each of these different points-of-view and make a distinct case for each. In course 2 groups were mixed and it was a learning goal that students, "Develop skills in cross functional communication and cooperation." However, students were expected principally to make a business case and follow structured tasks for doing so.

For three courses "challenge" in sense of CBL seem to be interpreted in practice mostly as the c*hallenge of commercialization of technologies*. This suggests a potential inconsistency with how CBL is commonly envisioned, namely as a means of prompting students to explore all kinds of societally relevant approaches and solutions to societal problems. In practice there can be a bias towards business-based solutions, when for instance other social sciences (or natural scientific) approaches may be preferable or even necessary for effective societal solutions.

The two honour's tracks allow students freedom in taking an approach to the challenge. After students decided upon an approach, they have to familiarize themselves with it if necessary. This is supported by workshops (e.g., research design methods; qualitative/quant research; prototyping; graphic design courses; professional skills courses) on relevant topics related to the subject of the challenge, and through meetings and students' personal-development plans (including plans for knowledge acquisition).

3.3 Student motivation

Students reported high motivation combined with anxiety for open and complex challenges. Over time this anxiety decreased, as students developed knowledge to solve the challenge. Students also reported a need for a clear mapping of learning goals to activities and assessment. For students it appeared often unclear how and on what criteria they would be assessed. Yet, they also reported support in developing ownership, self-directed learning, and collaborative learning.

Regarding social learning, the students showed a hands-on attitude rather than a learning attitude. They appeared focused more on solving day-to-day hassles than developing and working on a team learning agenda including personal learning goals (see also [11] and [12]).

4 DISCUSSION

This paper explored how interdisciplinarity can be supported in courses that are based on the educational concept of CBL. We focused on collaboration and integration as aspects of interdisciplinarity, and open-ended versus structured to characterise challenges.

Regarding collaboration, the results suggest the need for attention to equal division of disciplines in team selection. However, this in itself is not enough to ensure interdisciplinary engagement. This is confirmed by students who reported to be in need of support in bringing disciplines together and learning to speak each other's language. This can be done by weekly team meetings with a coach, and designated workshops. Finally, it is advised to make interdisciplinary collaboration part of the learning goals and assessment, for example with individual reflection or peer-review assignments [7].

Teachers appear in need of competence development especially on assessing integration and integrating discipline knowledge, and on supporting students in integration and synthesis. Integration can be scaffolded by activities that emphasize the relevant contribution of single disciplines to the challenge, for instance by discipline pitches given by individual team members.

With respect to interdisciplinarity overall it is not suggested that students need to produce a novel or unique methodological approach which goes beyond their existing disciplinary frameworks. However, it appears better to ask students to explain how each part might have contributed to improvement in other parts.

Whatever approach is chosen, it is important to make clear to students how integration will be assessed [13]. The challenge for teachers is to clarify basic concepts for interdisciplinarity ("synthesis, integration etc"), define them in practical rather than abstracts terms, and make clear to students how to satisfy them.

If integration of both engineering fields and non-engineering fields, such as entrepreneurship, are in the learning goals, they should be mentioned explicitly in assessment criteria, to avoid biases with respect to what kinds of integration students think of as important or necessary [14]. If interdisciplinarity is to be a learning approach then there needs to be incentives for students to think about integration. Assessment is a relevant tool here for creating such incentives.

Deeper assessment of interdisciplinary skills can be made by asking students individually at some point in the course to represent their understanding of the other fields in their groups. This would encourage them to seek out this knowledge from others, and explain its relevance. Further to this -more in the line of formative assessment- students could be asked to perform perspective-taking tasks on problems – by being asked to explain themselves how other fields might address or perceive the task.

From our results it can be concluded that challenges need not necessarily be fully open-ended, although it is important to avoid conflicts between expecting students to contribute their expertise, but then largely constraining them to use instruments and methods from just particular fields. If interdisciplinary collaboration and integration are goals or expectations but all the tasks are geared just towards a limited set of fields, then this risks frustrating students who are not from business science. As such it appears more important that students have ownership of the problem/challenge and have control over it, and that this ownership is well supported and scaffolded. Scaffolding can be done by encouraging students to cross boundaries themselves and take on different roles and developing different expertise. This potentially allows students a much deeper insight into interdisciplinary work, by gaining the perspective of how others using other methods might think.

Motivation for working on challenges appeared high in this study. However, this was combined with anxiety for the challenge and stakeholders. The result could be that students develop a hands-on attitude, rather than a learning attitude, by focusing on daily hassles of the project. It is suggested to support students in developing a learning attitude by helping them develop and reach individual and team learning goals.

This study confirms existing literature that emphasises difficulties in students developing rigorous discipline knowledge in CBL and interdisciplinary assessment (see also [8]). The results contribute to our understanding of challenge design and how interdisciplinarity can be situated in this design. It offers starting points for research on motivation and collaborative learning in CBL.

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VARIETY IN CHALLENGE-BASED LEARNING IN HIGHER EDUCATION

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ABSTRACT

Increasingly higher education programs are made open and flexible to face challenges demanded by societal changes. Challenge-based learning (CBL) is perceived as an educational concept shaping these open and flexible programs. However, CBL as a field of research is still in its infancy. The present study searches for all-embracing commonalities of CBL in engineering education. We propose an evaluative framework that both includes commonalities and allows for variety in CBL characteristics between study components. This framework, labelled CBL-compass, serves as a methodological approach for educational staff and researchers to visualise the local colour of CBL in higher education institutions. With this study we aim to advance the field by contributing to a conceptual basis in flexibility in CBL. Our research question was: How can we assess the variety of CBL implementations in engineering education experiments? This question was answered by an evaluative case study. First, existing literature on CBL was scoped. The characteristics following from this review were perceived as dimensions, each with associated indicators. Empirical data were collected from an evaluation of six CBL experiments. The variety of scores on the CBL-compass gave an impression of how teachers implemented CBL in their course or project and can thus be used as an evaluation mechanism to improve this implementation. Filling in the CBL-compass triggered

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reflection among teachers about their course and CBL. The added value of the CBL-compass is the attention for, amongst others assessment or teacher skills and support, which are important for the overall quality of study components.

1 INTRODUCTION

In Challenge-based learning (CBL) challenges are seen as self-directed work scenarios in which students engage [1]. The goal of these challenges is to learn how to define and address the problem and to learn what it takes to work towards a solution, rather than to solve the problem itself. The final deliverable can be tangible or a proposal for a solution to the challenge [2].

The present study searches for all-embracing commonalities of CBL in engineering education. The use of commonalities might suggest that CBL implies implementation of a full-fledged version of challenges. However, because educational practice aims to stimulate and facilitate students' development, the need arises to allow for different forms of challenges. Therefore, we aim for a framework that both includes commonalities, and allows for variety in CBL characteristics between study components or curricula. This framework can serve as a methodological approach to make engineering education (more) CBL [3].

Existing literature shows a limited understanding of this variety in CBL characteristics, and how it affects research and educational development. This paper addresses this gap in knowledge by bringing together evidence informed characteristics of CBL, and second, use these principles to evaluate a set of exploratory projects initiated at university [blinded], in the Netherlands. We propose an evaluative framework, to be used by teachers, teacher supporters, and researchers to visualise the local colour of CBL in higher education institutions. It contributes to a conceptual basis in flexibility [3], needed to inform debate and development in a field of research that is still in its infancy.

1.1 CBL as an educational concept

CBL in our perception is an educational concept, rather than a teaching method (see also [1]). Educational concepts can be defined as views on what is worth learning and how students should acquire that learning [4]. Educational concepts underscore a complex set of educational practices that ask for a specific organisation. These practices include vision and support, but above all teaching methods, which in turn can be defined as the principles and activities used by teachers to enable student learning.

If universities intend to use CBL as a concept for the complete curriculum, a developmental perspective is needed, which implies a variety in CBL characteristics across study components. Furthermore, we argue for a fine granulated view on CBL, including for instance active learning, deep learning to develop meta-cognitive skills, and self-regulatory abilities [5][6]. More specifically for engineering education, aspects such as systems thinking, entrepreneurial thinking, or working in an iterative cyclical way can be added [7].

To guide the analysis of variety in CBL, we propose a framework in two parts: a high-level conceptual framework, and for each concept a set of accompanying dimensions and indicators. The high-level concepts allow to identify educational processes at the three levels of vision, teaching and learning, and support [7][8]. Vision serves as a foundation for the implementation of CBL by describing the basic motivations and goals governing an educational program. Teaching and learning include curricular aspects such as learning goals, design of instruction, coaching and assessment. Teaching thus puts vision into action, with learning as a mutually enforcing parallel process. Teaching and learning processes depend on conditions and resources being in place that facilitate their development and operation. Support consists of aspects such as infrastructure and institutional support, tools and techniques, and resources for developing teacher skills.

Our exploration of CBL characteristics across study components was guided by the following research question:

How can we assess the variety of CBL implementations in engineering education experiments?

To address this research question in a real-life context, we selected six educational experiments carried out at university [blinded]. We answer our research question by bringing together commonalities of CBL on the levels of vision, teaching and learning, and support.

2 METHODOLOGY

To understand the CBL-compass as a tool for visualising variety in CBL implementations, an evaluative case study method was chosen. The context for the current case study is an extensive educational innovation initiative focused on large-scale development, implementation, and evaluation of CBL at a Dutch university of technology.

2.1 Data collection

First, existing literature on CBL was scoped using search engines and referrals from relevant articles. Included were seminal CBL defining studies, derived from queries in Google Scholar and Web of Science, and snowballing the resulting articles for other often cited sources. The intention was a grounded overview of characteristics of CBL, rather than an exhaustive literature review.

The characteristics following from this review were ordered on the three levels of the higher-order conceptual framework. These characteristics were perceived as dimensions, each with associated indicators. All indicators draw on four-point Likert-scale items (Not implemented - 1; To some extent - 2; To large extent - 3; Fully implemented - 4) indicating evidence of the characteristics.

Subsequently, empirical data were collected from meetings, and evaluation of six experiments focused on CBL. Each of these experiments were considered to represent the university's purpose in its own way, and included courses showing a variety of CBL implementations. In collaboration with responsible teachers the level of CBL implementation was assessed using the grounded overview of CBL characteristics derived from existing literature.

3 RESULTS

3.1 Framework description

Existing literature shows that CBL most often is perceived as an additional pedagogical approach to existing structures [3]. In contrast, our university aims at CBL as embedded curriculum practice. This large-scale curriculum approach, in combination with research intends to contribute to the current limited body of evidence for mechanisms that cause CBL interventions to be effective.

3.2 Variety of perceptions of CBL

Following existing literature of CBL and engineering education, and overarching educational characteristics such as active learning and deep learning, a set of dimensions and indicators of CBL can be discerned. Our argument is not that all indicators are fully present in every project or course. Rather, we expect a variety of designs and perceptions of CBL to be found in current and future study components. To depict this variety, we consider the CBL dimensions, and on a more granulated level indicators for each dimension, as 'sliders' that can be adjusted following the study component's definition of CBL and intended learning gains. These sliders measure personal reflections of teachers or curriculum designers, on the level of CBL implementation.

3.3 Dimensions and indicators

The dimensions and indicators below are categorised following the higher order model of vision, teaching and learning, and support. The (intended or observed) presence of individual indicators in experiments can be set with a slider representing the extent of their presence.

Vision

Real-life open-ended challenges

CBL focusses on relevant real-life, authentic, open-ended challenges to trigger learning. These challenges can be mono- and interdisciplinary, originating from various sources (problems/challenges trigger learning) [9]. Authentic here refers to resembling or being derived from the activities of real-world professionals (see also [10]) to allow also for challenges that could emerge in the future. Open-ended assignments are common in engineering education because engineering design is open-ended with respect to both the solution and the process [11]. Open-ended challenges allow students to discover both a problem and a solution, allowing varying solution paths [12].

Global themes

Thematic content areas addressed in CBL are predominantly rooted in themes of global importance, such as sustainability [3]. In that respect CBL is value-driven, with a focus on transformative value and integrative value [13][14]. Transformative value is perceived as outcomes that challenge business-as-usual practices understood as unsustainable. Integrative value can be described as awareness raised and trust built when a diverse group of actors, disciplines, and perspectives are brought together in dialogue to explore a common issue. Both types of value can have either a short-term or long-term societal impact, of which students need to be aware.

Involvement of stakeholders

CBL engages students by involving stakeholders from science, industry, or the societal context [14]. A distinction can be made between 1) university developed challenges, reflecting little collaboration with external stakeholders, and 2) challenges brought and actively supported by stakeholders [15].

Teaching and learning

T-shaped engineers

Engineering education has long emphasized metacognitive abilities such as systems thinking, and T-shape competencies, in which an in-depth disciplinary expertise is coupled with the ability to work with a broad range of people and situations [16][7]. CBL challenges educators to present learning activities that contribute to an in-depth disciplinary expertise, by creating a rigorous treatment of engineering fundamentals [14]. Furthermore, innovation and creativity are considered important aspects in many CBL cases [3]. This can be operationalised in critical thinking (see also [17][18]) and creative thinking [19]. Finally, CBL is characterized by a combination of problem formulating and designing, which implies working in an iterative cyclical way, involving both analysis and synthesis [9].

Self-directed learning

CBL creates a learning urgency, by encouraging students to both acquire and apply knowledge and skills that are needed to work on a specific challenge, which makes their learning contextualised (e.g., [20]). The materials and learning activities will be different for each student, thus enhancing student participation in conceiving and defining their own pathway in learning, also known as 'learning trajectories' [21].

CBL fosters deep learning by supporting the development of metacognitive skills. CBL is also active learning that allows students to construct a network of knowledge and take ownership (agency) of their own learning process (self-directed learning), including the freedom to choose within a broader challenge the specific problem they want to focus on [22]. Active learning is perceived as an approach that creates student engagement with learning materials through interactions such as reading, watching, listening, writing, analysing, experimenting, and thinking [23][6]. Agency and Self-directed learning also include an entrepreneurial mindset, which finds ways to deal with uncertainty [24] and open-endedness.

Assessment

CBL stimulates forms of assessment between product focused assessment and process focused assessment. In product focused assessment the deliverable represents what is learnt in terms of content knowledge and understanding, and the mastery of real-world skills [25]. Process focused assessment evaluates whether the knowledge and skills have been obtained. The balance between these two stands for the extent to which intended learning behaviour becomes visible in both product and process [26]. Gallagher and Savage (2020) show how different approaches to CBL lead to a variety in assessment, especially regarding (in)formative and summative assessment, and assessment of individual and team involvement. Balancing also these forms of assessment implies that CBL aspects such as team progress, interdisciplinarity, and advanced knowledge and skills are evaluated during regular checkpoints with teams and individuals [25].

Teaching

CBL involves adaptive teacher and expert guidance of construction of knowledge by students. Students need scaffolding towards content (also known as clear signposting), and towards active learning [1][27][28]. Yet, given the level of open-endedness and complexity of challenges, teachers are suggested to find a balance between openness and scaffolding. It appears that this balance is easier to be found when teachers act as coaches and co-learners and co-creators (cf., [29][30]).

Collaborative learning

CBL means working in an iterative cyclical way in teams [31][10]. These cycles consist of divergent and convergent reasoning bringing students closer to possible solutions to the challenge. Divergent reasoning includes a variety of perspectives and solutions, while convergent reasoning brings focus and priority to this variety. Ideally these cycles are discussed and evaluated in groups, which in turn enables room for peer feedback and support.

Interdisciplinarity

Interdisciplinary CBL facilitates students from different (sub-)disciplines to learn to work in a team. Their interdisciplinary interactions can be seen as attempts to integrate heterogeneous knowledge bases and knowledge-making practices [32]. Interdisciplinarity thus requires some level of integration between fields of expertise [33]. Individuals in interdisciplinary teams learn from others' perspectives and produce work in an integrative process that would not have been possible in a mono-disciplinary setting [34]. The result, at least in theory, is that participants emerge from such interactions speaking “one language” [7].

Learning technology

Because the nature of CBL presumes extensive access to technology [35], technology rich learning environments lend themselves to support learning aspects of CBL such as active learning, deep learning, social learning, and learning analytics [1][3]. Especially for engineering education, learning technology plays a key role in learning processes, for example with simulators and virtual labs, and is also often a product of this learning [36].

Support

Facilities

CBL involves facilitation of learning and teaching in terms of required materials, spaces such as classrooms or laboratories, and tools including ICT [37][38]. Especially the combination and alignment of physical and online facilities is reported as important by stakeholders [39].

Teacher support

CBL involves support for teachers and tutors, not only on the design of challenges and related learning activities, but also in dealing with uncertainty, and in their shift from content expert to being both expert and coach [2].

4 FRAMEWORK APPLICATION AND VISUALISATION

For each course included in the sample of experiments the score on CBL dimensions and indicators was calculated. We found a variety of scores, with the largest between-experiment variance on the dimensions 'Self-directed learning', 'Teaching', and 'Interdisciplinarity'. This indicates a variety among teachers on their perceived roles and how they guide and support students. Between-experiment variances on other indicators were usually explained by teachers as deliberate choices within their specific course or project.

The resulting scores were visualised in a radar-graph (see Figure 1). This visualisation immediately triggered teachers to reflect on different aspects of their course, and how they could 'make it more CBL'. During the interviews it was emphasised that the resulting image is a perception rather than a value judgement on the level of CBL in a specific course.

4.1 Vision

We examined the extent to which challenges were relevant to 'Real-life open-ended challenges', 'Global themes', and 'Involvement of stakeholders'. The indicator 'Real-life and authentic', considered as a 'must have' was perceived as largely or fully implemented in most courses. The other indicators under this dimension, 'open-ended', 'complex' and 'interdisciplinary' showed a more diverse image. The dimensions 'Global themes' and 'Involvement of stakeholders' also showed variety between courses. When asked for the level of implementation, teachers responded that it either was on purpose, or that it was an aim for future course development to implement these dimensions to higher levels.

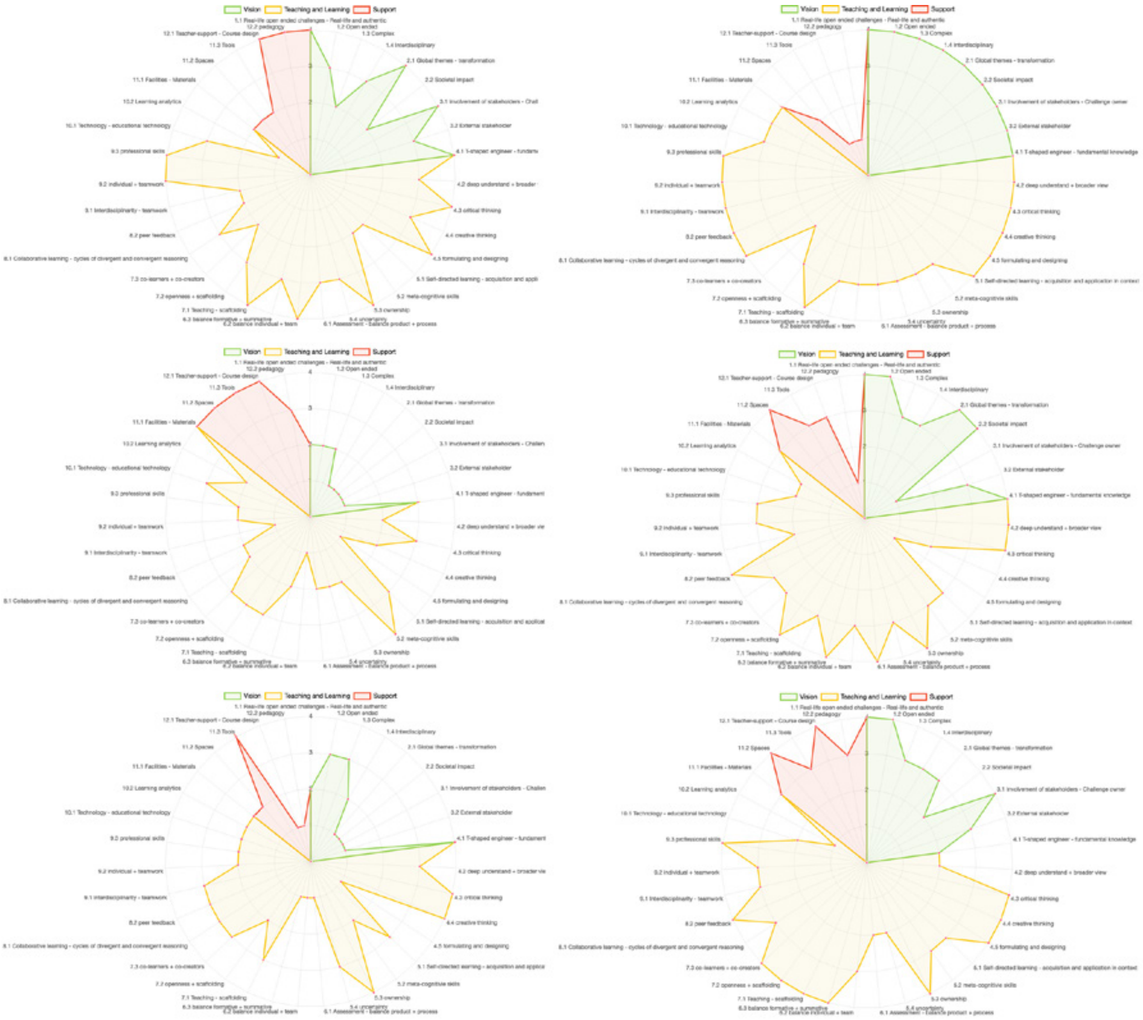

Fig. 1. CBL-compass results for six courses

4.2 Teaching and learning

The indicators under 'T-shaped engineers' scored unevenly: 'Rigorous treatment of discipline knowledge received in general high scores. Teachers reported it as a 'must have', with the only exception being a project focussing on entrepreneurship and interdisciplinary teamwork. The second indicator of this dimension, 'Combining a deep understanding and broader view' received moderate to high scores. All indicators under the dimension 'Self-directed learning' were addressed, however with a disharmonic result across courses: not all indicators were addressed evenly and not all indicators at the same level within a course. Teachers reported on 'Self-directed learning' that their aims were high, however, in their perception students were often not able to reach the intended levels.

Scores on the dimension 'Assessment' were influenced by the perceived level of balance on all three indicators. Teachers explained how they perceive their score as an encouragement to bring more balance to assessing process and product, individual and teamwork, and formative and summative assessment. Furthermore, although teachers reported to go to large extents in scaffolding students, they in general did not consider themselves as co-learners or co-creators of solutions.

4.3 Support

The indicators under support provoked strong responses by teachers. They responded either highly positive about each of these dimensions, or highly negative. Teachers explained their response being related to perceived support on a university level, either in terms of materials or in terms of pedagogical support.

5 DISCUSSION AND CONCLUSION

This study explored an analysis and visualisation of the variety of CBL characteristics within and between study components in an academic engineering curriculum. The aim was an evaluative framework, to be used by teachers, teacher supporters, and researchers to visualise the local colour of CBL in higher education institutions.

The variety of scores on the CBL dimensions and indicators in the CBL-compass, together gave an impression of how teachers implemented CBL in their course or project. More importantly, filling in the CBL-compass triggered a constructive dialogue and reflection among teachers about their course and about the degree to which CBL principles were implemented. In general, they expressed a developmental perspective, with low scoring indicators as starting points for future work. Furthermore, with CBL being visualised for a growing number of study components a finer granulated view of indicators will appear.

Researchers could use the CBL-compass to systematically evaluate the variety of CBL implementation across study components. The question behind each combination of values for CBL characteristics would be "what do students gain from this specific CBL approach?" Furthermore, a related question is "which learning mechanisms need to be activated with CBL?". Further research could detail distinctive CBL characteristics of courses, which scored highly on some of the indicators, identifying patterns in these indicators.

The instrument proposed in this study supports faculty and educators in their design of CBL courses and projects. The CBL-compass can be integrated into course and curriculum design processes as an evaluation mechanism to improve implementation of CBL. The added value over existing frameworks is the attention for, amongst others assessment or teacher skills and support, which are important for the overall quality of study components. Using the CBL-compass presented in this paper in conjunction with for instance design principles would broaden the evaluation of CBL implementation and thus strengthen CBL as an educational concept. The dimensions and indicators of the CBL-compass are fundamental characteristics of CBL. However, the CBL-compass is considered a living tool that grows with CBL implementation to reflect the local colour of CBL.

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Working-life ethical issues faced by engineers

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ABSTRACT

In recent years, there have been public discussions about novel ethical issues emerging from new engineering fields, such as the usage of artificial intelligence. While those are important issues to discuss, they do not necessarily reflect the ethical issues engineers face in their work. In this paper, we discuss problems that engineers of different disciplines face in their professional life, based on a survey sent to members of the Association of Academic Engineers and Architects in Finland. From the 433 respondents, we received over 130 descriptions of ethical issues encountered within their professional lives.

We divided the encountered issues of the survey into two main categories: ethical issues about general work life and those on more engineering-specific situations. The focus of this paper is on the engineering specific ethical issues and the reactions they encounter. We discuss about who noticed the problems and how the workplaces reacted to the issues. In addition, it is addressed whether companies have policies in place to handle ethical issues. Furthermore, we discuss the types of support the engineers indicated hoping to receive from different stakeholders. On a larger scale, the goal is also to gather knowledge on how to improve engineering education to meet the needs of future engineers on ethical issues.

Conference Key areas: Sustainability and ethics. Engineering curriculum design.

Keywords: engineering ethics

1 INTRODUCTION

One of the learning goals of the curricula of our university includes that the students know the ethical norms of their field and can apply them in their work. This goal has not been addressed well in engineering curricula, i.e., the student may pass a curriculum without being exposed to ethical questions. For engineering education, the problem is that for students in engineering, ethics is not high in their interest. A compulsory course on ethics would formally fulfil the requirement, but not in terms of learning if it is the only time to discuss ethics-related issues. To be effective in ethics teaching, we have to know the real-world ethical problems of the engineering profession and embed ethical questions in teaching whenever relevant in the studies.

Meanwhile, there was an ongoing discussion in the Association of Academic Engineers and

Architects in Finland (TEK) about ethical issues. TEK had a Board of Honour to handle the ethical issues. During its existence, the Board adopted the idea of Archimedean Oath [1] and made a Finnish version of it. It organised some events and released publications related to ethics, but the members of TEK did not contact the Board regarding their problems. The Board members felt they were not fulfilling the purpose of the Board, and finally, the Board suggested its termination.

However, the Council of TEK felt the need for ethical discussion is needed more than ever before; it was only the form of the Board of Honour that was outdated. The importance of ethical issues was greatly motivated by the discussions emerging from new engineering fields, such as using artificial intelligence as part of engineering products: a simple search "ethical problems of artificial intelligence" produces about 160 million hits (3.5.2021). Further, the Council wanted to know the real-world ethical issues the members of TEK were facing.

The needs of the university and TEK gave the motivation for this research since the same information would be extremely useful in designing ethical studies for engineering students and helping TEK solve its problem. Further, the study formed an opportunity to get real-world examples for handling and teaching ethical questions, too.

In this paper, we discuss issues that engineers of different disciplines face in their professional life, based on a survey conducted to members of TEK. From the 433 respondents, we received over 130 descriptions of ethical issues encountered within their professional lives.

The research questions of this paper are:

1. What kind of ethical issues the engineers face in their everyday work?
2. What are the processes of handling ethical issues in the companies, and what kind of reactions they raised?
3. Regarding the ethical issues, what kind of support engineers had got and what they wanted to have?
4. Do the findings of the above have an impact on the ethics education of engineers?

The Section 2 of the paper is a short snapshot about ethics-related work. Section 3 describes the methodology used, and the results are presented in Section 4. Section 5 contains the conclusions and discussion.

2 Related work

There has been discussion about ethics in engineering a lot, but there are not many surveys available on the everyday ethical problems of engineers. The target group of surveys is most often engineering students, or they are focusing on ethical attitudes. Some surveys include ethical issues as part of a larger set of questions ([2] is an example of this). However, also the engineers have been interviewed about ethical problems in their work. These interviews have been the basis of several example cases [3][4]. In general, most of the interview results are published in the form of example cases.

Since our final goal is the ethics education of engineers, the rest of this section is about engineering ethics education.

The engineering curricula can include ethics in many ways. The three main alternatives recognised by Colby and Sullivan are a stand-alone course, a brief discussion about ethics whenever ethical issues arise naturally in the courses, or modules of few hours to be included in subject courses [5]. These alternatives appear in many other publications, too, but there is no clear consensus of the best practice. However, these alternatives are not exclusive [6]. Harris et al.

emphasise the importance to introduce ethics to the students as often as possible [7].

A specific course on ethics is a simple solution to ethics education. Unfortunately, the general problem in teaching ethics to engineering students is that the students are interested in engineering, not ethics [5]. A stand-alone course might pinpoint this, lowering the interest of the students. The usefulness of the course is further decreased if it is graded accepted/fail or the credit points are low or even zero [6]. The latter is happening if there is no room in the curriculum for ethics. One of the problems can be if the teachers are from the philosophy unit. They are experts, but they do not use the language of the students. This may be one cause to skip the stand-alone course. The drawback of not having a stand-alone course is that there will not be a comprehensive view of ethics, and a stand-alone course is strongly supported by Unger [8].

The ethics studies often include the ethical codes on engineering, like Archimedean oath or codes of engineering organisations [1][9][10]. Another traditional type of bringing up ethical questions have been case studies [7][8]. Example cases are a natural way to embed ethics as a part of the engineering courses. Naturally, the cases are an integral part of stand-alone ethics courses, too. For instance, the Markkula centre at Santa Clara University offers a collection of short cases on engineering area [3]. The selection of cases is important. If they are descriptions of disasters, they do not have the desired effect. Perhaps the students do not feel they will be facing such problems themselves. The case examples should reflect the everyday life of the engineers [4].

Because of the limited amount of hours available for ethics, teaching ethics for engineers is often on the level of ethical awareness. However, that is not enough. What we want is both ethical awareness and behaviour [6].

3 METHODOLOGY

Survey was held as online survey, distributed to 6000 members of the association, 2000 of which where retired and 4000 in active work force. TEK has a policy to restrict the number of attendees to about 10 per cent of the TEK's members not to make too many surveys to appear for any individuals. Survey link was sent to the selected subjects by email. The retired members were included for two reasons: to make the number of attendees bigger, and it was thought, that because of their longer career, they had more experience on the possible problems.

Survey included common sections for all respondents, which included demographic questions as well as questions about their ethical attitudes. In addition, the common sections asked about general wishes for availability of ethical issue handling support, and if ethical issues were discussed during their studies. Secondly, respondents could describe ethical issues they had encountered in more detail. The survey structure and questions as well as answer options are fully detailed in [11]. A single respondent could describe up to three different ethical issues in more detail. The survey was provided in both English and Finnish.

Total of 433 full responses were received, incomplete responses were excluded from the analysis. The survey produced over 130 more detailed descriptions of different ethical issues or problems respondents had encountered during their work life. Respondent could classify the issues under broader categories, but in addition to the self reported classification, we analyzed the descriptions. From our analysis we formed ethical issue types that were commonly present in the descriptions. These categories are discussed further in Section 4.

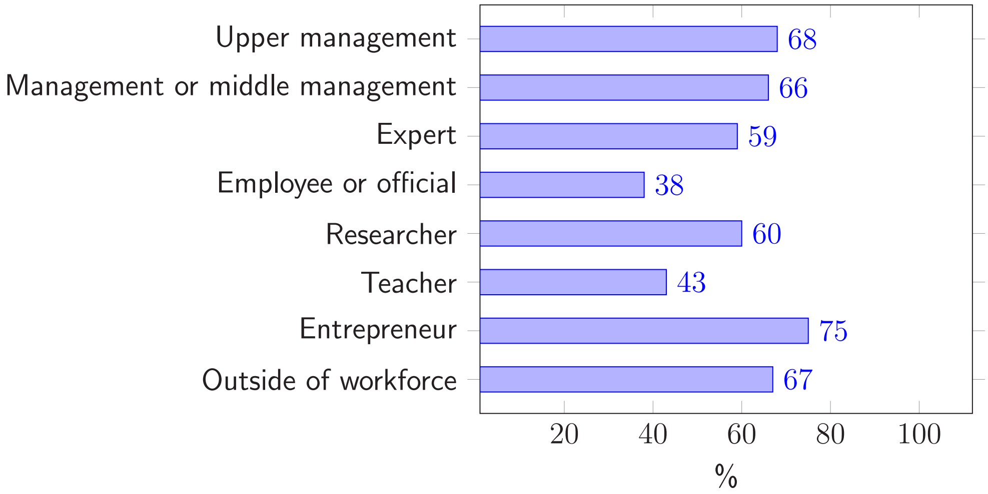

Figure 1: Relationship between respondents' position in work and encountering ethical issues.

4 RESULTS

The survey received 433 responses, of which 75% from males, 21% from females and 4% other. Among the responses there were over 130 more detailed case descriptions about different ethical issues the respondents had encountered during their work life. In this section, we discuss first backgrounds of the respondents and then focus on the case descriptions that fall under more engineering specific ethical issues rather than generic workplace issues.

Of all the respondents, approximately 60% reported having faced ethically problematic situations in their work life. There were differences between reporting with males, females and the other: 58% of males, 64% of females and 82% of other reported encountering problematic situations. From Figure 1 we can observe the differences between respondents' position in their current workplace and whether they have encountered issues or not. Based on the results, it seems that increased responsibility correlates with the likelihood of encountering ethical issues during work life. We are speculating that the increased responsibility comes with longer work career as well as wider visibility to the issues over the whole work place. It can also be noted that management as well as upper management are recognizing and aware of ethical issues that are appearing in the work life.

From the respondents and their position in the work place, it should also be noted that researchers, teachers and entrepreneurs formed together only 7% of the respondents, and expert position was most notable, with 49% of the respondents belonging in that category. People outside workforce formed only 12% of the respondents, even if the sample included disproportioned amount of retired members.

From the engineering education point of view it was alarming that 70% of the respondents mentioned that ethical issues or problems were not discussed during their studies.

4.1 The nature of problems encountered

Respondents, who described ethical issues in more detail, were able to self-classify what areas of work life situations the issues were related to. The reported areas are depicted in Figure 2. Behavior and attitudes at work places as well as working terms, conditions, management or human resources were the two most prominent categories that the respondents identified from the issues they had encountered.

In addition to the self-reported categories, we analyzed the given descriptions to identify typical

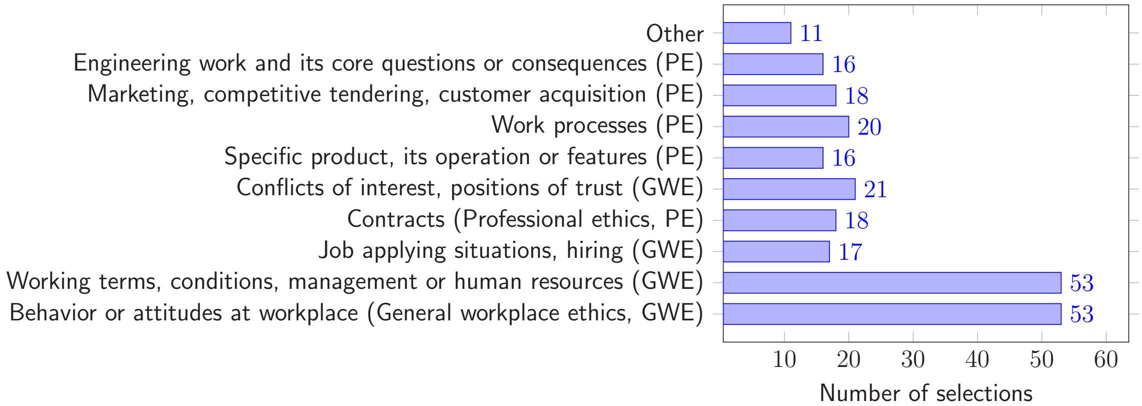

Figure 2: Self-reported categories for encountered ethical issues from the respondents.

issues. Although there has been a lot of discussion about problems arising because of artificial intelligence, there were no issues reported in this survey, that were related to AI or it's usage. In further analysis we formed first two high level classes: ethical issues related to relationships between coworkers and management of human resources and ethical issues related to technical and/or economical aspects of the work. From the descriptions, approximately 57% belonged to the first high level class and 43% to the second.

In the ethical issues related to relationships between coworkers and management of human resources, respondents discussed for example issues of unacceptable behaviour in the work place, such as harassment or discrimination. Poor management and issues with work arrangements were also common in this class. This result also shows, that respondents are considering these work place problems ethical issues as well.

Rest of this section is used to discuss in further detail the issue types that were prominent in the ethical issues related to technical and/or economical aspects of the work. Within this high level class, we identified five subcategories that were more notable: Technology-specific issues, bribery, other ethical issues in project acquisition, customer or collaborator related issues and questionable money usage.

Technology-specific issues formed 17% of the issues in the second high level class. In these descriptions, the core of the ethical issue is for example potential miss-use of the technology in unethical manner or ill-fitting or unsafe design decision that can cause harm in long term.

Bribery and so called horse-trading, or use of inside knowledge for example in project acquisition or pricing, was mentioned in 16% of the second high level class descriptions. Respondents gave descriptions, where forms of bribery ranged from providing excess hospitality to significant monetary rewards. Other observable type of project acquisition issue was exaggerated or otherwise questionable information provided during the project acquisition. It appeared in 7% of the descriptions belonging in second high level class, for example in the context of marketing exaggerated expertise for potential customers.

Engineers experienced also ethical challenges regarding the customers or collaborators they worked or considered working with. 12% of the descriptions from second high level category focused on the customers' nature, for example questioning if co-operation with organization, that engaged in unethical practices in the respondent's opinion, was ethically acceptable or not.

Questionable money usage in different manners also stood out in the case descriptions, however as a category the actual issues were more diverse in nature compared to the other categories

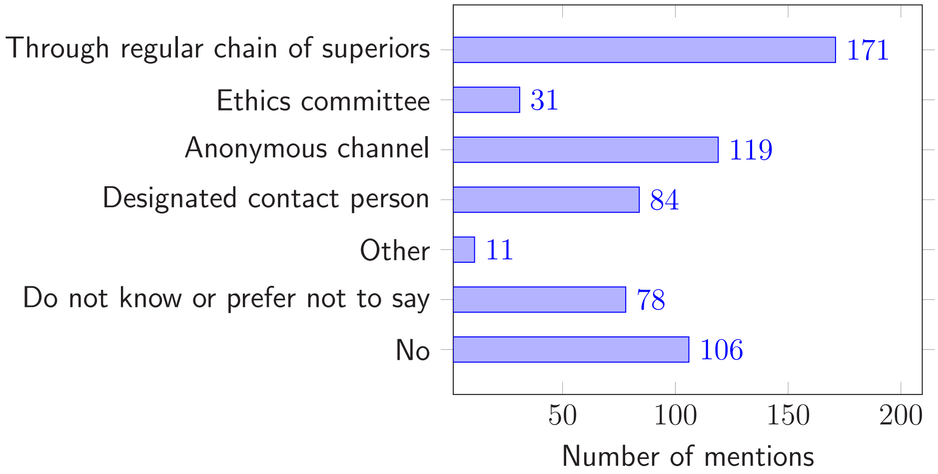

Figure 3: Respondent reported procedures in their current workplace to bring forth ethical issues or problems.

mentioned in this section. Examples ranged from questionable investments to pricing practices. 17% from these descriptions fell under the questionable money usage category.

4.2 The handling of problems in companies

Handling the ethical issues in companies varied: Some companies had existing procedures for both bringing ethical issues forth as well as ways of supporting the employees in solving the issue. Figure 3 presents the methods to bring ethical issues forth. Respondents could select several fitting options, if their employer had multiple options available. It is notable, that out of the 433 respondents, 42% reported that there either was no procedure to report ethical issues, or they were not aware of such procedure. In the places that had procedures at place, reporting through regular chain of superiors was common occurrence, as 39% of the respondents reported at least this method of bringing forth the ethical issues. It should be noted though that as 15% of the case descriptions directly mentioned someone in the employee's chain of command being part of the ethical issue, relying purely on reporting through the chain of command may leave employees at loss, when the issue is regarding the superiors.

Figure 4 presents the procedures that are available in companies to address the ethical issues, or to support the employees after the problem has been encountered. Again the "no" or "do not know or prefer not to answer" options are dominating the responses, with 57% of respondents reporting either of those options.

Within the described cases, it was extremely rare that the ethical issue was noticed purely by external actors. Out of the 135 cases, 74% reported that the ethical issue was noticed by the respondent themselves and 51% by other members of the project group or work community, often by both. Cases, where either other project stakeholders or external actors noticed the ethical issue while respondent or other project members did not, were extremely rare. Only two cases from the 135 descriptions filled this criteria.

Reactions to situations, where ethical issue was brought forward varied as we can see from the responses. When asked, what was the reaction of the decision makers to solve or handle the ethical issue (during the first encounter if respondent told about type example), respondents reported following: 25% mentioned negative reactions towards bringing it forth. 32% reported that the issue was ignored or buried and 29% mentioned that it was discussed but actions were not taken or issue was left to hang in the air. Only in 13% of the cases the policies or practices were changed, and even more rare, reported by 4%, the identified ethical issue led

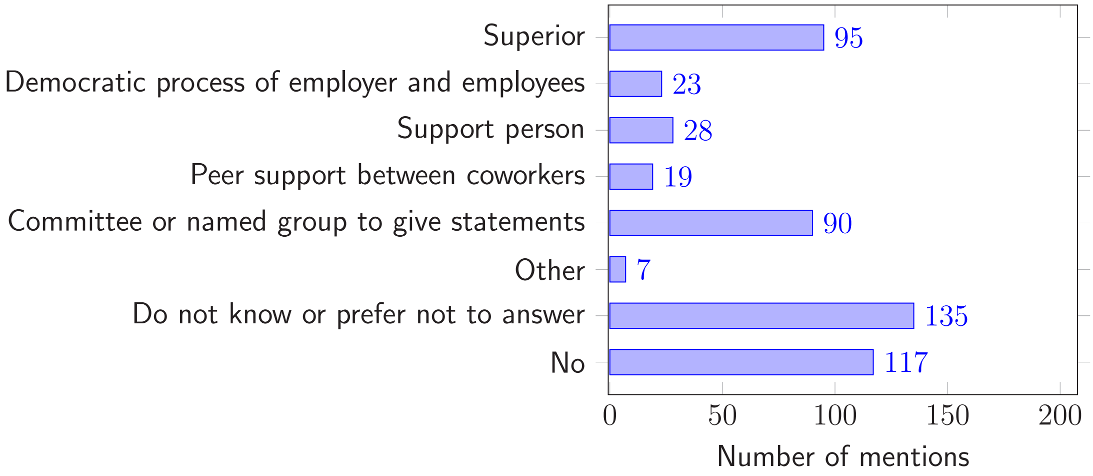

Figure 4: Respondent reported procedures in their current workplace to address and solve ethical issues, or provided after-care.

to withdrawing from the situation or project, or refusing to join or participate in it in the first place.

4.3 The support received and desired

Based on the case descriptions, engineers are lacking in available support to help with handling the ethical issues they encounter. 55% of those who left more detailed description said that there was no available support to solve the situation. In addition to that, 16% responded with "do not know or prefer not to answer". It seems, that large majority of the respondents who reported the ethical issues, either did not have help available or were not aware of the potential help they could have. This is in line with the general responses, that outlined the available support in their current companies.

Figure 5 presents the results of what kind of support respondent wished to have for handling ethical issues, as well as who should provide said support. In most of the areas respondents felt, that it was the duty of the employer to provide the support, either directly or through external actors. Only in legal services the labour unions were the most desired support provider.

The most desired support were example cases, educational material like ethical codes and support personnel.

4.4 Threats to validity

The survey was sent to 6000 members of TEK, out of which 2000 were retired. Of the 433 respondents, only 50 were not in the working life. That number includes retired and unemployed. Hence, about 88% were working, meaning that the results give a good snapshot of the current situation. However, it has to be noted that the respondents could describe quite old cases if they wanted to. For some groups of the respondent background (in Figure 1), the number of respondents is small.

5 DISCUSSION

Although the study was partly motivated by AI applications in the engineering domain, none of the respondents reported a case where AI was present. This does not mean the problem of AI is not a real one. Only small minority of engineers are working close to AI applications, and the survey was not limited to areas where AI is known to be used. The results indicate that the education of ethical issues has to cover traditional engineering areas, too. This is clearly

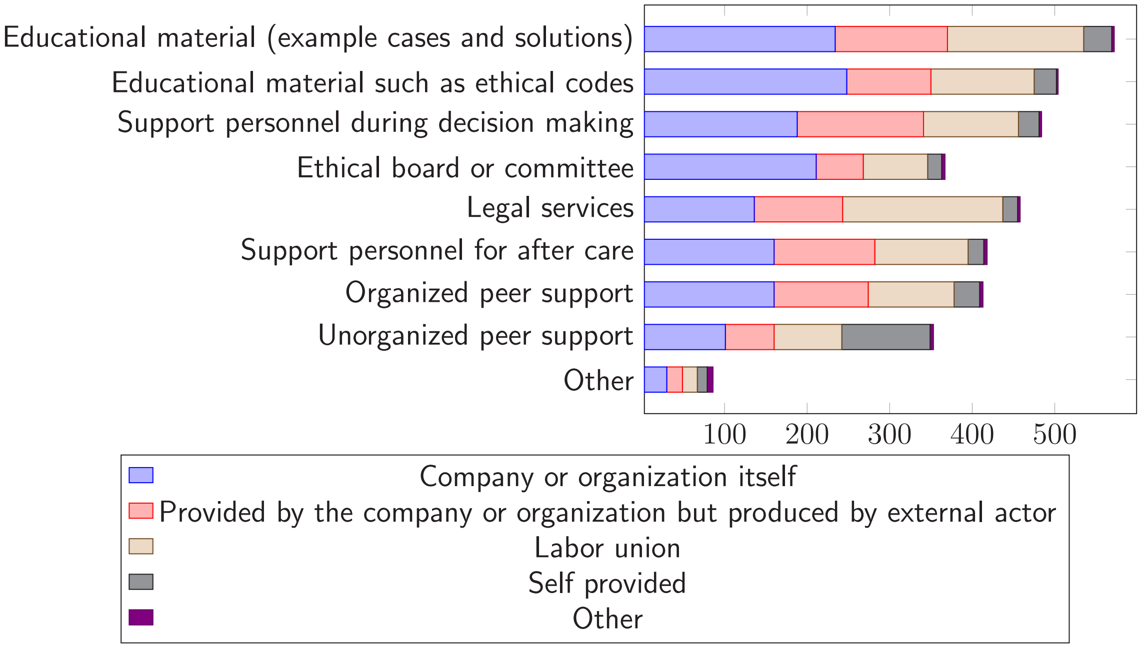

Figure 5: What kind of support respondents wanted to have and who would provide it.

evident in software products, where the program may make decisions based on traditional algorithms without AI [11], but even these cases were missing in the responses.

In general, it was a surprise that cases which were related to engineering or technology were clearly few in number, compared to those related to human factors. Human factors show up also in some published example cases [3]. Its importance emphasise that the ethics education in engineering cannot be focused on ethical problems in engineering only but should give a comprehensive view of ethics.

A notable trend from the responses was, that engineers do not have much support when solving the ethical issues. As over half of all the respondents noted, that their current workplace did not have or the respondent did not know about the procedures to handle ethical issues, it is not surprising that similarly, over half of the description givers noted, that they did not receive any support to handle the ethical issue they encountered. This lack of support challenges also the ethical education of engineers, as current situation requires self reliance from the engineers for solving the problems.

The respondents expected the employer to organise support for ethical issues either directly or indirectly. The second choice of providers for support was the labour union (like TEK). This fits well to the result that the higher role in the company the respondent had, the more problems they had noticed. Only for legal support, the labour unions' role was bigger than that of the employer, which may be an indication of problems where the employer is on the opposite side of the issue. The two top desired ways for support were example cases and ethical codes, which fits well to the core topics of ethical education reported in the literature. The descriptions collected in this survey can, in their part, be used to create example cases.

6 ACKNOWLEDGEMENTS

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FOSTERING QUALITY OF REFLECTION IN FIRST-YEAR HONOURS STUDENTS IN A BACHELOR ENGINEERING PROGRAM TECHNOLOGY, LIBERAL ARTS & SCIENCE

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Conference Key Areas: *Competence development for engineering professions, Engineering skills*
Keywords: *student reflection*

ABSTRACT

This study focused on fostering the quality reflection displayed in semester self-evaluation reports (SERs) of First-year Honours Students in a Bachelor engineering program Technology, Liberal Arts and Science (ATLAS) of the University of Twente in the Netherlands. The underlying problem that inspired this study was that the quality of reflection was considered too low. In addition, there was unclarity in the program on to what was expected of students with respect to reflection. Twenty-nine participants, not previously exposed to academic training on reflection before, received a Reflection Guide on how to write written reflections in their SERs. Two online lectorials (interactive lectures) were provided to elaborate on the content of the guide and to address any questions of the students. Quality of reflection in the SERs was assessed using a standardized rubric and quality scores in the intervention group were compared with scores of the student cohort of the previous academic year (n = 33). Results showed that the intervention group reflected significantly on a higher level than the comparison group.

1 INTRODUCTION

1.1. Background

ATLAS University College Twente is a bachelor of science program in Technology, Liberal Arts & Science that aims at educating the 'New Engineer' (Goldberg & Sommerville, 2014). The program has embraced the concept of self-directed learning (Gibbons, 2002; Saks & Leijen, 2014), meaning that students attain learning goals mostly in their own way. Semester goals (there are six semesters) define a developmental framework that allows students to gradually build their own academic profile as New Engineers. At the same time, the framework safeguards that all students reach the intended learning outcomes of the program as a whole. At the start of each semester, students write a plan in which they explain how they intend to reach the semester goals of their current semester. At the end of each semester, students write a self-evaluation report (SER) in which they reflect on their development and evaluate whether they reached the goals of the semester. The SER is input for a semester assessment meeting in which a group of assessors decides to what extent the students' self-evaluation can be justified. As part of this assessment, students receive feedback on the *quality* of reflection and self-evaluation displayed in their SERs. As a requirement to pass the semester, quality of reflection and self-evaluation needs to be at a sufficient level.
Reflecting and self-evaluating are considered important skills by the program, both for the students' learning, and for their role as New Engineers in society. New Engineers typically work interdisciplinary, meaning that they need to be able to quickly familiarize themselves with new fields of expertise to be a linking pin in interdisciplinary teams. Actively monitoring what one knows and what still needs to be learned through continuous reflection and self-evaluation is therefore of seminal importance. Life-long learning characterizes the professional practice of New Engineers and reflection is regarded an important skill in this respect (Rogers, 2001, see also Yost et al., 2000).
Skills in reflection do not come naturally, but can be trained (e.g. Gün, 2011; Kori et al., 2014; Russel, 2005). However, reflection is considered challenging for students and, for different reasons, support is needed (Abou Baker El-Dib, 2007; Lee, 2005). For example, reflection requires creative thinking and seeing alternatives, which might be challenging for students (e.g. Leijen et al. 2012). Obviously, it is not enough to tell students to just "go and reflect" (Welch, 1999).

Kori et al. (2014) reviewed several studies that aimed at supporting reflection in technology-enhanced learning environments. Several support measures were identified, ranging from videos, blogs and portfolios, to prompts and guiding questions, and peer/teacher interactions. Their research showed that these measures all have their benefits, but that this depends on the type of learning environment and the specific reflection activity. The authors also state that measures to evaluate the effect of the support measures in the studies they included in their review lacked in terms of validity and reliability.

For the underlying study, we based our intervention on the work of Ash and Clayton (2004) on *articulated learning*. On the one hand, their approach aligns with what Poldner et al. (2011) considered to be common to reflection definitions; 1) reflections are directed at something, 2) are part of a cyclical process, 3) can vary in strength, 4) include an affective component and 5) include an intention to change based on newly acquired insights. Also, there is evidence that their approach can foster quality of reflection (Ash et al., 2005) as measured with rubrics for assessing quality (or strength) of reflections. The rubric that was developed for this study was further inspired by Kember et al. (2008). Other means to assess the quality of reflection can be found in Dyment and O' Connell (2011).

On the other hand, their approach to support reflection is straightforward, it makes use of scaffolding questions to structure student reflections and stimulates students to think deeply about their object of reflection. Peer and teacher interaction, and feedback cycles (Ash et al., 2005) might add to the training effect, but in this case we decided not to add more to the intervention group' workload than strictly necessary because of the Covid-19 situation (the intervention was part of their curricular work). However, to increase the impact of the intervention, examples of reflections of different quality levels were provided, with an explanation of why, according to specific criteria, the example would fall into a certain reflection quality level category. This add-on is based on the well-established effect of learning from examples (see e.g. Hoogerheide & Roelle, 2020).

Up until the moment of the current study, the ATLAS program offered support to first-year students in writing their SERs by providing two pages of written instructions and one 1.5-hour *lectorial* (interactive lecture, similar to a workshop) on the nature of reflection and self-evaluation. However, the effect of this support, especially with respect to reflection, was not reflected in their SERs. Teacher-assessors generally noted the poor quality of reflection displayed in the SERs, but also appeared to use different criteria for assessing the SER reflections. Typically, the assessment manuals for assessors contained no information about criteria to use in providing feedback on the quality of reflection. Moreover, students did not seem to be aware what was expected of them with respect to reflection. These observations formed the motive for this study, the underlying problem being unclarity surrounding what constitutes proper reflection, both on the students' and the teachers' side. Without such clarity, the conditions needed to develop reflection skills are at least suboptimal. Typically, quality of reflections in the SERs remained stable throughout the program.

1.2 Research question

This study was part of a larger project that contained five studies. The research questions of the overall project were 1) What would be an appropriate reflection method for first-year ATLAS students that includes both support measures and feedback criteria? 2) What is the effect of an intervention targeted at fostering quality of reflection? and 3) What is the level of perceived usefulness and value of the proposed reflection method on which the intervention was based for students and teacher-assessors? In this paper, results of a study that targeted the second question will be reported.

1.3 Intervention design

A qualitative pilot test made clear that students tend to focus their reflections on their academic performance. In this, the distinction between reflection and self-evaluation becomes blurry, which is corroborated by several student statements that point to confusion about the distinction between them. Although most students feel that they can meet expectations regarding reflection, the majority states to need additional educational support. Clear instructions, templates and examples, feedback cycles and interactive SER writing sessions were suggested.

Due to the Covid-19 pandemic, education went online during the study and the first-year students were under quite some strain already. Therefore, it was decided to keep the intervention low-key. A Reflection Guide (based on the work of Ash & Clayton, 2004) was provided with clear instructions, scaffolding questions that served as a template to structure reflections and to stimulate students to think deeply about a reflection object, quality criteria (rubric), and examples of low to high quality reflections with fictitious examples that highlighted the criteria. These ingredients mostly aligned with the needs identified in the pilot study, with the exception of including peer/teacher interactions and feedback cycles, for reasons mentioned before. The Reflection Guide was written to be self-contained as additional instruction to write the SER, but the content of the guide was also discussed in two non-mandatory online lectorials of approximately 1.5 hours. The first lectorial focused in the students' task of writing reflections in their SERs, the second one repeated the first (on purpose; very few students showed up the first time), but also elaborated on the quality criteria and the reflection examples. There was room for questions in both lectorials.

2 METHODOLOGY

2.1 Participants

The intervention group consisted of 29 first-year ATLAS students in their first semester (Class of 2023). There were 14 females, 58.6% of the whole class was of native Dutch origin. For comparison, the first semester SERs of 33 students of the Class of 2022 were used (also 14 females, 60.6% of the whole class was of native Dutch origin[1]). Students in both cohorts were admitted on the basis of the same admission criteria. Students from both cohorts that failed their semester were excluded from analysis.

[1] The author could not find evidence to support the idea that quality of reflection is affected by cultural differences. ATLAS is an international study program, these data are included to show to what extent the intervention and comparison group could be compared.

2.2 Materials

To assess the quality of reflection displayed in the SERs of the students, a rubric was constructed based on the levels of reflection described in the Reflection Guide. There are four levels of reflection and the rubric also contains intermediate levels, see Table 1 below. The parameters that define the level of reflection are: 1) understanding of the critical incident in term of the student's learning (*understanding dimension*); 2) implication of the learning for other situations in which it might apply (*transfer dimension*); 3) the personal impact or - significance of the incident (*personal dimension*) and 4) the extent to which the incident has had implications for future goals or behaviours (*future dimension*). The highest level, which is not common according to Kember et al. (2008), also includes evidence of a fundamental change in perspective.

2.3 Procedure

SERs were retrieved from the program's data base. The principal researcher first identified the different reflections in the SERs and then assigned a level to each of them on the basis of the rubric. An excerpt was considered a reflection when 1) students apparently "looked inside", and apparently thought about an experience or 2) when the excerpt was headed with "reflection" (this was common in the intervention group because they were instructed to structure their SERs in separate reflection and self-evaluation paragraphs). Students in the intervention group were instructed to write three reflections, while students in the comparison group could write as many as they liked. In this group, when students wrote more than three reflections, the three highest-scoring reflections were taken as units of analysis.

2.4 Data analysis

Level 1 reflections were assigned a score of 1, 1+ reflections were assigned with a score of 1.5, level 2 reflections were assigned a score of 2, etc. Mean reflection level was calculated by averaging the scores of the three reflections with the highest individual scores. Difference in mean quality of reflection was tested with a T-test for independent samples. Possible effects of gender and nationality (Dutch/foreign) were controlled for.

Table 1. scoring rubric quality of reflection

Level 1: Non- reflection
The intended reflection shows no evidence of the student attempting to reach understanding of a critical incident or significant learning experience. The student is basically evaluating his or learning on a general level, the learning is not related to any other situation in which it might apply. The reflection is not personal, it could have been written by any student. No implications for future goals or behaviours mentioned.
Level 1+: the reflection scores higher on certain criteria, but not enough for the reflection to be fully classified on the next level.
Level 2: Understanding
A critical incident or learning experience is described to a certain extent, and the student is able to explain its meaning, but does not relate it to any other situation in which it might apply. Also, it does not become clear in what way the experience matters for the student personally, or how it affected future goals or behaviours.
Level 2+: the reflection scores higher on certain criteria, but not enough for the reflection to be fully classified on the next level.
Level 3: Reflection
A critical incident is described clearly, and the student is able to explain its meaning and how it relates to other situations in which it might apply. It is also clear how and why the experience has mattered to the student on a personal level.
Level 3+: the reflection scores higher on certain criteria, but not enough for the reflection to be fully classified on the next level.
Level 4: Critical reflection
All of the above (level 3), while it is also clear how the incident has affected the student's future goals or behaviours. In addition, there is clear evidence of a change in perspective over a fundamental belief.

Note: criteria relate to four dimensions: *understanding*, *transfer*, *personal* and *future*

3. Results & Discussion

First, it must be noted that students in the comparison group delivered reflections that were assessible with the criteria in the Reflection Guide. This indicates that they, to a certain extent, had similar ideas about what reflection entails compared to the intervention group. Therefore, it seems fair to compare the groups.

Average level of reflection in the intervention group was 2.0 (SD: .56, range 1.17 – 2.67). In the comparison group, this was 1.3 (SD: .30, range 1.0 – 2.17). A T-test for

Table 2. Percentages of reflections at different levels in comparison and intervention group

		Reflection levels						
	SRs	*1*	*1.5*	*2*	*2.5*	*3*	*3.5*	*4*
Comparison group	T1	39.4	33.3	21.2	6.1	-	-	-
(n = 33)	T2	54.5	36.4	6.1	3.0	-	-	-
	T3	90.9	9.1	-	-	-	-	-
Intervention group	T1	-	13.8	24.1	20.7	34.5	6.9	-
(n = 29)	T2	13.8	27.6	31.0	13.8	10.3	3.4	-
	T3	34.5	31.0	17.2	13.8	3.4	-	-

Note: SRs: three strongest reflections found in the semester 1 Self-Evaluation Reports of the participants (T1 – T3). Reflection levels: 1 = lowest, 4 = highest (see also Table 1).

independent samples showed this difference to be significant ($t = -6.64$, $df = 60$, $p < .001$); compared to the students in the comparison group, students in the intervention group reflected on a higher level. To provide more insight into the effect of the intervention, see Table 2. As can be seen, across the three strongest reflections (SRs) found in the SERs of the students in the comparison and intervention group, variation in the intervention group is stronger, with fewer reflections at level 1 and 1.5 and more at level 2 – 3. In the comparison group, no reflections at level 3 and onward were found, while in the intervention group, these were quite common. No effects of gender were found. In the intervention group, difference in reflection levels between Dutch students and foreign students approached significance favouring the Dutch students (means were 2.2, SD: .54 vs. 1.8, SD: .53, sign. < .06 for the Dutch and foreign students respectively), however these groups were relatively small (17 vs. 13 students, respectively). Average number of reflections per group was 5.5 (SD: 3.1) for the comparison group and 4.8 (SD: 4.9) for the intervention group. This difference was not significant. Apparently, students in the intervention group tended to produce more reflections than the minimum of three that was expected.

In conclusion, despite being low-key due to Covid-19, the intervention was successful in its aim to foster the quality of reflection in the SERs of the students. In two additional studies that were part of the overall project, both students and teachers valued the reflection method, implicating that there is support base for further implementation. The results also support earlier findings by Ash et al. (2005) and Kori et a, (2014), showing that quality of reflection can be enhanced by intervention. This implicates that, with relatively simple means (scaffolding questions and examples), educators can foster their students' reflective abilities. Adding feedback cycles and (peer-) interaction can further strengthen and reinforce quality of reflection.

Two important shortcomings of this study will now be addressed. Firstly, the study uses a between subject design to study the effect of the intervention. A pre-post control group design would have been a more valid test, because now we must assume that the intervention and comparison group were comparable in their initial reflective ability. However, splitting the Class of 2023 in two to create a control and comparison group was not deemed ethical because students might profit from the intervention in terms of study progress (a SER rewrite is needed when the quality of reflection is not up to par). Moreover, collecting base-rate information was deemed inappropriate because of the serious workload the students had. On the other hand, the comparison and intervention group were comparable in terms of gender distribution, Dutch/foreign nationality distribution and ATLAS admission criteria. Of course, the relevancy of these characteristics for reflective ability is not known (in fact, results showed gender and nationality were unrelated to mean level of reflection quality) and measures that could predict reflection ability were not taken, but overall it is assumed the comparison was fair.

Secondly, the reflections in the SERs were identified and coded by the main researcher. Although the coding rubric is deemed elaborate and insightful, a certain expectation on his hand could have influenced the results. Involving a second coder to assess the interrater reliability of the coding protocol would have solved this problem.

Further research and development could focus on testing the effect of a more elaborate intervention including feedback cycles and peer/teacher interaction.

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RESILIENCE AS A KEY COMPETENCE IN ENGINEERING EDUCATION – DEVELOPMENT OF A CONCEPTUAL FRAMEWORK

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ABSTRACT

Engineering graduates have to cope with dynamic and complex changes and ongoing challenges that directly affect society, for which they are jointly responsible. Accordingly, engineering education requires competencies that enable future engineers to create adaptive systems that are capable of dealing with crises and sudden disruptions. These abilities are generally referred to as resilience. The purpose of this study was to develop a conceptual framework to define and categorize resilience-related competencies in engineering education, such as flexibility, adaptability or dealing with uncertainty. Based on this framework, the extent to which resilience-related competencies are considered necessary in existing frameworks and in engineering education research can be explored.

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1 INTRODUCTION

Given the fact that climate change increases the frequency of natural disasters such as floods and hurricanes, concern about global risks is increasing and there is a great demand for sustainable, interdisciplinary solutions. Likewise, there is an agreement that risk analysis alone is not sufficient to protect threatened infrastructures from emerging disruptive events [1, 2]. Instead, those require solutions which also increase preparedness for response and recovery. This discourse is frequently summarized under resilience, which describes a system's ability to cope with sudden disturbances, to learn from them and to be adaptive.

As engineering "is a collaborative, complex activity that demands socio-technical, societal and systems perspective" [3], graduates have to cope with dynamic changes, challenges and ongoing complex problems that directly affect society, for which they are jointly responsible. Thus, there is a need for more detailed description of competencies engineering graduates should have which goes beyond basic technological knowledge and skills and also focuses on adaptation to change and complexity [3, 4].

The growing discourse on future skills of engineers often focuses on the relevance of competencies for sustainable development [5, 6]. Less in the foreground, however, are competencies that enable the handling of sudden disruptions or disasters, such as the abovementioned, earthquakes or wildfires, and the associated responsibility of engineers (see e.g. the literature review by Beagon et al. [7]). In their study on engineering habits of mind, Lucas and Hanson [8] identified resilience as one "learning habit of mind" of engineers. At the same time, studies with students showed that there are less knowledge and understanding of the relevance of resilience in context of engineering [4, 9-11]. Accordingly, Baytiyeh and Kaja [11], for example, are explicitly calling for more awareness on dealing with crises within engineering education, as engineers are jointly responsible for mitigation strategies with regard to earthquakes. With regard to competence-oriented teaching and learning as well as the integration of resilience into engineering education, however, it is first necessary to clearly define the concept of resilience and the associated relevant competencies.

For this purpose, we propose a conceptual framework, the development of which is presented in this paper. The framework is derived from theory to define and categorize resilience-related competencies in engineering education, such as flexibility, adaptability or dealing with uncertainty. Furthermore, we show how this framework can be applied on existing frameworks, such as the CDIO Syllabus.

2 THEORETICAL BACKGROUND

2.1 Definitions of Resilience

Growing discourses, definitions and publications regarding resilience have emerged in the last years. Resilience finds application in several disciplines, like ecology, psychology, geography or engineering. Holling [12] shaped the discourse by studying the behavior of ecosystems with respect to sudden disturbances. Building on this, resilience has evolved as an approach to study and understand complex adaptive systems and their behavior in response to (surprising) perturbations [13, 14]. As socio-ecological systems, like cities, are characterized by many interactions of people and their environment, complexity and change are inherent to these systems. Folke et al. [15] identified four factors which characterize resilience in socio-ecological systems: learning to live with change and uncertainty, nurturing diversity in its various forms, combining different types of knowledge for learning and creating opportunity for self-organization and cross-scale linkages. Moreover, it is important to differentiate between resilience and robustness or persistence to disturbances. “[Resilience] is also about the opportunities that disturbance opens up in terms of recombination of evolved structures and processes, renewal of the system and emergence of new trajectories. In this sense, resilience provides adaptive capacity that allow for continuous development, like a dynamic adaptive interplay between sustaining and developing with change.” [16] Accordingly, resilience is a dynamic concept based on interdisciplinary thinking and perspectives.

With regard to engineered, or socio-technical systems, the concept was expanded to “resilience engineering”, especially by Hollnagel [1, 17]. Typically understood as an exercise in problem solving, engineering design focuses on optimization of systems with regard to “known information in pursuit of maximum efficiency” [2]. In contrast to socio-ecological systems, engineered systems are based on direct human invention and construction, they are accordingly directly subject to human influence and control. Urban systems, for example, based on infrastructure and buildings, are created and maintained to provide a service to society [2].
Hollnagel [1, 17] defined four key abilities which are relevant for building resilience engineering: Responding to regular and irregular disruptions (knowing what to do – addressing the actual), monitoring which is or can become a threat in the near term (knowing what to look for – addressing the critical), learning from experience, both successes as well as failures (knowing what to expect – addressing the potential) and anticipating developments, threats and opportunities further into the future, such as potential changes, disruptions, pressures and their consequences (knowing what has happened – addressing the factual). Park et al. [2] refined these abilities as sensing, anticipation, adaptation and learning. Both approaches describe properties or abilities a resilient engineered system at least should have.

Both the socio-ecological and the socio-technical approach are illustrated especially by urban systems, as they are characterized by multiple socio-ecological and socio-technical interactions. Infrastructure, mobility or buildings are based on engineering work which directly affects people living in the respective urban area. The discourse about resilience in urban systems is called as "urban resilience", which "refers to the ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity." [18] This definition, based on a broad literature review by Meerow et al. [18], shows the dynamic approach of resilience as well as the multiple pathways to resilience.

In summary, all understandings of resilience or definitions have the following aspects in common: we consider the occurrence of a threat or disturbance, we consider systems trying to cope with that disturbance and we analyze mechanisms or capabilities (coping strategies) for how systems learn from those disturbances to provide adaptive capacity [see also 14].

2.2 Resilience-related Competencies

As resilience always describes the ability of a system to cope with disturbances, there are several concrete sub-competencies which go along with this. In their broad literature review, Francis and Bekera [19] summarized several abilities which were characterized by different definitions of resilience. These can help to divide the dynamic and sometimes complex definitions into single sub-competencies, a resilient system or individual should possess. To give a brief overview, those resilience-based competencies are for example: the ability to anticipate, to absorb, to adapt, to recover, to recognize unanticipated perturbations, to cope with stress, to response, to withstand or in general also flexibility. As mentioned before, these properties are not the same as robustness, because resilience is especially about the opportunities inherent to change, as it provides adaptive capacity for continuous development [14, 16].

Since the above definitions and key aspects regarding resilience are not all listed in the literature review by Francis and Bekera [19], the following table will serve as an illustration of how competencies for resilience can be derived from theoretical concepts.

Table 1. Examples of resilience-related competencies derived from theoretical concepts

Socio-ecological resilience	Competencies
[15, 16]	- Dealing with change - Dealing with uncertainty - Promoting diversity - Interdisciplinary thinking

	- Learning - Self-organization - Adaptive capacity
Resilience Engineering	Competencies
[1, 2, 17]	- Responding to disruptions - Monitoring of threats - Sensing - Learning - Anticipating - Adapting
Urban Resilience	Competencies
[18]	- Adapting to change - Transforming

3 CONCEPTUAL FRAMEWORK

The purpose of this study was to develop a conceptual framework for defining and characterizing resilience-related competencies in engineering education. This framework is based on two steps: At first, resilience-related competencies were be compiled. For this, several definitions of resilience were surveyed with regards to their underlying competencies. One option was shown through the literature review by Francis and Bekera [19], which was described in the theory section. Based on this step, the identified resilience-related competencies were categorized in order to specify their relevance to resilience, as it is not always clear to what extent individual competencies actually address resilience.

The authors recommend a division of resilience-related competencies into subcategories “Specific-Resilience” (SR), “General-Resilience” (GR) and “No Relevance” (NO). These are based on the following rules:

(1) Specific-Resilience: This category includes competencies that are inherent to the idea of resilience, as described in the theory section, such as “dealing with uncertainty” or “to recognize unanticipated perturbations”. The competencies in this category can be described as sufficient for characterizing resilience.

(2) General-Resilience: This category includes all competencies that are linked to resilience, like “system-thinking” or “problem solving”, but only implicitly deal with it. However, these may be necessary preconditions for practical application of resilience.

(3) No Relevance: Here, we consider competencies that do not have specific relevance to resilience, like “teamwork”. This category is only relevant when

deductively assigning all competencies, as we, for example, do with regards to the CDIO Syllabus.

The second step, categorizing resilience-related competencies, presents the most significant challenge. There are some competencies that are considered relevant in the context of engineering education and also address resilience, but do not necessarily characterize resilience on their own. This is the case, for example, with “problem solving” or “system-thinking”. In general, problem solving is a key attribute of engineers, but problem solving alone does not necessarily entail resilience.

Based on these steps, the framework was exemplarily applied using an excerpt of the CDIO Syllabus, which is explained below. By applying it to existing frameworks, it is possible to examine the extent to which resilience-related competencies are considered relevant for engineers.

The engineering education initiative CDIO (Conceive, Design, Implement and Operate) has developed a Syllabus of knowledge, skills and attitudes engineers should acquire [5, 20]. By comparison to other standards, such as the European EUR-ACE® framework standards for accreditation of engineering programs or the American Accreditation Board for Engineering and Technology (ABET) criteria, it was found that an engineering program based on the Syllabus would also meet other standards [5, 20]. Thus, we take the CDIO Syllabus and in excerpts its second section dealing with personal and professional skills as an example for the third step of the conceptual framework. The following table shows an exemplary application of the categorization of resilience-related competencies.

Table 2. Examples for categorization of resilience-based competencies in CDIO Syllabus – excerpt from chapter 2.1–2.4

Personal and professional skills and attributes	**Category**
Problem Identification and Formulation	GR
Modeling	GR
Estimation and Qualitative Analysis	SR
Analysis with Uncertainty	SR
Thinking Holistically	SR
Emergence and Interactions in Systems	SR
Initiative and the Willingness to Make Decisions in the Face of Uncertainty	SR
Creative Thinking	GR
Critical Thinking	GR
Professional Behavior	NO

The assignment to the resilience categories is also associated with a number of difficulties. The description and interpretation of competencies is often not uniform, so

that the same competence may be meant but formulated differently [6]. For example, the CDIO Syllabus is divided into chapters and categories. One category is described as “System Thinking” (2.3) with further sub-competencies like “Emergence and Interactions in Systems”. Here, it is questionable to what extent the assignment to resilience should be made based on the higher-level chapter or the more detailed lower-level competencies.
Further, biases cannot be ruled out in the classification into “specific” and “general” resilience. Others would perhaps assign “system thinking” to “specific resilience”. Therefore, it is of central importance to define resilience-related competencies uniformly, in order to be able to establish a framework for their characterization.

Applying this framework then to existing ones, such as CDIO, EUR-ACE, ABET, or even specifically to specific study program outcomes, it is thus possible to determine the extent to which resilience-related competencies are considered relevant in engineering education.

4 CONCLUSIONS

As engineering graduates will have to cope with increasing change and complex problems, competencies are needed which go beyond pure technical knowledge [3]. One possible approach can be described by resilience thinking in order to promote dealing with change and uncertainty with regard to creating resilient systems.

In this paper, relevant definitions of resilience were presented. Based on this, examples were given of how these can be divided into categories with regard to the relevance of resilience in order to be able to classify them in existing frameworks, such as the CDIO Syllabus. On the one hand, this framework can be used to examine existing frameworks or research with regard to resilience-based competencies in order to determine to what extent these are considered relevant in the context of engineering education. Furthermore, the framework can be a starting point for the implementation of these competencies in engineering curricula.

Ongoing research regarding to what extent resilience competencies are already discussed in engineering education research is based upon this framework. A next and ongoing step is to screen diploma supplements of different engineering programs at European Universities to investigate whether and how these competencies are already implemented in engineering education. On the one hand, this makes it possible to examine what relevance resilience-related competencies currently have in these study programs. Here, first of all, it must be qualitatively examined to what extent the already existing resilience-related competencies are used directly or indirectly, i.e. to what extent resilience is actually implied with these competencies. On the other hand, the results of the analysis of the diploma supplements can have implications for the universities. By applying the framework, gaps can be made visible and curricula can be further developed with regard to resilience-related competencies.

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A COLLABORATIVE ROBOT IN THE CLASSROOM: DESIGNING 21ST CENTURY ENGINEERING EDUCATION TOGETHER

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ABSTRACT

A new industrial robot found its way to the Dutch manufacturing floor: the collaborative robot (cobot). For the first time, production workers can directly interact with an industrial robot. Such human-cobot collaboration creates opportunities to improve production system productivity and flexibility. However, it raises the question how we should prepare production workers and engineers for human-cobot collaboration. The aim of this paper is to research what engineering education could prepare future production workers and engineers for human-cobot collaboration.

Since it is unclear what criteria engineering education should meet to prepare future production workers and engineers for human-cobot collaboration, we researched what knowledge, skills, abilities, and other characteristics (KSAOs) are relevant for creating and maintaining human-cobot collaboration. We used the O*NET Content Model to search 60 interviews on cobot implementation in Dutch industry for cobot-related KSAOs. We discovered how 31 KSAOs were relevant for the design, programming, operation, and reparation of human-cobot collaboration and how these were divided amongst production workers and engineers. The repair KSAOs were mastered by both production workers and engineers. Most of the design and programming KSAOs were mastered by engineers. The operation KSAOs were mastered by production workers.

Based on these results and the effort of two community colleges, three manufacturers, a system integrator and two research groups, a 240-hour vocational education course on human-cobot collaboration was designed. In the discussion section, we illustrate how engineering education can be kept up-to-date when educators, scientists, and practitioners unite in a community of practice and design education together.

INTRODUCTION

European manufacturers are experimenting with a new type of industrial robot: the collaborative robot arm (cobot) [1-3]. The cobot is smaller, weaker, and shorter than other industrial robots. Nonetheless, it is more accurate and easier to program [4]. Manufacturers use cobots to load and unload machines, pack boxes, glue and weld objects, and assemble products [5-7]. These cobots execute simple and repetitive tasks, often around the clock. Although these cobots are used as (semi) autonomous robots, production workers and engineers still play an important role in the production system.

Production workers are increasingly responsible for operating the cobot next to their other production tasks [8]. They provide the cobot with products, activate the cobot, and process the products handled by the cobot. Furthermore, they solve small cobot errors. Engineers, on the other hand, are often responsible for installing the cobot, integrating it into the production system, and solving cobot errors that could not be solved by the production workers. To prepare their production workers and engineers for the creation and maintenance of such 'human-cobot collaboration', manufacturers organize different types of facilitating conditions. These conditions vary from info sessions, to formal and informal training and workplace assistance. Knowing how manufacturers prepare their production workers and engineers for human-cobot collaboration is not only helpful to other manufacturers who want to implement cobots. Engineering education could benefit too. The question our local engineering educators are having is: what engineering education prepares future production workers and engineers for human-cobot collaboration?

Until recently, cobots could not be found in the engineering education of our local community colleges and university of applied sciences. However, the number of cobots in industry is rising [9-10]. To prepare their students – the next generation of production workers and engineers – for human-cobot collaboration, these educators want to include cobot education into their curricula. Currently, they are creating cobot education. They, however, have trouble finding relevant content, are unfamiliar with the cobot technology and lack clear best practices from industry. Furthermore, the cobot research oversteps the capability requirements human-cobot collaboration comes with [11].

To achieve our goal, research what engineering education could prepare future production workers and engineers for human-cobot collaboration, we must have a clear understanding what knowledge, skills, abilities, and other characteristics (KSAOs) current production workers and engineers need to create and maintain a human-cobot collaboration [12-13]. Knowledge refers to all procedural and declarative facts and information one memorizes [14]. Skills reflect all work-related and general behaviours one could enact [15]. Abilities are one's physical, mental and perceptual capacities to enact and sustain a particular skill [16]. Other characteristics refer to actor-related traits, such as personality and interests [17]. We formulated the following research question: *which KSAOs do production workers and engineers in Dutch industry need given their responsibilities for creating and maintaining human-cobot collaboration?*

METHODOLOGY

To discover the KSAOs relevant for creating and maintaining human-cobot collaboration, we used the data from our prior research on human-cobot collaboration in Dutch industry [8]. The study included 21 manufacturers having working experience with cobots. Using a semi-structured interview protocol, we asked engineers (N=29), line managers (N=11), and production workers (N=20) what their human-cobot collaboration looked like and how these collaborations were implemented. The interviews were recorded and converted into verbatim transcripts.

The O*NET Content Model [18] was used to code the transcripts. The model captures a number of theories, such as Theory of Work Adjustment [19], to describe occupations and workers. We considered the O*NET Content Model comprehensive and suitable for this research as it was used for describing over 1,000 occupations and its workers both inside and outside industry. In this research, we focus on the model's worker-oriented descriptors: worker characteristics and worker requirements – we excluded worker experience since we had insufficient data to determine interviewees' experiential backgrounds. The work characteristics and worker requirements descriptors comprise eight variables (e.g., knowledge), 30 sub-variables (e.g., Manufacturing and Production), and 70 indicators (e.g., production and processing).

Since the KSAO variables, sub-variables, and indicators were provided by the O*NET Content Model, we used a deductive coding method [20] to analyse the data. Prior to the analyses, a coding structure was created using the above-mentioned variables, sub-variables, and indicators. In the structure, a distinction was made between production worker KSAOs and engineer KSAOs. The coding structure was imported into the coding software tool Atlas.TI. In total, three researchers used the coding structure to analyse a part of the transcripts. They mainly coded the tasks production workers and engineers executed to create and maintain a human-cobot collaboration. In line with thematic analysis [20], the transcripts were analysed in three steps. First, the variables under study were used to deduct relevant quotes from the transcripts (e.g., "… production workers should have basic understanding about the cobot's movement" was linked to "Knowledge"). Second, per variable, the quotations were linked to the sub-variables (e.g., 'Engineering and Technology'). Third, per sub-variable, the quotations were linked to an indicator (e.g., 'Mechanical Knowledge'). The researchers compared their outcomes to determine the production worker KSAOs and engineer KSAOs. Since the deducted KSAOs clustered around a part of the human-cobot collaboration, four characteristic groups we created.

RESULTS

In total, we found 31 KSAOs relevant to the creation and maintenance of human-cobot collaboration. We clustered these into four characteristics groups: design characteristics, program characteristics, operate characteristics, and repair characteristics. Table 1 (page 4) provides an overview.

Cluster 1: Design characteristics

This cluster captures all KSAOs to create a human-cobot collaboration design. Engineers used their *production and processing knowledge* and *operations analysis skills* to thoroughly analyse the production system the cobot would be implemented into. Furthermore, they used their *engineering and technology knowledge* to understand cobot and cobot tooling specifications and how both could be used in practice (e.g., by searching for online use cases). Based on the analyses, engineers used their *originality ability* to come up with feasible human-cobot collaboration designs. They used their *equipment selection skills* to select the cobot tooling most suitable to their designs. Once the design was ready, engineers presented the designs to the production workers using their *speaking skills* (e.g., through images or videos). Production workers were asked to review the design and propose alternatives. Production workers used their *fluency of ideas ability* to come up with a number of preferred human-cobot collaborations. Engineers used their *active listening skills* to understand the production workers' input.

Cluster 2: Program Characteristics

This cluster captures all KSAOs to install and program the human-cobot collaboration. Since only engineers installed the cobot and wrote the cobot programs, this cluster appeals to engineers exclusively. Engineers used their *engineering and technology knowledge* about the cobot hardware and machine programming to install and program the cobot. By using their *installation skills*, they unboxed the cobot, its transformer and controller, and assembled these onto the workstation. Next, they attached the tooling to the cobot, wired it to the cobot and transformer, installed the software, and centred the cobot. Once the cobot was installed, they wrote the program underlying the cobot application using their *programming skills*. During the installation and programming, complex cobot error occurred (e.g., miscommunication between the cobot and a CNC machine). Engineers had to use their *complex problem-solving skills* and *inductive reasoning ability* to give meaning to these errors, search for their cause, and come up with a solution. Once programmed, engineers trained production workers for their role (Cluster 3) in the human-cobot collaboration using their *instructing skills*.

Table 1. Overview of Characteristic Clusters and KSAOs

Cluster 1: Design Characteristics			
KSAO	*Sub-Variable*	*Relevant to Engineers*	*Relevant to Production Workers*
Knowledge	Production and Processing	X	-
Knowledge	Engineering and Technology	X	-
Skills	Operations Analysis	X	-
Skills	Equipment Selection	X	-
Skills	Speaking	X	-
Skills	Active Listening	X	-
Abilities	Originality	X	-
Abilities	Fluency of Ideas	-	X
Cluster 2: Program Characteristics			
KSAO	*Sub-Variable*	*Relevant to Engineers*	*Relevant to Production Workers*
Knowledge	Engineering and Technology	X	-
Skills	Complex Problem Solving	X	-
Skills	Installation	X	-
Skills	Programming	X	-
Skills	Instructing	X	-
Abilities	Inductive Reasoning	X	-
Cluster 3: Operate Characteristics			
KSAO	*Sub-Variable*	*Relevant to Engineers*	*Relevant to Production Workers*
Knowledge	Mechanical	-	X
Skills	Operation and Control	-	X
Skills	Time Management	-	X
Abilities	Reaction Time	-	X
Abilities	Visualization	-	X
Abilities	Problem Sensitivity	-	X
Abilities	Spatial Orientation	-	X
Abilities	Manual Dexterity	-	X
Other Characteristics	Self-Control	-	X
Cluster 4: Repair Characteristics			
KSAO	*Sub-Variable*	*Relevant to Engineers*	*Relevant to Production Workers*
Knowledge	Engineering and Technology	X	-

Knowledge	Mechanical	-	X
Skills	Complex Problem Solving	XX²	X
Skills	Troubleshooting	XX²	X
Skills	Repairing	XX²	X
Abilities	Reaction Time	-	X
Abilities	Deductive Reasoning	-	X
Abilities	Inductive Reasoning	X	-

²XX = Engineers should master this KSAO in a more advanced level compared to production workers.

Cluster 3: Operate Characteristics

This cluster captures all KSAOs to operating the human-cobot collaboration and preventing it from falling into a standstill. In contrast to the program capacities, the operate characteristics appeals to production workers exclusively. They used their *mechanical knowledge* to operate the cobot, supply the cobot with parts, and determine what a well-functioning cobot looks like (e.g., movements, appearance). They used their *manual dexterity ability* to precisely place parts for the cobot to handle in a designated pick-up area. Once handled, the production worker used the same skill to collect the products from the drop-off area. Using their *operation and control skills*, production workers switched-on the cobot, used the controller to select one of the prewritten programs, and press the start button. Since most cobots under study used one of a few programs, production workers had to changeover the cobot rarely.

To prevent the cobot from falling into a standstill, production workers had to timely load and unload the cobot using their *reaction time ability*. Furthermore, they used their *spatial orientation ability* prevent themselves from colliding with the cobot and causing it to stop. To monitor the cobot's performance, they used their mechanical knowledge, operation and control skills, and *visualization ability* to create a mental image telling them when the cobot functions well. Their *problem sensibility ability* helped production workers to predict if the cobot would run into a standstill. In addition, since most production workers ran parallel tasks when the cobot was running its program, they had to use their *time management skills* to plan when they would execute their cobot and parallel tasks without letting the one overshadowing the other. Finally, production workers had to have the *self-control* to work with the cobot. They had to perceive it as a tool that would help them to do a better job and not hinder or destruct it.

Cluster 4: Repair Characteristics

This cluster captures all KSAOs to reactivate the cobot once fallen into a standstill. Production workers used their *reaction time ability* to troubleshoot and, when possible, repair the cobot as soon as an error occurred. They used their *mechanical knowledge* to follow the prescribed troubleshooting and repair procedures. With their *troubleshooting skill* they would visually inspect the state of the cobot, the tooling, and parts being handled. Their *deductive reasoning ability* and *complex problem-solving skills* allowed production workers to define the cause of the basic issue and apply standardized repair duties accordingly. The production workers' *repair skills* knew two degrees of freedom: rebooting the cobot using its power switch and reselecting the program. In case these repair efforts did not solve the issue, the engineers would be called to the scene and took over.

The engineers would use their in-depth *engineering and technology knowledge* about the cobot's hardware and software to troubleshoot and solve cobot errors that could not be solved by the production worker. Engineers would not only inspect the scene visually but also digitally (e.g., reading the history on controller and checking the program). Since engineers faced a wide variety of more complex errors that could go beyond general rules, procedures, and guidelines, they had to highly rely on their *inductive reason ability* to solve these. In addition, the complexity of the errors also required the engineers to have more complex problem-solving and repair skills compared to production workers.

CONCLUSION & DISCUSSION

In this study, we asked ourselves the question what engineering education prepares future production workers and engineers for human-cobot collaboration. Since it is unclear what KSAOs production workers and engineers should master to create and maintain a human-cobot collaboration, we used the O*NET Content Model [18] to analyse 60 transcripts about cobot implementation in Dutch industry. We found 31 KSAOs relevant to the creation and maintenance of human-cobot collaboration. We were able to group the KSAOs into four categories and connect these to production workers, engineers, or both. Our results revealed a classic distinction between production worker and engineer responsibilities: the engineer (together with management) determines the machine's application, implements the machine, and solves complex errors; the production worker operates the machine and solves errors using detailed instructions [21-23].

Cobot education provided to future production workers should develop them into *cobot operators*. Cobot operators are willing to work with the cobot, can think along with engineers about the cobot's application, can prepare and maintain the cobot and its workstation according to instructions, can solve and communicate cobot errors, and are able to manage multiple production systems. The cobot operators should learn the following: the use of the cobots' control panel, cobot (dis)functioning, cobot loading and unloading, and basic cobot troubleshooting.

Cobot education provided to future engineers should prepare them to become *cobot programmers*. Cobot programmers are able to determine which cobot application and tooling are best given the state of the production system, build cobot programs from scratch, integrate the cobot with other machines and devices, develop the social skills to engage and instruct cobot operators, and solve complex cobot errors. The cobot programmers should be educated about the following: the cobot and tooling specifications, the cobot programming language, cobot input and output management, and expert cobot troubleshooting. In addition, they should learn how to thoroughly analyse a production system and conduct professional conversations.

Designing 21st Century Engineering Education Together

In the latter part of our contribution, we illustrate how we used our results to develop engineering education that prepares vocational education student, the next generation of production workers, for human-cobot collaboration. We used the educational design model [24] to structure the development process. The model uses an *iterative* process consisting three stages, namely: 1) exploration, 2) design, and 3) evaluation.

In order to translate the needed KSAOs for cobot operators, as mentioned before, we formed a *community of practice*. The community of practice comprised the following members: six vocational education teachers from two different community colleges with different technical backgrounds (mechatronics, ICT, laser technique), four researchers from two research groups specialized in HRM, industrial design, and mechatronics, two educational designers, three practitioners from technical companies, and a cobot integrator. The diverse expertise in this community of practice allowed us to embed all required KSAOs in our engineering education and align it with industrial practice.

Phase 1: Exploration of the Current Situation
During the first meetings with the community of practice, we reflected on the 16 KSAOs relevant to production workers working with a cobot. We asked the members to elaborate on two questions: how do these KSAOs match the prior knowledge of students and how should we, as a community of practice, educate the missing KSAOs? We asked educators how they wanted to embed the cobot education into their engineering education system. Since creating a completely new course and redesigning the community colleges' engineering education programs were considered too time-consuming by the educators, we picked an existing 240-hour elective module called Working with an industrial robot. The elective module came with two advantages. First, the elective module was already certified and came with clear-cut learning goals and exam criteria which allowed us to place more focus on developing course content. Second, the elective module's learning goals and exam criteria were in line with the KSAOs relevant to production workers working with a cobot. This alignment allowed us to build course content that could prepare students for human-cobot collaboration without violating the elective module's goals and criteria.

Phase 2: Designing Cobot Education Content
Based on the insights obtained in the exploration phase (phase 1), we created the content for our elective course. Since we found both knowledge and practical KSAOs, a hybrid learning environment was considered optimal. A hybrid learning environment is authentic and situated [25]. It combines the advantages of school-based and workplace learning arrangements by binding these intersecting practices together, without losing the strength of either. A hybrid learning environment combines two learning dimensions. The first dimension is about the learning processes that are to be embedded in vocational education and varies from *acquisition* (knowledge is considered as a commodity that can be acquired, transferred and shared) to *participation* (learning as growing into becoming a full member of a professional community). The second dimension is about the conditions under which the learning process can take place in vocational education and varies from *constructed* (near work exercises like cases and simulations) to *realistic* (how novices participate in authentic work).

The dimensions of a hybrid learning environment were used to structure our elective module, as shown in Table 2. In part A, students' learn about cobots and their applications in a class setting (e.g., images, video's, MOOCs, story-telling). Part B takes place in the workshop and the classroom. In the workshop, students will witness educator-lead cobot demonstrations to experience the cobot's functionalities, programming, and safety measures. In the classroom, the students will work on online cobot programming assignments. In part C, taking place in the workshop, students will apply and improve their cobot KSAOs by working together with a cobot in a mock-up assembly line.

Table 2. Content and corresponding aspects of hybrid learning in the course.

Part A: An introduction to human-cobot collaboration	**Part B: Functionalities of a cobot**	**Part C: Working with a cobot in experimental set-ups**
Basic knowledge of the (kinds of) cobots, introduction to smart industry, differences of a robot/cobot, ethical questions and impact of work	Basic knowledge about working with a cobot, types of cobots and components, basic of programming (computational thinking), safety and applications of the cobot in business contexts	Working with human-cobot collaboration in realistic situations, experimenting with self-designed cobot applications, and recognize and correcting malfunctions with cobots
Constructed acquisition Illustrating theoretical concepts; contextualization of concepts in the form of examples in textbooks by using pictures of video's. *Example: e-learning about the knowledge needed, i.e. parts of the cobot.*	**Realistic acquisition** Learning processes under realistic conditions, to make wok process knowledge explicit (reflective practice). *Example: small assignments about programming a cobot, in which theory is translated to practice.*	**Realistic participation** Learning through work experience or on-the-job learning; at school grounds or at the workplace. *Example: final assignment based on a realistic example of the workplace or short internship; solving a problem in human-cobot collaboration.*
Constructed participation Elements of the rich reality of the professional practice are present, but not entirely. Parts are for example left out , simplified of simulated. *Example: (digital) simulations to practice working with a cobot or semi-structured assignments.*		

Phase 3: Improving the design

Designing an elective course on human-cobot collaboration was an iterative process and relied heavily on the members in the community of practice. The network meetings served as great moments to reflect on what was designed and compare it to new experiences in work and experiments with students. During the design process, five vocational education students tested the designed content, assignments and applications with cobots. We did this to gain a first understanding on how vocational education students deal with the course content and to learn what support they needed from their educator. It seemed that – most of the time – the students found it quite simple to work with basic aspects of the cobot (e.g., activating a cobot program). Furthermore, the occurrence of cobot-related errors showed to be a great opportunity for students to translate their learned knowledge about cobots into practice and use it for troubleshooting. It also stimulated their the fluency of ideas as they provided suggestions for optimizing their human-cobot collaboration.

Another aspect which seemed to be very important, is to have a digital platform that is accessible to all member in the community of practice. Such a platform was in our case needed to share expertise and course content across institutions. The design process resulted in long-term partnerships between education, practice, and science.

With this study, we contributed to the engineering education community and industrial practice by specifying the KSAOs production workers and engineers need to work with a collaborative robot. Furthermore, together with two community colleges, three manufacturers, a system integrator and two research groups, we developed a 240-hour vocational education course on human-cobot collaboration. Co-creating education and a pioneering mindset proved to be of great value and a necessity to keep engineering education up-to-date. We are looking forward to launching our cobot education in the Fall of 2021 and report upon our findings in a follow-up contribution.

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Concept Papers

ordered alphabetically
by first author

DEVELOPMENT OF ONLINE LEARNING PRACTICES IN A JAPANESE UNIVERSITY BASED ON THE QUESTIONNAIRE SURVEYS

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Conference Key Areas: *Online assessments, Changes beyond Covid-19*
Keywords: *COVID-19, Faculty survey, Online/blended learning, Student survey*

ABSTRACT

This study aims to clarify the development of online learning practice of engineering education in a Japanese university under the pandemic of the COVID-19. The research question is how online learning , especially blended learning, was practiced. By 2020, advances in Internet technology and its widespread use had already formed the basis for online classes. However, face-to-face classes were the mainstream, and there were few online classes for undergraduate education. We will present the development of online learning at a Japanese university, which is a private technical university in the bay area of Tokyo, Japan, as an example. This university had conducted all classes online in the first semester of 2020. The transition to online classes was unexpected, and classes started in May, a month late. In the second semester, some classes were face-to-face, while many classes were online. We will present:

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1. how progressed the teaching style to blended learning,
2. how changed the students' understanding of classes,
3. how changed the students' satisfaction level of classes.

The significant difference is that blended learning started in the second semester. The understanding and satisfaction of the students have improved in the second semester. The background of this development is also that the faculty, administrators, and students collaborated to work on education innovation.

1 INTRODUCTION

There are two challenges facing engineering education today. One is the promotion of digitalization toward the pandemic of COVID-19. Universities around the world are currently taking various steps toward the digitization of higher education. According to a study by Crawford et al., higher education institutions worldwide respond that some universities have no response at all, while others have a strategy of closing campuses and redeveloping a complete online curriculum [1]. The other is integration with the Sustainable Development Goals (SDGs) and emerging technologies and employability and lifelong learning. Editor of the European Journal of Engineering Education says, "With all the challenges lining up, engineering education in 2030 will require a student-centered and flexible curriculum, personalized learning environments and transformation of learning experiences into students' competences. [2]" The two issues are interconnected. The case of a German university reports that COVID-19 promotes the digitization of university education [3]. A study by the British Computer Science Education Community reports that COVID-19 has a significant impact not only negative but also positive on all stages of education [4]. In the United States, the Chronicle of Higher Education surveyed faculty members and academic administrators. Half of the faculty members do not have sufficient experience in online learning , then training on online learning is emphasized [5]. In engineering education, a survey of university faculty and students conducted at a state university in Long Beach, California, reports on the challenges of university education in the COVID-19 disaster [6]. The COVID-19 has also provided an opportunity for universities to innovate.

Regarding Japan, Kang reports in detail on higher education as of the spring of 2020 based on the Ministry of Education, Culture, Sports, Science and Technology (MEXT) surveys [7]. In Japan, the semester begins on April 1st. However, according to a survey by the MEXT, 86.9% of universities and colleges postponed the start. Furthermore, although the semester started about a month later, 90.0% of the universities and colleges had only distance classes. Although distance learning started relatively smoothly in response to a sudden situation, the quality of education was questioned by students and the MEXT. A Japanese university began a survey on distance learning in June 2020. Details will be described in the next section. The results of the June survey were reported at the IEEE International Conference on Teaching, Assessment, and Learning for Engineering (IEEE TALE) [8]. In addition, faculty members and administrators held a workshop meeting on online learning on campus periodically. It was also an opportunity for professional development who need the skills of online learning . MEXT introduced the efforts of this university to improve the quality of teaching using online as an excellent example [9]. In engineering education at a graduate school in Spain, they report that the shift from face-to-face to blended and full-online learning has improved the number of enrollments, students' satisfaction, and academic performance [10]. In this presentation, we will report on the practice at a Japanese university in Japan.

2 METHODOLOGY

As shown in Table 1, this university conducted five "Surveys on Distance Learning" in 2020 academic year. These surveys were anonymous questionnaire surveys using a website. The first survey was conducted on faculty members from June 10 to 20 of the first semester, one month after classes. We received responses from 466 faculty members (78.1% response rate). The second survey was conducted on faculty members from August 19 to 31 after the first semester ended, and 390 faculty members responded (60.9% response rate). The third survey was conducted on students from August 27 to September 3. Responses were received from 3,616 students (40.1% response rate). The fourth survey was conducted from February 12 to 19 after the end of the second semester. 310 faculty members responded (48.4% response rate). The fifth survey was conducted on students from February 16 to March 2. Responses were received from 4,416 students (49.0% response rate). Faculty members include part-time lecturers. Students include full-time undergraduate and graduate students. We prepared both Japanese and English versions of the questionnaires.

Table 1. Questionnaire survey on distance learning in 2020 academic year

Web survey	Survey target	Survey period	Number of respondents (response rate)
First semester June	Faculty member (inc. part-time)	June 10-20, 2020	468 (78.1%)
First semester Aug.	Faculty member (inc. part-time)	Aug. 19-31 , 2020	390 (60.9%)
	Student (Inc. graduate students)	Aug. 27-Sept. 3, 2020	3,616(40.1%)
Second semester	Faculty member (inc. part-time)	Feb. 12-19, 2021	310(48.4%)
	Student (Inc. graduate students)	Feb. 16-Mar. 2, 2021	4,416(49.0%)

3 RESULTS

The following three points show the development of online learning. First is the progress of the teaching style. The first survey focused on only conducting online teaching. After that, the horizons expanded to flipped classrooms and blended learning. The next is the students' understanding and satisfaction with the classes. Did the introduction of flipped classrooms and blended learning improve the understanding and satisfaction of the classes?

3.1 Progress of teaching style

The development of online learning practice in this university is reflected in the progress of teaching style. We asked faculty members about the teaching style each time they surveyed. Question options were updated with each survey, receiving feedback from the progress of distance learning. As shown in Figure 1., in the first semester June survey, there were three options for the teaching style, and we asked multiple answers. 90% of university faculty members are live. In the first semester August survey, there were four options. Practices such as flipped classroom that combine on-demand and live have been added. Then, the faculty members selected one main teaching style for each of the lectures, seminars, and experiments, practical training. The live type accounts for the majority, and is the most common. However, flipped classroom are practiced in 12% of lectures, 13% of seminars, and 20% of experiments, practical training. Classes only on demand are few in lectures (11%), seminars (4%), and experiments, practical training (11%). In the second semester survey, there were five options. Blended learning, which combines face-to-face and online learning, has been added. Although it is as low as 6% in lectures, it accounts for 31% of seminars and 44% of experiments, practical training.

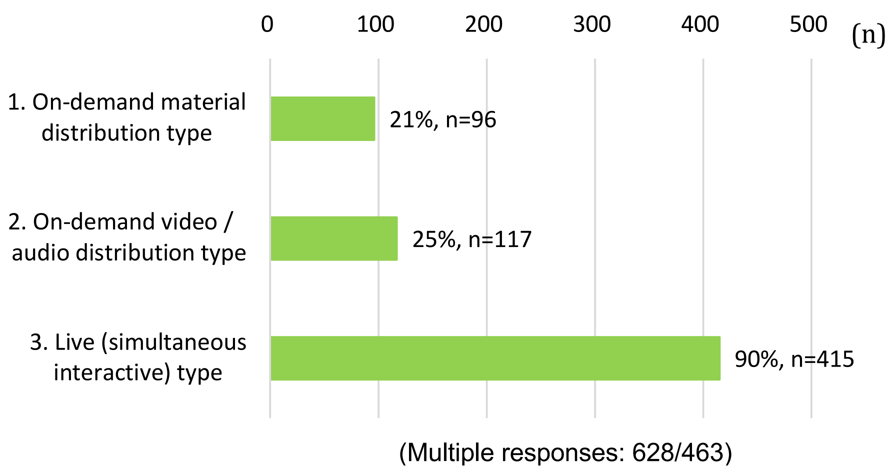

Fig. 1-1. Main teaching style (first semester June, faculty members survey)

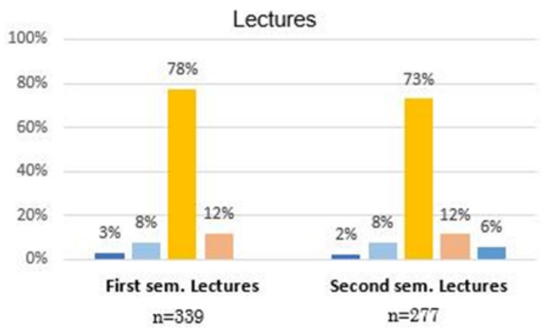

Fig. 1-2. Main teaching style of lectures (first semester Aug. and second semester)

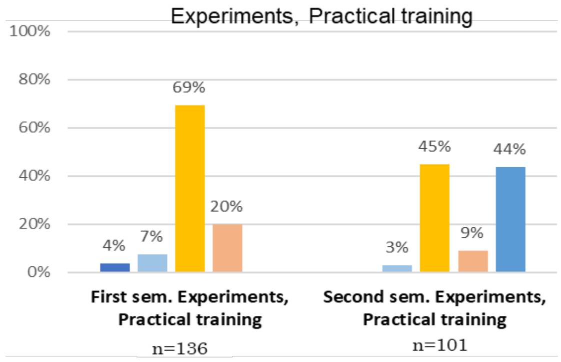

Fig. 1-4. Main teaching style of experiments and practical training (first semester Aug. and second semester)

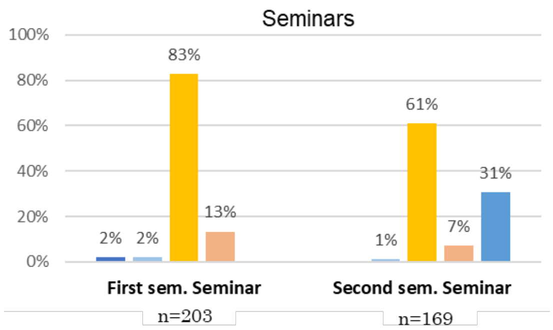

Fig. 1-3. Main teaching style of seminars (first semester Aug. and second semester)

graph legends of Fig. 1-2, 1-3, 1-4

1. On-demand (asynchronous) material distribution type
2. On-demand (asynchronous) video / audio distribution type
3. Live (simultaneous interactive)type
4. Combine live (simultaneous interactive) and on-demand: flipped classroom, etc.
5. Combine face-to-face and live (simultaneous interactive): blended learning, etc.

3.2 Students' understanding of the class

The development of online learning practice in this university is reflected in students' understanding of the class. From the first semester to the second semester, students' understanding of the class increased. This is most evident in seminars. The change in the percentage of "Very good" as indicated by the red circle in Fig.2 shows students' understanding of the class. The percentage of "Very good" increased by 6 points for lectures, 11 points for seminars, and 4 points for experiments, practical training. And the percentage of "Bad" and "Not good" decreased.

3.3 Students' satisfaction of the class

The development of online learning practices in this university is also reflected in the students' satisfaction of the class. From the first semester to the second semester, students' satisfaction increased. This is most evident in seminars. The change in the percentage of "Very satisfied" classes as indicated by the red circle in Fig. 3 shows the increase of students' satisfaction of the class. The percentage of "Very satisfied" increased by 6 points for lectures, 10 points for seminars, and 2 points for experiments, practical training. And the percentages of "Very dissatisfied" and "Dissatisfied" decreased.

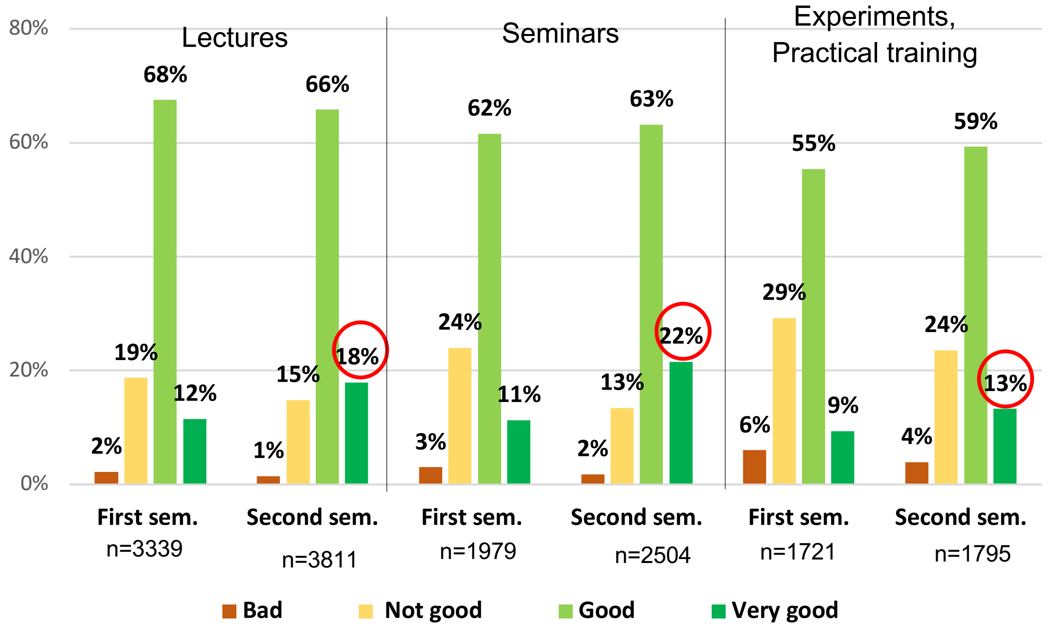

Fig. 2. Students' understanding of the class (first semester Aug. and second semester)

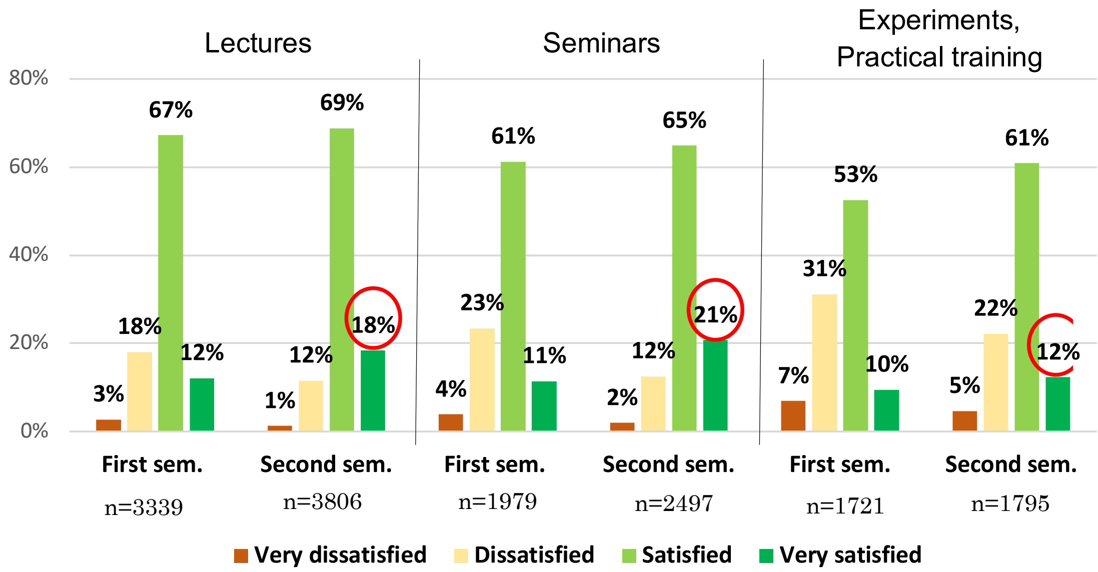

Fig. 3. Students' satisfaction of the class (first semester Aug. and second semester)

4 DISCUSSION

The pandemic of COVID-19 has brought the university an unexpected response to the implementation of full distance learning. It is also related to the Sustainable Development Goals (SDGs) and emerging technologies, employability and lifelong learning. Editor of the European Journal of Engineering Education said, "With all the challenges lining up, engineering education in 2030 will require a student-centered and flexible curriculum, personalized learning environments and transformation of learning experiences into students' competences. [2] "

In this study, we reported on the progress of teaching style from a large-scale questionnaire survey conducted to faculty members and students at a private technical university in Tokyo bay area, Japan. The teaching style has expanded from only online teaching to flipped classrooms and blended learning. Students' understanding the class and satisfaction of the class both improved in the second semester after introducing blended learning. The effect was particularly obvious to the seminars. In this university, faculty members and administrators held a workshop meeting on online teaching periodically. These organizational efforts may be reflected in the background of the development of online learning in this university. Further progress is desired toward the realization of engineering education in 2030.

5 ACKNOWLEDGMENTS

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STUDENTS' BEHAVIOUR IN GROUP DISCUSSIONS DURING ONLINE TEACHING

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Keywords: *Online teaching, group discussions, active learning, students' perception, qualitative data.*

ABSTRACT

Group discussions are used as a tool to increase student activity. In this paper students' behaviour in group discussions during online teaching is investigated. The students' activity and participation in the group conversations led the teachers to believe the online learning activities were successful, however, an anonymous questionnaire uncovered that many students had challenges and were uncomfortable in the situation. This study was done in a preparatory physics course for engineering education where the majority of the 56 students have a vocational background. The questionnaire contained both quantitative and qualitative questions and 27 of the students responded. The qualitative data were analysed with inspiration from the constant comparative method of analysis. This systematic analysis resulted in categorising the students' behaviour as either taking actions, that promote learning, or as dominated by a lack of initiative, something that hampers learning. A relationship between the students' use of webcams and behaviour that promotes learning is found. Further, the students who use webcams perceive the students who do not use webcams as passive and less interested in learning. This paper aims to shed light on challenges perceived by the students in an online teaching format.

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1 INTRODUCTION

1.1 The background for this study

For the autumn semester of 2020, the two authors designed online teaching activities in a preparatory physics course for engineering educations adapted to the covid-19 situation. The aim was to create a learning environment where the students have productive discussions in groups. Most of the students have a vocational background, and it is several years since they went to school. Usually, these students would have all classes on the campus. Instead, the students had a three hours session of online teaching activities two days a week, and one day a week the students met at the campus for a two hours session of group work with their cohort, a smaller group, according to the covid-regulations at the time. In the campus sessions, the students performed practical experiments aimed at improving their understanding of physical concepts. Before the online teaching activities, the students watched recommended learning videos. During the online sessions, the students discussed topics from the videos using guided questions and worked with calculus-based exercises. The discussions took place in smaller groups, which were created randomly using the breakout rooms function in Zoom. The same groups were kept during a three hours session, and the students were guided through the session by the teacher who alternated between group work in breakout rooms and giving explanations or summaries in the plenum. This teaching method was explained in several ways, by a written document, verbally in class, and a video. During the online sessions, the students were encouraged to use the chat, a webcam, and their microphone. In plenum many students used the chat, approximately half the students used a webcam, but no one used their microphone. In the breakout rooms, more students used their webcams, and they discussed verbally.

Based on the students' activity and the conversations in the groups, the teachers found the online learning activities successful, however, in the first meeting with the reference group (following the university's system for the quality assurance of education [1]), it became clear that some of the students did not like the online sessions. Students had reported misliking the use of random breakout rooms.

Two teachers (the authors of this paper) shared the responsibility for this class, both have an interest in developing group work sessions for the students to learn collaboratively. We noticed that it was always the same students who used a webcam, and these students appeared more active just because of this. Since students had reported misliking the online group discussions we were interested in how these were perceived, and the possibility to take action. We, therefore, decided to investigate the following research questions:

How do the students perceive the online group discussions?

How is the use of a webcam related to the students' participation?

1.2 Theoretical framework

This study is placed in the sociocultural view of learning where students actively learn together through interactions and compromises using language according to the learning theory of Vygotsky [2,3]. Our intention by planning for the students to work in groups was to promote active learning since active learning is found to improve students performance [4]. We think of active learning as defined by Freeman et al. "*Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work"* p. 8413 in [4]. Both the online group discussions and the sessions at the campus were designed for collaborative learning, that is, a specific kind of group work, in which the students actively work together on the same task, where the intention is for the students to learn together [5].

2 METHODOLOGY

2.1 Data collection

Data was collected through an anonymous online questionnaire, which was sent to the students by e-mail. To get detailed and rich information about the students' experiences the main emphasis was on open questions in combination with some closed questions. As conferring Robson and McCartan [6] p. 272, "*the main purpose is to simplify many individual responses by classifying them into a smaller number of groups, each including responses that are similar in content"*. The questions were:

About the use of webcam:

- Do you use a webcam? (Options: Yes/No)
- Why? (Text answer)

About the online group discussions:

- How have the breakout rooms worked for you? (Text answer)
- How often do you start talking in the breakout rooms? (Options: Always/ Often/Sometimes/Almost never/Never)
- What is the reason for your answer? (Text answer)

This is a small scale study out of the 56 students, 27 responded over a week.

2.2 Method of analysis

We followed a standard procedure to copy all responses to a particular question on a large sheet of paper [6], that is, all responses of *always* to the question *How often do you start talking in the breakout rooms?* were put together with the corresponding answers to the open questions *How have the breakout rooms worked for you?* and *What is the reason for your answer?* Hence the questions concerning the breakout rooms were divided into five sheets of paper one for each of the options. A similar procedure was used for the questions about the use of a webcam.

The basic principles of the constant comparison method guided our analysis [7]. In short, using the constant comparative method the researcher compares data to form codes, codes are compared to form categories, which then again are compared to form a core category [7]. As the researcher is going through the three phases of the constant comparative method, more and more abstract categories are generated, and a theory is developed when data is reduced to concepts. We did the first phase, open coding, separately, asking ourselves “What is this the case of?” or “What is the student expressing by this?”. We went through the students’ answers one sentence at a time and attached codes to the sentences, a code could be in the form of a sentence describing our reflection over what the student is expressing. In the second phase, axial coding, the researcher makes connections between the codes from the first phase. We extracted our preliminary categories separately before we met for a discussion. In practice we read out loud the students’ answers, discussed our codes from the first phase before we did a thorough comparison of our codes, to create a common set of categories in the second phase. After comparing categories to codes for each of the five sheets corresponding to *How often do you start talking in the breakout rooms?* we compared categories to find the main categories in the third phase, and we quantitatively compared how many of the students used a webcam. Hence on our way to the third phase, the selective coding phase, where the main categories are extracted from the data we discussed and reflected together during the process of analysis. The result was a shared and deeper understanding of the students’ answers and a common set of categories. In addition, we recorded our conversations, something which was helpful when writing the results afterwards and summing up on the developed theory grounded in the data. A theory grounded in the data is here understood as the connection between the main categories, which are students having: *A behaviour that promotes learning* (section 3.1), *A behaviour that may promote learning occasionally* (section 3.2), and *A behaviour dominated by a lack of initiative* (section 3.3). These main categories explain the students’ behaviour in the breakout rooms seen in the light of their use of a webcam. Students’ reasons for not using a webcam are described in the last main category: *Reasons for avoiding the use of a webcam* (section 3.4).

2.3 Ethical considerations and quality

The students were informed verbally and in writing at the beginning of the questionnaire that their anonymous answers could be used for research and development purposes. Further, it was voluntary to give answers. To ensure the quality of the work, all students in the class received an earlier version of this paper by e-mail with an invitation to give feedback. One student replied with a confirmation of our description.

3 RESULTS

An overview of the quantitative data is shown in Table 1, where the number of answers to *How often do you start talking in the breakout rooms?* is shown together with the number of students answering *yes* to *Do you use a webcam?*

Table 1. Quantitative answers.

	Always	Often	Sometimes	Almost never	Never
Starting talking	1	12	8	4	2
Yes to webcam	1	9	2	1	0

We see the number of students using a webcam is higher for those who start talking *always* and *often* as compared to the rest of the students. This is indicating a more active attitude among these students.

3.1 A behaviour that promotes learning

The students answering *always* or *often* write explanations showing that they take responsibility for their own and other students' learning by initiating a discussion, thus exhibiting a behaviour that promotes learning. As expressed by this student, *"I like to participate in discussions, and is happy to start them if no one else is talking"*. Or by another student answering: *"The breakout rooms have worked quite well, but I wish everyone was more active".* The students in this category seem to have recognized the benefit from sociocultural learning activities*, "I feel I can contribute to my group, and I know I learn from discussing the exercises in physics".*

Even though these students take action by initiating discussions they still prefer to work together with students from their cohort. *"I have a low outcome from discussions with students I don't know, as they often participate very little in the collaboration. There is a big difference from working with someone you know".* Or as this student expresses: *"It is more difficult to start a discussion with someone you have never met before ... with my cohort we manage good discussions, and learn from each other".*

Students within this category are more likely to use a webcam, as seen from the numbers in Table 1. The data shows that these students perceive students without a webcam as less interested in learning, since *"if fellow students do not participate with a microphone or a webcam they rarely wish to contribute in a collaboration".* It is challenging (or impossible) to discuss with other students if they don't see (or hear) them.

As opposed to the rest of the students, most of the students answering *always* or *often* uses a webcam, and they *always* or *often* start talking in the breakout rooms and initiates a discussion either because they like to discuss or they see they benefit from it. Though they do prefer to discuss with students they already know, they try to initiate a discussion when they are in a group with students they do not know.

3.2 A behaviour that may promote learning occasionally

This category, a behaviour that may promote learning occasionally is based on the explanations from students answering they *sometimes* initiate a conversation. These students start talking only if they feel like, "*it depends on the situation"* writes a student. Since these students may "*say something in the breakout group only if I* *have a question"* or *"usually I don't need to ask anything, then I don't bother to talk".* That is, these students may or may not participate in the online group work, depending on the situation.

As for the students described in section 3.1, these students also indicate they prefer to work with people they know. "*Randomly formed breakout rooms have led to only little discussion, but I haven't had the need to discuss either".* Or *"when you come together with four students you don't know in a breakout room, then very often it results in no one saying anything, then I have to start talking myself otherwise no one will start the discussion".*

For these students their personality may inhibit them from starting or joining a discussion, *"I'm pretty shy, but I try to take an initiative. Breakout rooms have worked poorly for me since if I don't know those I end up with, there will be almost no one who talks"*.

The students answering *sometimes* do not feel a responsibility for the group. They start talking only if they themselves wonder about something, this is in contrast to the students described in section 3.1, who feels a responsibility for the whole group, and would start a discussion even if they don't feel like it or for some because they like to discuss.

3.3 A behaviour dominated by a lack of initiative

The students answering they *almost never* or *never* start talking in breakout rooms appear to have a personality that prevents them from taking part in the online group work, as a student explain *"I don't like to talk".* Another student writes: *"because I don't know the people it feels odd to have a conversation with them, when they are shy, too".* A quote which might indicate that this lack of action is due to social insecureness within the class. "*Sometimes there is nobody who talks because you don't know each other*". Though one student does *"start talking if I feel like I need it. It's okay that people do not talk if we are doing exercises, as it can be difficult to discuss if there is something you do not understand".* These students have not learned or experienced how it is to learn in a sociocultural learning environment, where discussions are a natural part of the activities. Expressed as "*I'm not able to talk when I end up in groups where no one gives any feedback".* The students in this category have in common that they have bad experiences from the online group work, as "*random groups work very poorly"* or *"no one is using a webcam and microphone, then it's just a waste of time".* The random breakout rooms have not worked as intended for these students. The students were not left alone when working in the breakout rooms, the teacher visited the groups from time to time, to follow up or they could use the raise hand option.

The students within this category experience weak relations with other students from the class, and since they are shy online breakout rooms have worked poorly for them. In addition, since most of them do not use a webcam they send a signal which by the students from section 3.1 is perceived as these students are not interested in participating in the group work.

3.4 Reasons for avoiding the use of a webcam

Out of 27 students responding to the questionnaire, 14 of them do not use a webcam. We categorised their explanations for not using a webcam into, problems with equipment (5 students), the surroundings (3 students), being uncomfortable showing oneself (5 students), or they find it unnecessary (3 students). Some students gave more than one explanation.

Problems with equipment, like a bad internet connection, or sound problems are mentioned. Students mentioning their surroundings as the reason write *"I work at the kitchen table and live with several people who don't want to suddenly appear in the background"* or *"I find it uncomfortable to use a camera when I'm at home, I can spend a lot of time thinking about how I and the room look, also I live with others who may not want to appear in front of 60 students".* The students who feel uncomfortable showing themselves have more personal reasons. *"I find it uncomfortable that people I don't know can look at me through the screen."* Or they *"feel like others are looking at me"*. They also say: *"I don't need to show my frustration to other students"*. The students who find it unnecessary to use a webcam have no good reason, *"I have no good reason, I'm using it only a little, lately".* Thus all these students have reasons for not using a webcam, it is worth considering this behaviour in the light of how other students perceive this behaviour in a learning situation.

4 DISCUSSION

We see that the covid-19 circumstances, where the students were encouraged to stick to their cohort and only to get to know a small group of students made it unnatural to get to know each other across the cohorts in online teaching. When we decided to use random breakout rooms it was with the intention that the students would get to know each other across the cohorts and that this could contribute to better learning over time, since the students would discuss with more people not only those from their cohort. It was also the intention that this would contribute to a strengthening of the learning environment in the class as a whole. Previous students have reported that a random group setting for group work at the campus has resulted in more focused group work, we experienced here that this was not directly transferable to the online teaching format. In the case, studied here we continued to use breakout rooms, but now only for fixed groups, the cohorts. To facilitate the group work process we visited the breakout rooms more frequently. After finishing the school year we experienced, from a teacher's perspective, that only half of the fixed groups worked as intended. We, therefore, believe that randomly formed groups are preferable since the students get to know and discuss with all the students and get access to more views and perspectives.

This study has limitations as all information is collected through the questionnaire. We planned to do interviews to obtain a deeper understanding of the students' behaviour and experience, however, the increased covid-19 restrictions made this too complicated.

5 SUMMARY

The analysis showed that the students either took responsibility for their own and others' learning by initiating discussions or they had a more passive behaviour in the breakout rooms. We found a connection between the students who use a webcam and have a behaviour that promotes learning. Furthermore, these students perceive the other students without a webcam as less interested in learning. When students in breakout rooms do not use a microphone or a webcam, this sends a signal which is perceived by other students as if they don't want to participate. The students reported different reasons for not using webcams, differing from technological difficulties to consideration for others and social discomfort. Our analysis shows that many students experience weak relations with fellow students and a form of social insecurity that prevents them from being active in online group discussions. The students who take responsibility for their own and others' learning like to discuss and therefore starts talking in online group discussions. Therefore the online group discussions studied here only worked occasionally, depending on who ended up together in the random breakout rooms. Many students across all categories write that online group discussions can work, or work the best if they are together with their cohort because then they know each other and dare to talk. As described in the discussion this may be the case only as long as the students in the fixed groups have productive collaborations.

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DESIGNING A RESILIENT CURRICULUM FOR A JOINT ENGINEERING FIRST YEAR

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SEFI Conference Key Area*: 'Resilient Curricula and teaching methodology'*
Keywords*: curriculum reform, curriculum review, resilience, engineering first year*

ABSTRACT

In March 2020, the University of Bristol in the UK was in the middle of the development of a new curriculum for a joint first year of 4-year undergraduate Engineering degrees for introduction in September 2021. This curriculum was designed using constructive alignment principles informed by significant student and staff input. The focus was on skills development, challenge-led projects, and creativity for professional programmes. Assessment was rebalanced from mostly summative to mostly formative. The arrival of the global COVID-19 pandemic accelerated the rollout of this curriculum: the new approach had so many advantages for this challenging situation that its introduction was brought forward to September 2020.

This paper centres on the elements of the new curriculum which made it particularly resilient for the pandemic. The constructive alignment approach ensured that curriculum developers concentrated on the overall educational aims of the first year, rather than trying to fit the education into set forms and modes of delivery. The process of developing programme-level intended learning outcomes, followed by a process of paring down the content and assessment of the programmes to focus on these learning outcomes, resulted in a simplification of the structure of the programme. Delivery methods were greatly diversified and blended, allowing teaching to very large cohorts in a variety of situations. True team teaching with staff members developing content together (rather than delivering sequentially) meant that, for the first time, there was some redundancy in the teaching teams. These and other positive and negative aspects of the features of the curriculum in terms of adaptability in the pandemic are discussed in the paper.

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1 INTRODUCTION

1.1 Background

In March 2020, the University of Bristol was in the middle of the development of a new curriculum for a joint first year of many of its four-year undergraduate engineering degrees planned for introduction in September 2021. When the COVID-19 pandemic hit the UK, the new curriculum had so many advantages for this challenging situation that it was rolled out early in September 2020.

The impact of the COVID-19 pandemic on higher education around the world [1] to the challenges and opportunities that it offered [2] have already been described in the literature. Whilst these authors have taken stock of what has happened, others emphasise the need for 'reenvisioning' and 'reimagining' our higher education systems in the future. We need to ensure that our education systems are robust to pandemics and other types of adversity.

Recent recommendations for transitioning to life after the COVID-19 pandemic explicitly identify **resilience** as a necessary element [3]. Resilience in human development has been defined as 'positive adaptation in the context of significant adversity'. Previous work has looked at Universities as resilient organisations and define the construct of resilience "as the institutional capability to effectively absorb, respond to and recover from an internally or externally induced set of extraordinary demands" [4]. Pinheiro and Young use a complex systems perspective to identify three qualities desirable in Universities for resilience: 'slack' – a buffer of redundancies and resources, 'requisite variety' – a diversity of possible responses and lastly, 'decoupling' – a loose coupling between the entities in the organisation [5]. They also point out the difference between resilience planning and strategic planning: the former focusing on flexibility and having redundancy and resources, whilst the latter focuses on hierarchy and streamlining.

Chow, Lam and King have proposed useful ideas on crisis resilient pedagogy, suggesting that adaptability, creativity, connectivity (sharing resources), diversity and endurance are all attributes which teachers, students and administrators can apply to increase the resilience of their teaching methods [6]. Other authors suggest that preparing courses as suitable for delivery via multiple modalities: online, hybrid or face to face; engaging in projects with uncertain outcomes; working in groups to strengthen teamwork and networking and caring beyond the self will all contribute to encourage flexibility and creativity and to promote resilience [7]. In this work, we look at what features of a curriculum might make it resilient. But what are the possible types of adversity that a curriculum would need to adapt to?

1.2 Types of adversity

Whilst the list of possible scenarios includes social unrest, pandemics, war, natural disasters, shifts in political climate or demographics etc, the ways in which these events could affect curricula are more limited. Just as there are thousands of diseases, but only a limited number of symptoms of disease. The possible effects of the adversity might include the following:

1. Numbers of students increasing or decreasing
2. Numbers of staff increasing or decreasing
3. Study conditions for students
4. Closure of facilities (such as classrooms and laboratories)
5. The movement of students away from campus (for campus-based Universities)
6. Changing preparation of students for study
7. Changing mental and physical health of students
8. Changing attitudes towards study
9. Changing relevance of skills and content taught
10. Demographic of students coming to study

It could be said that the coronavirus pandemic of 2020 affected UK universities in all but the last two of these ways. In the future, those beginning a process of curriculum reform could ask: how adaptable is our new curriculum going to be? Very little work has looked at how to make a curriculum itself resilient. Adaptability and flexibility do not generally go well with the rigidity of curriculum structures and timetabling. Are there features of a curriculum that we can consider during curriculum reform to promote resilience? This study looks at a particular example of a curriculum and which elements of it made it resilient and not resilient in the face of the COVID-19 pandemic.

1.3 Structure of the paper

Section 1 of this paper covers previous work in this area, the section 2 describes the context engineering at the University of Bristol and degree structure. Section 3 explains the drivers, process and a structure of the new curriculum, whilst section 4 describes the features of the curriculum that were particularly useful in the pandemic. Section 5, on the other hand, describes features that were challenging during the pandemic. The discussion in section 6 offers an application of some of the concepts of resilience to these features, whilst next steps and conclusions are outlined in sections 7 and 8.

2 CONTEXT

2.1 The UK system

The UK has a system of accreditation of higher education institutions for their engineering degrees which is carried out by professional engineering institutions, such as the Institution of Mechanical Engineers. The degrees must follow a specification and the Universities are regularly inspected by a team from the institution. This means that any curriculum change must be compliant to the institution’s specifications [8].

2.2 The University of Bristol

The University of Bristol is a research-led UK University with approximately 27 400 students and 7600 staff (data from 2019/20). It is a top five UK university for research and a top six European university for teaching, according to the Times Higher Education magazine in 2018. The courses are structured for students who have attained excellent grades in their final school/college exams in mathematics and sciences. In the school of Civil, Aerospace and Mechanical Engineering (CAME) in the Faculty of Engineering, approximately 650 students start 3 year (BEng) or 4 year (MEng) undergraduate degrees each year. These run as separate programmes for each engineering discipline, plus there is a more general programme in Engineering Design. Whilst very highly rated by students, the curricula in the first year of all these degree programmes had not been completely refreshed for several years and there were several reasons for redesigning the curriculum which are discussed in the next section.

3 DRIVERS AND PROCESS

3.1 Drivers

The University of Bristol mechanical, civil and aerospace undergraduate engineering degree programmes have not been subject to major review for many years. They had evolved piecewise via a series of changes to individual taught units in response to student feedback and periodic review for professional accreditation, but the overall structure of the programmes and their organisation had not been examined or revised. Simultaneously, the scale at which undergraduate teaching is delivered had grown significantly, with the number of students per year growing from around 200 to around 460. This resulted in some issues with the curriculum including:

1. Overassessment of students resulting in high student workloads
2. Low engagement with non-assessed activities
3. High marking and feedback load for staff
4. Poor interconnection between units and lack of interdisciplinarity
5. Many staff teaching units by themselves
6. An over-emphasis on science and mathematics at the expense of practical, professional and design skills

The school also wished to support the increase in the diversity of its student population and widen its participation, so a driver for curriculum change was to enable a smoother transition to university for all students.

A common structure of the first year for the range of engineering programmes was proposed to address some of these issues and to allow students to transfer between programmes easily in the first year so that they could make an informed decision on the discipline they have chosen to follow.

3.2 Methods and Process

The method by which the curriculum review was conducted, and some preliminary results is described in detail in another paper by the authors and is summarised in the diagram in Figure 1.[10]. This paper describes, amongst other things, how constructive alignment [9] was selected as being the most appropriate method for curriculum design for this particular context.

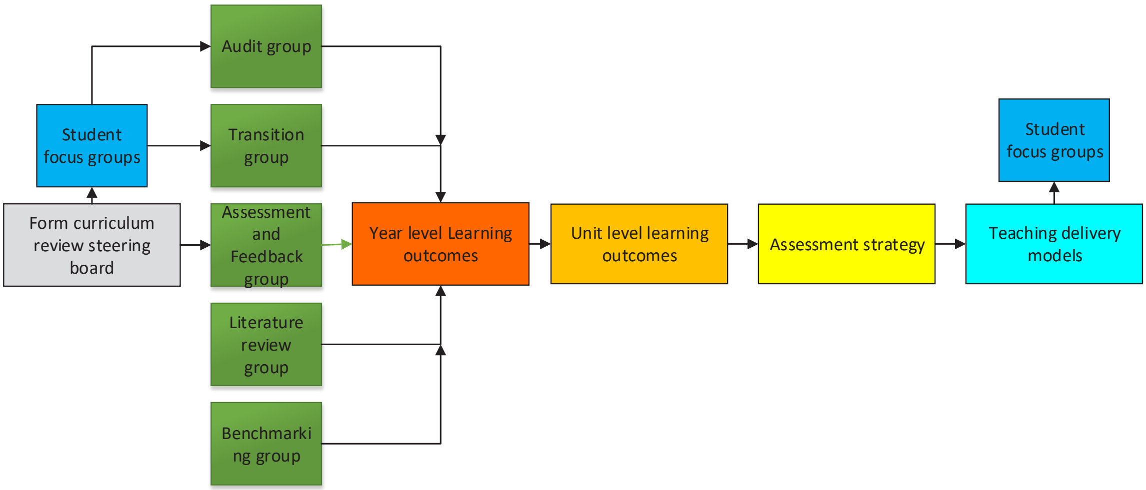

Figure 1: the process of curriculum review used by the University of Bristol [10]

The old programme structures were highly complex, with many different units (or modules), each of different credit value and each managed by a different department. Academics taught units individually and engineering science and mathematics comprised 80% of the old programme. The structure of the new curriculum contains a core of five units (Engineering Mathematics, Engineering Science , Engineering by Investigation, Engineering by Design, which are common to all programmes. This is shown in Figure 2. There is also one discipline-specific unit for each different discipline: ‘Principles of Aero/Mechanical/Civil/Design Engineering’. In the new curriculum, Engineering Science and Mathematics now comprises 50% of the programme, with the introduction of new modules on skills (Engineering by Investigation) and on group projects focusing on global challenges (Engineering by Design).

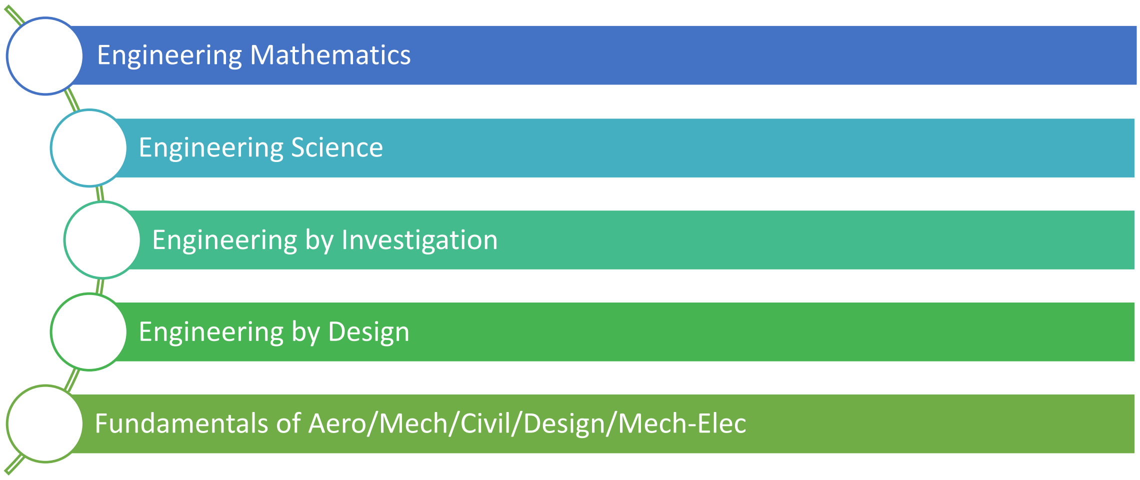

Figure 2: The simplified structure of the new first year curriculum

3.3 Monitoring and Evaluation

Feedback from students was (and continues to be) gathered from several sources: Staff-Student Liaison Committees for each programme of study were held at approximately bi-monthly intervals throughout the year, with students representing all years present; a "town hall" event after the Easter break specifically to discuss aspects of the new first year; the annual University student survey questionnaire, though these data will become available later in the summer. Assessment results data will also be used, when available, to gauge the progress of students against the learning objectives for them in the first year. To date, student feedback has been largely positive. Students enjoyed the opportunities to work in interdisciplinary groups: "*It was great to work with students on the other courses*". They also appreciated the multidisciplinary design unit and its timing: "*I liked the design unit – it was good to do this from the beginning*".

The use of formative assessments to encourage regular learning when operating remotely was highlighted: "*the tests were good to get me into the rhythm of working*".

On the negative side, students were frustrated by not being able to meet their fellow tutor group members in person and found studying the practical 'Engineering by Investigation' unit remotely, necessitated by public health measures, instead of in the Labs, particularly challenging: "*The lab unit is a good idea, but it didn't really work well online*".

In the following section, the features of the new curriculum which were suited to the difficult conditions of the pandemic are discussed.

4 RESILIENT FEATURES OF THE NEW CURRICULUM

4.1 Introduction

The following features were identified as contributing towards the decision to bring forward the curriculum review changes by a year. They all lent the new curriculum an adaptability and robustness to the various adverse effects of the pandemic in 2020.

4.2 Use of constructive alignment

The constructive alignment approach to curriculum review ensured that curriculum developers concentrated on the overall educational aims of the first year, rather than trying to fit the education into set forms and modes of delivery. The process of developing programme-level intended learning outcomes, followed by a process of paring down the content and assessment of the programmes to focus on these learning outcomes, resulted in the competing areas of content for the first year to be accommodated and reconciled.

4.3 Simplified structure

The simplified structure of the programme allowed a coherent delivery of the different Engineering Science topics with Engineering Mathematics phased to support the science. It also allowed better planning of formative and summative assessment. The clearer, more consistent structure reduced the burden on students of navigating many different academic expectations over a large range of units. In the fragmented, isolated world during the pandemic, this was particularly important, as students lost much of their peer support.

4.4 Standardised structure

Under the previous system, coordination of the many units provided by academics in several departments was difficult; when rapid change was demanded when remote working was necessary, it was difficult to do this effectively. The end of the secondary education of many of the students was badly disrupted and so sometimes their tacit understanding of how to plan and carry out their studies has been impaired. The standard structure made it much easier for students to appraise what is expected from them and what they needed to do to successfully complete the year. It also enabled more consistent support for students. Academic and pastoral support was targeted at specific activities throughout the year. The ability to plan these and generate appropriate resources helped transition activities like personal tutorials to function more effectively online.

4.5 An emphasis on skills

Practical laboratory content, previously embedded within the different science units, was now delivered in one ‘Engineering by Investigation’ unit. Whilst individual activities still support the engineering science theory, the emphasis was now on the techniques of conducting and reporting experimental practice. This decoupled the practical elements from the science units. A teaching team was specifically responsible for developing practical activities that the students could do both on-campus (when allowed) and at home. This meant the skills teaching was as consistent as possible and not reliant on piecemeal implementation across multiple units.

4.6 Interdisciplinarity

A common design unit, 'Engineering by Design', introduced students to the processes of problem solving and design through group projects. The unit explicitly aimed to encourage interdisciplinary working from the very beginning of their studies. For the first five weeks of the course, students undertook an immersive mixed-cohort group project with a global challenge theme. The aim of mixing the cohorts was to enable students to make connections outside their specific discipline, strengthening their networks and peer support. In the pandemic this had the unforeseen advantage of increasing the pool of students available to work together and the network of possible connections.

4.7 Programmatic assessment

Designing the delivery pattern and diet of assessment at programme level allowed careful planning of the nature and timing of formative assessment across the year. This allowed students to plan their work effectively. A diverse range of assessment types were used to prepare students for the forms of assessment they would experience later in their degrees and for their professional careers in engineering. From the point of view of resilience, programme level assessment planning allowed careful resource allocation by both the University and students.

4.8 Reducing the emphasis on summative assessment

Excessive summative assessment was having negative effects on our students. Assessment was capturing a disproportionate portion of students' attention and displacing other learning. The curriculum review reduced the number of summative assessments and increased the number of formative assessments. This separated the periods of learning from the periods of summative assessment which meant time management and engagement were easier for students.

4.9 Team teaching

Previously, across the four programmes there were 22 different units in operation for the first year. This resulted in little team teaching and a very high administrative workload. There was therefore limited scope for the transfer of best practice and resources between similar units on the different programmes. If any staff member needed to be off work, then it was a challenge to ensure continuity of teaching. The team teaching occasioned by the curriculum review enabled some redundancy in the system. Team teaching also had a positive impact on staff mental health and reduced the potential for loneliness in remote working, as it provided clear reasons for colleagues to interact to plan and discuss their teaching and assessment.

4.10 Teaching delivery methods

A flipped classroom delivery system was implemented i.e. pre-recording video sessions in bite-sized chunks and then running live sessions either face to face or via video/Zoom depending on the lockdown status. This was found to be highly effective in the pandemic and with a diverse student body, with many students finding the flexibility and ability to ‘rewind’ the videos particularly useful. When students could attend in-person, some of the teaching was delivered in a hybrid format. This meant that students could attend a session either in-person or online. The success of this was mixed. It did successfully allow teaching on the same basis for all the students, no matter where they were. However, it was challenging to deliverfor the staff.

The last point illustrates that not all the features of the new curriculum were found to be positive in the pandemic. The next section discusses more challenging areas.

5 NON-RESILIENT FEATURES OF THE NEW CURRICULUM

5.1 Dependence on laboratories

As is the case for many STEM subjects, first year engineering courses rely heavily on practical and laboratory work to enhance understanding of the science and to develop skills and techniques. The new ‘Engineering by Investigation’ unit on measurement and instrumentation was planned as a key feature of the first-year curriculum. It was to be delivered through a series of on-campus practical activities. However, it was clear during the pandemic that almost all these activities could not run. The mitigation devised by the teaching team was a range of home lab activities. These were supported by a University-supplied kit of components which were sent out to students around the world. By their nature, these were small scale activities, so the more substantial supporting experiments had to be delivered in the form of video recordings which were less effective than campus-based hands-on learning.

5.2 Timetabling

The new curriculum made timetabling easier than for several different but interconnected programmes. However, for in-person teaching there were issues with room capacities when social distancing was required. The number of concurrent sessions required for the large cohort filled the timetable and put a strain on teaching resources. This meant that activities such as laboratories and design classes took place over the entire year, and with lockdown periods switching on and off, this created disappointment for students who did not have the opportunity to undertake the activities.

5.3 Student teamworking

Effective teamworking is an essential skill in engineering and having multiple opportunities for students to practice this in their first year was key to the curriculum design. It was planned that teamwork would form the main teaching and learning environment for the ‘Engineering by Investigation’ and ‘Engineering by Design’ units.

So, during lockdown this was implemented by online group-working tools such as Blackboard Collaborate and MS Teams. However, many students struggled to form effective teams in this way, particularly if they had never met in person, and this appeared particularly acute for first years. There was a general reluctance to engage in public online activity which resulted in some disengagement from the group activities. Whilst this was not unique to this programme, having group-working central to the curriculum has proved particularly challenging for remote and hybrid learners. It became clear that the degree of support that students receive in person from each other is critical to their ability to work in teams.

6 DISCUSSION

In this study several features of a new Engineering first year curriculum implemented at the University of Bristol have been discussed. Evaluation is ongoing and proper results will only be available at the end of the summer, but initial indications are positive.

Some of the positive features have been illuminated by the harsh light of the pandemic, but would they have been suitable in all adverse situations? To answer this it might be useful to see if the features fit with the essential qualities of resilience such 'slack', 'requisite variety' and 'decoupling' proposed by Pinheiro and Chow et al [5,6]. The concept of slack – a buffer of redundancies and resources – could be said to be promoted by team teaching, teaching delivery methods such as the flipped classroom and the use of mixed sources/online sources, and by programmatic assessment. However, in recent years, a drive towards efficiency and strategic management in Universities runs contrary to the accumulation of sufficient buffers and resources to be capable of handling any situation. Partly because of this, during the pandemic, staff and resources have been stretched to their limits. Requisite variety is promoted again by teaching delivery methods, but also by skills teaching and interdisciplinarity. It is important to ensure that this diversity of staff, methods and approaches continues forward into the future. The loose coupling of entities within the system is encouraged by the autonomy and independence of academic staff generally in the Universities in the UK and this was a considerable challenge to reconcile in the process of curriculum review. However, from this very autonomy allows agility and flexibility of action in a crisis. Generating staff commitment to the year as a whole is essential for generating resilience.

Chow et al.'s suggested qualities of adaptability, creativity, connectivity, diversity and endurance were also embodied by some of these features. Adaptability was promoted by the simple structure, the focus on programmatic outcomes, programmatic assessment. Creativity was promoted by the focus on learning outcomes, thus allowing staff to be more creative in their ideas. Interdisciplinarity also led to creativity, as did team teaching, as staff worked across disciplines to develop ideas together. Connectivity and sharing of resources happened across the departments allowing best practice to flourish and diversity of approaches to be catered for. Diversity often means different viewpoints and it took considerable tact and goodwill to ensure that all voices were heard to move forwards together. Endurance was a quality much needed by staff and students throughout the pilot year and reducing the emphasis on summative assessment gave a little more space to develop this, rather than the usual relentless schedule of coursework and exams.

It would be useful to reflect on how well this or any curriculum can flex to all the possible effects of adversity. The COVID-19 pandemic has caused all but two possible adverse effects to higher education mentioned in the introduction and Universities have adapted accordingly, demonstrating their resilience as institutions; but there are elements of this new curriculum which the first-year curriculum team have struggled with, including managing laboratory closures (despite some exceptionally innovative workaround solutions), the high level of student teamworking required for the new curriculum and its timetabling. These elements will be the focus of efforts next year, as it is important to note that this curriculum review is in its pilot year. The next section will discuss the next steps and the final implementation of this curriculum review project.

7 NEXT STEPS

The new combined first year will be fully implemented in September 2021. The curriculum implemented in September 2020 will be further consolidated and adapted over the next academic year: there will be a single engineering science unit with the introduction of more electrical engineering and more complementary sequencing of subject matter. Computing will be combined with experimental practice, which reflects practice in industry and the disciplinary unit for each programme will be strengthened. The year will be extended to include the new Bristol Electrical and Mechanical Engineering degree course.

There will be further movement from summative to formative assessment and pass/ fail summative assessments. Overall, these further developments are moving towards thinking about the learning outcomes of a programme as a whole and focusing students' efforts on meeting those. This builds resilience both in the delivery of the programme and in students' study, where the connections between the units should hopefully become clearer. The increase in formative assessment and the online nature of the teaching means that it may be possible to find out more easily where and when students are having difficulty. The emphasis of the first-year assessment will be on the skills that they need to display to be successful for the remainder of their degrees.

After the first year, the students follow disciplinary programmes. The changes engendered by the new first year have caused change to the curriculum in later years. The overall aim is that all students will have a good grounding in the basic academic and professional skills required and will have developed effective and healthy study methods by the beginning of the second year.

8 CONCLUSIONS

In this work, the features of a new engineering first year curriculum have been examined in terms of resilience and lack of resilience. A simple and standardised structure, an emphasis on skills-based learning and interdisciplinarity, more programmatic and less summative assessment, team-teaching and best practice pedagogy have all played their part in making this curriculum suitable to be rolled out a year early. Aspects that have been problematic have included the dependence on laboratories, timetabling limitations, and student teamworking. The next steps in the implementation of the curriculum have been discussed. This crisis has offered an opportunity to look at features of curricula that may make them more resilient. It is hoped that this work offers ideas to others who wish to embed resilience into their curricula.

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CONCEPT FOR EXTERNAL QUALITY ASSURANCE OF AN INSTITUTE'S COURSE PORTFOLIO

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ABSTRACT

In most manufacturing firms, processes and products undergo continuous and often rigorous quality assurance (QA). Such QA-systems ensure that products adhere to quality standards and specifications. In addition, a firm's sales numbers are a direct measure of the continuous relevance and attractiveness of the firm's products.

Universities 'produce' courses. Some courses teach fundamentals (e.g. mathematics and physics), while others teach specific methods for application in graduates' future careers. Ideally, the skillset that students receive from the specific-method-courses should continuously develop. However, courses often run for decades without enacting necessary changes, and when change happens, the reasons are often student dissatisfaction or new instructors. Most universities have elaborate systems for student evaluations, while inputs from employers and the wider society are scarce. Skillsets must develop in concert with employer needs, technological progress, and the wider needs of society.

This paper presents a system for course quality assurance (CQA-system) developed at the center for bachelor of engineering studies at the Technical University of Denmark. The CQA-system is inspired by manufacturing industries, were quality assurance has a long history. The system includes a four-step process for the quality

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assurance of individual courses, a procedure for selecting courses for review, and principles for organizing the overall effort in an institute's management infrastructure.

1 INTRODUCTION

In manufacturing industries, quality is an ever present focus since customer demand for quality product is always present. To meet the demand, manufacturers are certified to various quality standards that ensure that quality is built into every aspect of the company's activities. All activities are documented and audited/reviewed in a structured and systematic way to ensure quality in both products and services.

In universities, the assurance of quality often occurs at more overall (superficial) levels where audits and reviews concern entire educations rather than specific courses. Deepening the quality assurance of university educations, requires a system developed to ensure the right quality all the way down to individual courses.

The inspiration for developing such a system is found in the traditional approach for quality improvement projects. In Lean manufacturing and industrial quality standards the approach Plan – Do – Check – Act (Deming circle) [1] is often used as basis for designing a systematic and structured method for improving quality. This approach also constitutes the foundations for the course quality assurance system (CQA-system) presented in this paper. The CQA-system ensures quality for 'customers' of the individual courses.

The motivation behind developing the system was an interest in making the best educated engineering students in Europe by developing graduate skillsets that match current employer demands as well as future demands and the needs of society at large.

1.1 Overall requirements of successful QSA-systems

To operate successfully, a CQA-system must function as a systematic and structured process for all system activities. Furthermore, the system must function in an awarding and positive atmosphere that inspires participant engagement and fosters receptive attitude. The system must include a process of selecting the relevant individual courses for review and nominating the right set of persons for a review panel. Nominating the review panel must be a careful process that matches the experience and job positions of panel lists with the content and purpose of a course selected for review. The course reviews must follow a structured process that leads to the identification of the right changes. Finally, review outcomes must be documented, so learnings are kept and can be applied. Knowledge that is transferable to other courses, must be conveyed to the responsible instructors and institute management.

2 THE CHALLENGE OF ENSURING CONTIUOUS COURSE QUALITY AND RELEVANCE

When examining how individual courses are updated and how often they accommodate changes in theory, models, technologies, etc., it appears that courses are often only updated when the instructor changes or when the course receives poor ratings or complaints. Since instructors often teach the same course for years and years, universities face an uphill battle in continuously ensuring a match between the skillset a course teaches and the needs of current and future employers as well as society at large.

One reason for widening mismatches is that instructor's year-by-year lose their connection with the development and changes in fast evolving industrial sectors, when their primary focus is their job of teaching. Therefore, implementing and operating a CQA-system that continuously ensures quality and relevance, is needed.

3 REQUIREMENTS FOR CQA-SYSTEMS AND THE PITFALLS OF IMPLEMENTING THE SYSTEM

This section details the requirements of CQA-systems and implementation pitfalls.

3.1 Trust and psychological safety

Reviews are conducted in group sessions with participants in different places in their professional lives. So, the experience and social status among reviewers as well as reviewees differs. These differences impact participant openness, which is counterproductive for the right review outcomes. In addition, instructors who are subjected to a review often feel nervous and may perceive the review as an exam. To get the best review outcomes, all parties involved must feel safe [2], both when signing up for the review as well as during the process. Only with trust and psychological security, people will open up and speak freely without bias about their course and the topics that surface during the review.

3.2 Anchoring the CQA-system in the overall management infrastructure

As with any other part of a Quality Management system, the focus and support of upper management is an absolute requirement [3]. Management must activate and promote the CQA-system. Focus and organization-wide involvement is ensured by management involvement. Upper institute management should be present or at least represented among the participants in the review panel.

3.3 Fostering a continuous improvement culture

Motivation for developing and operating a CQA-system that ensures the highest quality and relevance in engineering education should be a heartfelt wish among all educators. "Greatness attracts talent". By being and striving for high course quality and relevance, the institute can attract great instructors and motivate students. A continuous quality improvement effort may call for a change in culture. In particular, a new approach to course updating and maintenance. In the end, a result may be a new perception of engineering courses that results in combinations of fundamental skills in mathematics and physics, and cutting-edge skills that employers need.

4 THE CQA-SYSTEM AND ITS ELEMENTS

This section details the individual elements that together comprise the CQA-system.

4.1 Selection of courses for review

The selection of courses follows a structured sequence of prioritization and selection:

1. A rough division is made between courses that offer fundamental skills as mathematics and physics, and courses that teach specific skills for direct application on graduates' future careers. The latter group is the focus of the CQA-system.
2. The portfolio of courses for one education is scrutinized for courses relevant for review
3. A priority of course reviews is set

The prioritization is made using a combination of different criteria. These may differ slightly among universities depending on the balance of the research v. practice orientation scale. Examples of criteria are:

- Courses with substantial amounts of methods and models for direct career application
- Courses where technology and methods are undergoing rapid changes
- Courses that are a part of the identity (key courses) on an education

To ease the process of starting up the reviews, one approach is a call for instructors, who voluntarily wish to participate. As the CQA-system shows results, other instructors 'warm up' to the system and in the next stage selection can take place using the selection criteria. To ensure that all selected courses will undergo a review, a time frame for the review process has been set to be max five years.

4.2 Principles for ensuring a positive atmosphere for participation

To have successful and valuable outcomes of the process, the right working atmosphere is essential. One part of establishing this atmosphere is selecting the right pilot courses with cooperating instructors that are eager to have their course reviewed. For the review itself, setting the scene and clarifying condition under which the review will be held must be clear. First of all, a management participant and the internal review manager must emphasize that all meetings are held with a positive 'we want to learn' approach. A review is not a blame-game or a matter of pointing out what is wrong. Rather, the focus is on how the course can be improved. The aim is to focus on the positive things that can be added/changed to better match technological development and employer needs. Also important is to articulate how the course will benefit in the future after implementing changes.

The dialogue must be based on curiosity and avoid arguing. This will create a positive and creative atmosphere leading to great input on improvement and changes.

4.3 Selecting the review panel

The nomination of the review panel is a meticulous process. The goal is to have a broad spectrum of participants in the review panel. Ideally, a mix of seniority, branches of industry, and experience within the fields of the course topics. The panel should consist of several groups:

- Students who are either participating in the course or have just finished the course. Students are chosen on their track record, engagement in the course and their social skills. The students are urged to get opinions from their fellow students prior to the review thus ensuring the largest amount of input from students possible.
- External candidates from industry representing employers. These panel participant are often found through the personal network of the instructor or fellow colleagues. The preferred candidates have completed the course him- or herself and have worked with topics related to the course under review.

The total group of external review panelists should represent several industry branches or employer groupings. The aim is to ensure experience and course-knowledge of the individual panelists, and representation of a variety of industries or employer groupings from the total panel.

Part of the institute's upper management is invited to the review panel as well. The purpose is to show to the rest of the university that this is an important issue concerning the university's aim to offer the best and most relevant education. Furthermore upper management participation shows engagement in the review as well as having a chance to get information about what is really going on at the teaching level of the institute.

4.4 The review process for individual courses

Prior to the review, panelists are notified about their co-panelists, time and place for the review meeting. Shortly after, they will receive a description of the course and a lecture plan. The description of the course contains the following elements:

- General course objectives
- Objectives for learning outcomes
- Literature and readings
- The lecture plan

The lecture plan details all lectures, content and exercises described fairly detailed (3-4 pages). Panelists are asked to read the papers and prepare questions and opinions on the material.

The review meeting starts with a presentation of the purpose of the meeting and framing the plan for the meeting. Then, panelists make short presentations of themselves with information on their professional life and careers. This is followed by a presentation of the course by the instructor. This presentation provides in-depth information on the individual lectures. After the presentation the review board is encouraged to suggest themes for discussion. Each theme is then discussed and during the discussion, the instructor takes notes on any new subjects, methods and tools being brought forward. During the session, potential exclusion of current course elements are also evaluated. The review meeting finishes with an oral summary of the points discussed by the instructor. The instructor writes up a report that details the themes discussed and other findings. This report is then sent to all panelists for approval. Upon approval, the report is sent to the head of studies and the person responsible for the course (often this is the instructor, but it can be others).

Figure 1 Flow chart activities

4.5 Decisions about changes

Decisions about how to develop the course is taken on a meeting with the management of the faculty, the institute's head of studies, and the instructor. The report is discussed and the opinions and experience of the review panel is taken in consideration when taking decisions on what to change. A short report on the decisions made is written and sent to all parties involved and the upper management.

4.6 Implementing changes and follow-up

The implementation of changes/improvements is done by the instructor by changing the material for the course and the lecture plan. If needed, the official description of the course will be changed as well. This will be done as soon as possible. During the next run of the course, a midterm evaluation and an end term evaluation is conducted. These evaluations focus especially on feedback from students on the changes made to the course. The feedback in the evaluation is discussed with the students to clarify issues/opinions brought up.

4.7 General learnings for other courses

During the discussion on which changes to implement it is also discussed wether the changes present learning relevant for other parts of the university. If so, these points are reported to the dean of education.

4.8 Anchoring the CQA-system in the institute's management infrastructure

To make sure the whole university benefits from implementing the CQA-system, the system should ideally be implemented across all institutes in the university. It should be an integral part of the university's educational quality assurance system [4]. This system ensures not just the quality and relevance of courses, but naturally contributes to the upgrade to the newest knowledge within a field.

5 EXPERIENCES FROM APPLICATION AT DTU ENGINEERING TECHNOGLOGY

The experiences at DTU Engineering Technology (the center for bachelor of engineering studies at the Technical University of Denmark) have been a fruitful learning experience for both instructors and employers. Employers feel they are being heard about both their current demands for graduates as well as their expected needs for future skillsets.

The one challenge that rose from the pilot runs of the CQA- system concerned the implementation of new topics into a course's lecture plan. These lecture plans are already fully packed, so when panelists suggest new topics, something needs to go. Excluding topic is often a tough choice.

It is also clear that students' learning experience during their education does not always fit perfectly with their career needs. One example is students questioning the importance of delivering oral presentations ("too much and too often"). By contrast, the review panelists pointed out how important it is for an engineer to be able to present and explain topics with differing complexity to a broad set of employees and management levels. Training this discipline is crucial for career success and panelists emphasized how presentation skills was not an area for compromise.

6 CONCLUSION: CQA-SYSTEM SUMMARY

When building a system for continuous quality assurance of an institute's course portfolio it is important that the system is systematic, transparent and structured. The process starts with selection of courses. The right courses that need continuous quality assurance are courses that (a) teach specific methods and models for direct career application, (b) where technology and methods undergo rapid changes, and (c) courses that are key courses on an education. When selecting the review panelists, the preferred set of participants has mixed levels of seniority, represents different branches of industry, and has experience within the field of the course. During the review, a safe atmosphere and positive mindsets are crucial for successful and valuable outcomes. The focus must be improvement potentials. Outcomes cannot be successful if the review process is a blame-game or pointing out what is wrong. Anchoring the learnings from the review process has to be done both locally in the course and on a university level. Ideally, the CQA-system should be implemented across all institutes in the university as well as being integrated in the university's educational quality assurance system.

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USING TECHNOLOGY ASSESSMENT IN TECHNICAL STUDY PROGRAMS AS A MEANS TO FOSTER ETHICAL REFLECTIONS ON THE SOCIETAL EFFECTS OF TECHNOLOGIES AND ENGINEERING SOLUTIONS

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ABSTRACT

To dissiminate knowledge of Technology Assessment (TA) to the engineering ethics education research community this paper provides an overview of existing TA models: consequentialist TA, interdisciplinary TA, ethical TA, hermeneutical TA, participatory TA, and constructivist TA. The central result of the presented work is an analysis of how the different TA models compare to the science – society interface, including how the models relate to ethics, roles of experts, participation of stakeholders and the public, and output formats. It briefly mentions how the models are introduced in classes and used by students at Aalborg University in the 2nd semester of the bachelor program in Techno-Anthropology. Feedback from students indicate that they request concrete instructions on how to apply the models in their project work. All this to provide an argument for initiating research in how TA can be taught in Technical Study Programs as a means to foster ethical reflections on the societal effects of technologies and engineering solutions.

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1 INTRODUCTION

Technology Assessment (TA) is a collection of approaches focused on evaluating the short- and long-term consequences of the technologies under assessment. A technology assessment can focus on technological consequences for the economy, public health, the environment, democracy, culture, the good life, sustainability etc. There exists a number of TA models, and in this concept paper I describe and compare some of them. The rationale for doing this is that TA can be used in engineering ethics education as a means to stimulate ethical reflections on the wider consequences of technological solutions, which is a central skill for future engineers [1, 2]. To validate this claim a lot is needed. One thing that is needed is a good understanding of different TA models and how they compare. I will in this paper provide such an overview, and discuss very first ideas on application in education. Hence, I endeavour to promote a good understanding of different TA-models within the engineering ethics education research community.

TA is located between engineering science and politics / society as it is often, but not always, set up to support political decisions regarding public investment in technological solutions or legislation framing technological issues. Decision-makers are, as mentioned above, not always the target group of the TA. Sometimes the target group of a TA is engineers and technology designers when the idea is to implement ethical values or stakeholder perspectives in technological design [3, 4]

There are additional central tensions between the presented TA tools. Should TA experts only provide relevant information on the wider implications of technologies to facilitate politicians and decision-makers' decisions regarding technologies? Or, are they themselves expected to make assessments and estimates? Put in another way, how normative is TA supposed to be? [5].

A related tension regards who should do the TAs: Experts, scientific institutions, public authorities, or representatives of the public? And in this connection one can enquire the role of the engineers who are involved in TA. Roger Pielke Jr [6] distinguishes between five different roles of experts supporting politicians and decision-makers:

- Pure scientists (whose role are limited to summarizing the state of knowledge in a particular field),
- Science arbiters (who provide detailed answers to policymakers' specific questions),
- Issue advocates (who offer their expertise as resources in political battle)
- Stealth issue advocates (who disguise themselves as pure scientists, but are really advocating an issue) and
- Honest brokers (who clarify existing policy options and identify new ones).

In this concept paper, I present six TA models: Consequential technology assessment, Interdisciplinary technology assessment, Ethical technology assessment, Hermeneutical technology assessment, Participatory technology assessment and Constructivist technology assessment.

I will also compare these models with regard to the whether the models are purely descriptive, who is supposed to do the assessment, and the role of the engineers involved in the technology assessment.

2 TECHNOLOGY ASSESSMENT MODELS

2.1 Classical Technology assessment

What I call the classical TA model is the model used by the Office of Technology Assessment (OTA) [7]. OTA was set up in Washington DC, USA in 1974. Its role was to support the congress in its assessment of presidential proposals to invest in new technologies. Until 1974, the congress had acted as a rubber stamp as its members rarely had a technical background, and hence found it difficult to assess the technology proposals coming from the president's office. A central objective was to gain control over the negative implications of technology for human health and the environment. However, a focus on the financial implications also quickly became important in OTA's assessments.

In 1995 OTA closed down. The argument put forward by republicans underpinning this decision, was that it was expensive to have a special institution for technology assessment. Money could be saved, if technology assessment tasks were solved by other institutions.

The Federation of American Scientists hosts a digital repository of all technology assessment performed by OTA. OTA's technology assessment model was consequentialist in the sense that it almost in a positivistic sense tried to predict the wider consequences of technologies under assessment. This is rarely possible, and maybe this positivistic approach to knowledge about the future made the office fall out of synch with the post-modern waves in the 1990s?

The technology assessment experts were only supposed to present 'objective knowledge' of the wider impacts of technologies under assessment. The power over the TAs were situated in a congressional subcommittee with political majority over experts. It would decide which technologies OTA would assess and draw political conclusions from OTA's work. In terms of Pielke's topology, OTA's technology assessment model reflects the role of the science arbiter.

2.2 Interdisicplinary technology assessment

Armin Grunwald is the 'guru' of technology assessment. To revitalize TA after OTA was closed down he presented in the late 1990s and the beginning of 2000s a revised TA model [5]. Grunwald states that the background for the emergence of this TA model is the ambivalence of technology. There is a need for an early warning mechanism in relation to technological risk. Risks are often invisible, and require a scientific lens to identify. There is a need to involve experts, who in the interdisciplinary TA model also should have a strong normative flavor and recommend political decisions.

Hence, Grunwald suggests to merge technology ethics and classical technology assessment. The interdisciplinary technology assessment model involves representatives from different disciplines. It focuses on producing knowledge and information. This classic trait of technology assessment is then merged with ethical reasoning to guide the making of assessments and decisions. Ethical assessment / decision-making and classical technology assessment form a hybrid here.

In this model the TA experts both do both the science and policy recommendations. Grunwald's early technology assessment model only to some extend abandoned the consequentialist flavor of classical technology assessment, it is experts from different disciplines that do the assessment, though it adds normative and epistemological reflections to TA. In terms of Pielke's expert roles, it can be labelled 'pure science', as Grunwald delegate freedom to make recommendations to interdisciplinary assessment teams, and possibly 'science advocates' if they draw strong ethical or political conclusions from the expected technological effects.

2.3 Ethical technology assessment

A variant of interdisciplinary technology assessment that emphasizes and puts special focus on ethical judgment following the assessment of future consequences of a technology is often denoted Ethical technology assessment. Palm and Hansson makes the argument that there is a deficit of ethics in most TA models in the sense that little attention is made on how exactly to draw ethical conclusions based on an assessment of expected implications [8]. To remedy this lack of ethical reflection in technology assessment they proposed a list of ethical assessment criteria that can guide an ethical assessment:

1. "Dissemination and use of information
2. Control, influence and power
3. Impact on social contact patterns
4. Privacy
5. Sustainability
6. Human reproduction
7. Gender, minorities and justice
8. International relations
9. Impact on human values." [8].

I have made a list of 20 ethical assessment criteria that an ethical technology analysis can be based on [9]. I also suggest that ethical technology assessments should not only focus on the intended consequences, but also address possible abuse, long and short-term side effects and societal as well as cultural implications.

The target group of ethical technology assessment is engineers and technical experts in the sense that it does not aim at legislation, but rather in responsible innovation and ethical design.

Ethical technology assessment overlaps with many of the traits of interdisciplinary technology assessment, though it clarifies the normative dimension of interdisciplinary technology assessment and provides an argument for undertaking the role of the ‘issue advocate’ in specific situations.

2.4 Hermeneutic technology assessment

In later years Grunwald [10, 11] has developed a second approach to TA, the so-called hermeneutic technology assessment model. You can use this TA model when there is no valid knowledge, predictions or scenarios available about a technology's implications and consequences.

Hence, it is a criticism of or an alternative to consequentialist TA models that can easily shut down future opportunities on a false basis. Hermeneutic technology assessment considers knowledge about the future uncertain.

What this approach assesses is techno-visionary futures or future narratives, visions, expectations, and notions of new or future technologies. Is about technologies that do not exist or have not yet been implemented. It is about finding the meaning of ideas about new and emerging technologies. Hermeneutic technology assessment is anticipatory.

This model interprets texts, diagrams, oral presentations and works of art regarding imagined future technologies. The sender of techno-imaginaries can be science fiction writers and other artists, companies, organizations, politicians, scientific academies, futurists, intellectuals or entrepreneurs.

The assessment starts by choosing an iconoclastic intervention in the public debate regarding a non-existing, emerging or new technology. The intervention is interpreted in terms of what it says about its present context, how it has influenced the public debate, which reactions it caused and what we can learn from the resulting debates. A hermeneutic technology assessment is itself an intervention into the debate, and can itself be the starting point of a hermeneutic technology assessment.

This model has a focus on advising politicians and decision makers. The technical designers and technology developers are not the target audience. This approach to TA comes closest to the role of ‘the honest broker’.

2.5 Participatory technology assessment Tables

The Danish Board of Technology (DBT), among others, have developed models for technology assessment where citizens do the assessment.[2] These models have names like Consensus conference, Citizens' jury, Citizens' summit, and Kitchen table meeting. The idea is that a dilemma regarding a technology is identified – typically two arguments *pro et contra* regarding the implementation of a technology in a specific context – and that this dilemma is presented to a representative group of citizens. The size of the group depend on the chosen model, and can vary from several hundred people down to a number of meetings each attended by a handful of friends. The dilemma is presented to the citizens by experts or in material prepared by TA experts.

All these models share an underpinning assumption, here captured by Andreas Birkbak, Anders Koed Madsen and Anders Kristian Munk of the TANTlab at AAU:

> "They are rooted in expert evaluations about potential consequences and possibilities of a given technology - not in the free-running imagination of a lay person. Second, organising deliberation across tables around cross-cutting dilemmas eases the communication of 'public opinion'. Because the citizens are discussing comparable issues, they appear as a uniform public that - despite disagreeing on solutions - share each other's framings of the problems. In sum, the DBT approach to TA stages citizen involvement as a moderated endeavour that sits between expert-driven problem formulations and the output of findings to pass on to decision-makers." [12].

In participatory technology assessment there is a distribution of labor in the sense that experts feed into to a dilemma associated with a technology, citizen do the assessment, and decision-makers receive the citizens' recommendations as input to policy-making.

The role of the joined set of disagreeing technical experts and facilitating TA experts is to act as 'honest brokers' in the sense that different opportunities are presented that the citizens can choose between.

The proceedings from last years' SEFI conference include a paper that combines participatory and ethical technology assessment [13]. In the presented hybrid approach participants in a workshop both feed into the factual discussions on the implications of the assessed technology and do a collective ethical assessment.

2.6 Constructivist technology assessment

The script underpinning Constructive technology assessment is to replace an existing technology with a new technology [14]. It asks 'What can the existing

[2] More information about the DBT and its technology assessment models are found at their website: https://tekno.dk/?lang=en [accessed May, 5 2021].

technology that the new technology must also be able to do?' and 'What should the new technology add?' There are two movements 1) an historical analysis (a la SCOT) where one looks back at what choices were made, and which stakeholders negotiated when the technology was established. And, 2) a move where selected stakeholders look forward and collectively try to shape the new technology that will replace the existing one.

Constructive technology assessment perceives technology as a process (not a thing). It consists of four assessment criteria elements: What is the purpose of the technology? Is the organization synchronized for adopting the technology? Do employees have the needed knowledge to operate the technology? And do the technical elements work according to the purpose, the organization and the human landscape?

Another central assumption in this approach to TA is that affected stakeholders should be included in TA [14]. TA is not only (but also) for experts and engineers. Universities, civil society, public authorities and businesses are often mentioned as stakeholders that all must be included in TA.

Hence, TA is not a business for experts and engineers only. All the stakeholders in the technology assessment will act as issue advocates in the sense that they will bend the technology and the assessment in their direction. This is a means towards social acceptance. The TA experts will facilitate this negotiation, and act as honest brokers.

2.7 Comparison

To compare the different TA models I have set up a matrix where the different TA models are listed in the rows of the matrix. In the columns different items are listed that the TA models relate to in different ways: Who is the target group of the technology assessment model?, Who should be involved in the technology assessment process?, What is the role of the TA experts?, Should the TA experts conduct an ethical judgment?

The resulting comparison are seen in Figure 1:

	Target group	**Who is involved?**	**Role of TA experts**	**Judgment by TA experts?**
Classic TA	Politicians	Engineers, politicians	Science arbiter	No
Interdisciplinary TA	Politicians	Engineers, other experts	Pure scientist and possibly issue advocate	Yes
Ethical TA	Tech designers	Engineers, ethicists	Issue advocate	Yes

Hermeneutical TA	Public debate	Humanists	Honest broker	Yes
Participatory TA	Politicians	Engineers, other experts, citizens	Honest broker	No
Constructivist TA	Tech designers	Academia, public authorities, business, civil society	Honest broker	Yes. Joint judgement by all stakeholders

Figure 1 shows the field of technology assessment with some of its different models. We see that the different technology assessment models are quite different when it comes to target group, involvement of different groups, and the role of the technology assessment expert.

3 DISCUSSION AND CONCLUSION RESULTS

3.1 Tables

I have used the above described topology to present the field of technology assessment to Techno-Anthropology bachelor students at the 2nd semester in the spring of 2021. I presented each model in lectures followed by group discussions. The presentation of the TA models were part of a city engineering and planning course of formal reasons, and ran over six teaching sessions. The presentation of the field of TA was otherwise not linked to city engineering and planning. It could have also have been located as part of an engineering ethics course or in a separate course headlined 'Technology assessment'.

As all bachelor programs at Aalborg University Techno-Anthropology follows the principles of Problem-based learning. Each semester is split up in course modules (half of the time – 15 ETCS) and project modules (the remaining half – 15 ECTS). In the students' project work on the 2nd semester they are required to apply one of the TA models on a technology relevant to use by a municipality. Most student groups ended up assessing use of digital tools in social work. Few students assessed block chain technology to share info among municipalities or technologies to promote public health or foster green transition. By the time of writing this paper the students have not yet handed in their reports, but they have chosen which technology assessment model they apply: Around half of the student groups are using ethical technology assessment (6 groups), the remaining groups are divided between participatory (1 group), constructivist (3 groups) and hermeneutical technology assessment (1 group).

The topology did induce reflections among the project groups, as they needed to link their project to one of the models. It both helped the students to clarify their project and provided an overview of the field of TA.

Feedback from students at a midterm evaluation meeting indicated that they request concrete instructions on how to apply the models in their project work. Otherwise, the students found it difficult to do so. Hence, I provided clear instructions on the different steps of all the models except classic technology assessment.

Next time I offer this overview of TA models to students on the 2nd semester of Techno-Anthropology, I will revise the tasks I embed in the teaching. This year they were directed towards understanding and comparing the different technology models. I have previously had success in my teaching with embedding student presentations on pre-defined case studies [15, 16]. I will include case oriented tasks asking students to present concrete technology assessments that follow the instructions of the different models.

Many questions can be asked to whether TA is an useful approach to stimulate ethical reflections among engineering and technical science students. Hence, more research is needed to define and answer those. However, before these questions can be addressed an understanding of different TA-models must be conveyed to the engineering ethics education research community. This concept paper has tried to do just that.

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E-LEARNING AS MEANS TO FACILITATE SUCCESSFUL TRANSITION FROM AN ENGINEERING BACHELOR TO A TECHNICAL MASTER'S PROGRAM WITH ANTHROPOLOGICAL AND ETHICAL CONTENT

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ABSTRACT

The transition between BSc and MSc study programs can be challenging – especially if a student changes from one discipline to another, for example, when an engineering bachelor changes to the master's program in Techno-Anthropology (T-A) at Aalborg University, which is a technical master's program with anthropological and ethical content. To facilitate such transitions, Aalborg University allocated funding to develop and offer the e-course "Introduction to Techno-Anthropology". The e-course is a set of seven modules introducing the central concepts and methods of T-A to applicants without a bachelor degree in T-A. This paper sketches the design and provides a technology assessment of this e-course to determine how it could be improved and applied to ease the transition between different study-programmes that face similar challenges.

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1 INTRODUCTION

As a regular practice at Aalborg University, every course and semester have a feedback session where students and course coordinators reflect on the quality, content and other issues like the study environment. From 2014 until 2019, there was a repeated perception of repetition among the Techno-Anthropology (T-A) bachelor students who continued at the master's program regarding the content of the first semester. On the other hand, from the side of students who came from the outside with another study-program, university and/or country, the perception of concepts, topics and expressions, taken for granted by the T-A bachelors, generated overwhelm, frustration and sometimes desertion from the program. The confusion usually peaked when the program´s problem-based learning assignments nudged the students to collaborate in group work. The new PBL context, in addition to time restrictions, interdisciplinarity and heterogenic participant´s expectations, generated disappointment and uneasiness in students with both a background and a non-background in T-A. These conflictive situations overloaded the program coordinators, supervisors, career counsellors and sometimes staff from the international office and the program´s study secretariat; not to mention the foggy environment among students.

1.1 Method

As researchers and teachers at T-A we often recommend students to apply Action Research (AR) as a methodology to address technological challenges. Thus, we decided to take some of our own medicine and apply AR to deal with the problem at hand. An obligation in higher education is to enhance the quality of the teaching and continously improve the students' experiences e.g. in their on-boarding process when enrolling in a new master´s program. Having recognised the challenge described above, the different involved parties, the clear need for change, and the shared vision for a collective solution let us to recognise that the precondions were present to do a participatory action research project. The main purpose of this methodology revolves around an action group that recognizes that there is need for a change. The central element for AR projects is that transformative processes are designed collectively as a democratic practice, aiming at the community´s empowerment through shared knowledge production. [1,2,5,7]

1.2 The collective purpose

In September 2019, a collective planning session took place aiming to define the research objective and a shared vision to promote change and empowerment. The action group was made up of two researchers at the Techno-Anthropology and Participation research group (TAPAR), the head of the Study Board for Techno-Anthropology and Sustainable Design, an e-learning consultant at Aalborg University and a former T-A master´s student. One of the researchers and the e-learning consultant are no longer working at the university. They decided to leave the university when the project was in its final production phase. Their decision to leave did not jepordize the successful implementation of the project, as their final working tasks were taken over by other members of the action group.

The action group decided to address the challenge of conflicting experiences of the master's program in T-A though the setting up of an e-course with the purpose of levering the incoming external students' techno-anthropological knowledge. During the process of collective knowledge production, and after multiple co-creation instances, we managed to engage a selected group of teachers from the departments of Planning and Culture & Learning, aiming to contribute to the content design and production of the e-course. The teachers were seletected based on their seniority and involvement in the study program of T-A in terms of course responsibility. More than half of the staff teaching at T-A participated in the formation of this e-course. In addition to the possible solution to the challenge detected, this project created an instance of collaboration between university teachers located at different campuses in Aalborg and Copenhagen, who otherwise would not discuss nor share their teaching.

2 THE CO-CREATED SOLUTION

Both the action group and the participating teachers recognized e-learning as a promising pedagogical technology that has gained more attention in the latest times [6]. Therefore, the main outcome of the co-creative sessions, was to develop an introductory digital course to prepare non-T-A applicants for the T-A master´s program and level out the differences between them and the T-A bachelors (**empowerment**).

An intended effect was to create a showcase and a motor for developing film bits to be used in both the e-course and during the bachelor´s program, as part of the Aalborg University´s flipped approach (**change**). The flipped approach gives access to topic-related material to students in preparation for deeper discussions and reflections in class. The teacher can then perform basically as conductor and facilitator of interaction in class. In this modality, teachers use more efficiently their teaching time to enhance the student´s learning experience [8].

Finally, the conceptualization and development process for the e-course enabled co-constructive sessions aiming to build coherence and consistency in the master´s program between the Aalborg and Copenhagen branches (**interessement and collaboration**).

2.1 Exploring digital learning experiences

As part of the context exploration the action group was interested in understanding how scientific knowledge is disseminated, research results are shared, socio-technical content is taught, and technological innovations are communicated for a non-expert audience. That led us to explore references and cases of use of video-lectures, electronic courses (e-courses) and electronic learning platforms in topics closely related to our studies. The exploratory work allowed us to identify good and problematic elements, having consideration on two different points of view, the teachers and the students.

In Annex 1 one can find a table that shows detailed the key features that we mapped and assessed from a selection of digital training experiences. The items were identified through a internet search followed by manual assessment of the relevance of the identified ressources. Overall, we find three central elements in the configuration and disposition of educational content: the technical platform, the availability of additional resources, and the layout.

In regards to the technical platforms, there are all kinds of varieties of technological solutions; one can find in-house options with highly personalised training methodologies, including features that enhance the experience of the students, i.e the possibility to see independently the powerpoint presentation that the teacher is presenting in the video-lecture. A second option includes the private and standardized solutions such as Coursera, Future Learning, etc. These providers have an exigent list of requirements, content curation to guarantee a minimum of quality for their customers. The features of the courses are standardized, and the user can enable or disable different options depending of the level of usability desired. In the third option, we include the video platforms like Vimeo, YouTube, The Royal Institution, TED talks among others, that are channels for public dissemination of knowledge, and where the quality of the audio-visual explanation and its content relies mainly in the author.

The structure and additional resources have a relation to the way authors organize the course content. There are clear narratives in the themes included in the courses that give coherence and direction to the students' learning processes. In addition to the pedagogical approaches, there are several combinations of media and other resources as images, gags, games and assessments embedded in the main lectures. These elements not only are supplements to the learning experience but also help the students to focus their attention in the lectures and are incentives to complete the course.

Finally, the layout. It includes all kinds of combinations supported by aesthetics that aims to create not only the atmosphere for learning but to engage, attract and reflect the formality, seriousness and dedication from the authors presenting the content with quality. Some of the features include, professional audio and video filming and editing, a structured and coherent use of shapes, colours, figures and effects, and the use of various ways to present ideas for instance, the alternation between videos, slides presentations and the use of the blackboard. All these elements print a special dynamics to the courses.

The caring combination of most of the elements highlighted above needs to be analysed from extant possibilities when developing an electronic course. The action group recognized and identified the boundaries connected to their current technical capabilities, the lecturers´ skills, the time restrictions, the equipment limits, locations and budget. All these items had to be alligned in the course to capture and engage the desired audience - students facing a transition from a bachelor program in engineering and natural sciences to an interdisciplinary technical program with anthropological and ethical content [4,5,6] – which was quite a challenge.

2.2 Project design (approach structure):

The design of the e-course consisted of choosing the central theoretical concepts, methods and illustrative examples from the T-A bachelor program, and of deciding on features of usability from other courses explored.

The design, implementation and execution of an e-course initiative requires good practices on project management to accomplish the action groups' expectations regaring the budget approved, time limitations and teachers availability. Therefore, the planning stage established the following project structure: Agreeing and conveying project goals to all the participants, defining the course´s content, gathering available material, defining the course format and layout, making the content production plan, defining the evaluation scheme, and adjusting the teaching sequence. The sequence of the content becomes central because it assures that the students can follow the narrative of the course as a coherent and cohesive experience.

2.3 Content and Modules structure

The course was distributed into **three parts**, the e-course introduction, modules with lectures, and a PBL experience module.

2.3.1 Part 1.

The introductory guideline and context driven presentation of the e-course divided into sessions. a) The welcoming and explanation of the e-course, b) a second session where the students are introduced to the concept of Techno-Anthropology. They have access to some examples of how techno-anthropologist work, discuss and assess users and experts interaction with technologies. The main areas of research for the T-A master´s students is presented. Finally, students have access to some good practices on how to read academic papers and what does the PBL experience means for any student at Aalborg University.

2.3.2 Part II

Central concept modules. Organized in six modules, this part has inspiration from the content that is taught during the 6 semesters of the bachelor´s program in Techno-Anthropology. In the following, we will present the aim for each module. 1) Socio-technical understandings of technology (1st year). Presents, explains and provides examples of central theoretical concepts, the epistemological understandig of the techno-anthropological repertoire of theories and models, and how we use them in our projects. 2) Ethnographic and anthropological methods to support technological design (3rd semester). The module explains ethnographic and qualitative methods that we use to interpret the interaction between humans and technologies and to make design and performance improvements. 3) Digital Methods. The third module present the digital methods as an emerging field that allow researchers to make ethnography in the digital sphere, prepare the available information before going to the field. Students are introduced to why these digital methods becomes more relevant both in techno-anthropological research and contemporary society. 4) Technological intervention through action research and participatory research (4th and 5th semester). This part presents examples and theoretical background, pertinence and relevance of participatory design and action research approaches as the finger print that characterizes the techno-anthropological work. 5) Sustainable and responsible technological innovation (all semesters – the overall objective of the program). In this module, the students are introduced to concrete examples of contributions of techno-anthropological approaches to make responsible technological innovation. And the last module 6) is an invitation to write a motivational letter taking as inspiration the explanation that some T-A graduates and the honorary professor Peter-Paul Verbeek gives around the relevance of the Techno-Anthropology for the future of humans and technologies. This module explicitly liaises the applicant's background, competencies, and future employment interests. The motivational letter must address how combining the course participants' bachelor degree plus the MSc in T-A will help them achieve their professional and academic aspirations.

2.3.3 Part III

The PBL experience is a compilation of best practices, experiences and concepts that would facilitate the way new students understand how graduates from Aalborg University performs in their projects and future work environments. The carefull selection of topics in this module give tools for organizing the work, help to formulate research questions and among other tricks help the student to situate her as a key team member that enrich interdisciplinary work experiences.

2.3.4 Modules structure:

The e-course requires from the students three to four weeks of dedication with around six to nine hours of work per week. Each module follows a standard structure, as shown in the following illustration. The module configuration includes a basic description that highligths the main objectives and the learning goals of each lecture. Each teacher prepares a selective list of key references that the students are required to read, prepare and reflect upon before whatching the video lectures. The video-lectures' duration depend on each topic and in average the lessons are not longer than 7 minutes each. In between video lectures, some multiple choice and true-false quizzess were set to facilitate the progression of the students with the lectures' themes. At the end of each module there is a final quizz that assesses the attention, retention and understanding of the concepts presented in the module.

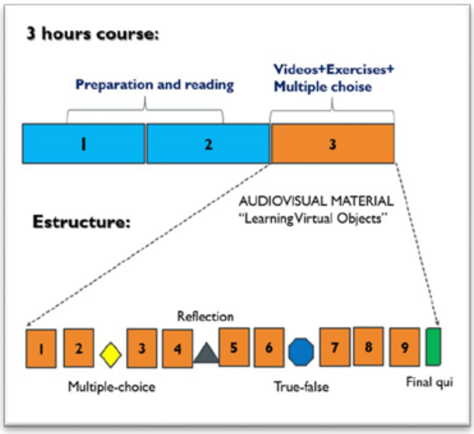

Fig 1. Configuration of each module in the e-course

The reader and other interested parties can enrol in the e-course by sending an e-mail to Introt-a@plan.aau.dk with the subject “Enrol me”. Next, one will receive a link to the course and further instructions.

3 WHAT WE LEARNED

The collective knowledge production represents the essence of AR; hence we want to present some lessons learned that made the process more straightforward and significant for all parties.

3.1 Engaging teachers in the defiance of synthetizing and digitalizing their lectures.

A live-lecture involves a teacher’s abilities to adapt and perform during the lecture depending of the characteristics of the audience, time limits and the specific context. The human to human interaction in class, plays an important role in the mutual feedback between students and teachers and here the experience of the teacher becomes essential to keep the students´ attention. In a video film, the teacher is performing in front of a camera, there is no eye contact thus, limited feedback from the reduced audience present in a film set. After making some footage samples, video mockups and a video lecture pilot, discret options were defined as the possibilities offered to the teachers for their digital lectures.

This was one of the most challenging tasks in the development of the e-course. The plan with teachers included classification and prioritization of the content of their lectures. All the selected material was upgraded and complimented when needed to have homogenous visual resources to include in the lectures. Some teachers felt more confident with the slides, others with some notes on paper, others supported by a script running in a teleprompter, and some more experienced with cameras act a hands-free speech lecture.

3.2 Technical and usability considerations

All the best practices for producing academic audiovisual content converge on four basic elements: quality of sound and video, natural light preferable over artificial illumination, clean cuts and edition, and dynamic elements included in the videos to call the attention of the audience. These considerations influenced the type of equipment and the editing software used. Furthermore, in the second part of the project, we incorporated a green screen to have more flexibility in the video edition and production stage. Some of the additional features embedded in the videos were various figures, graphs, gifs (micro-videos), flying words and illustrations to reinforce the messages. Considering the diversity of accents and facilitating non-native English speakers, the project included subtitles in English for all the content produced.

3.3 Minimal human support, but support

We designed and equipped the e-course with enough resources to provide the students with maximum autonomy, and knowing there were no resources to supervise students once following the course. The practice showed another reality. Very engaged students wanted to be sure that they were on the right track and nothing were missing in their process to produce their motivational letter for applying to the master´s program. Several questions reached different instances in the university with frustration. Thus, we introduced some changes and made public an email address for guidance. This simple gesture improved the perception of the rigour and professionalism at AAU and allowed the authors to have ongoing feedback from the students [3]. Some students expressed that they were not expecting a human interaction within the course and that it turns out as an incentive to consider applying to the program strongly.

4 ASSESSMENT AND PILOT

The first experience with the e-course with a real audience was in a focus group with five students from the second semester and two graduates from the master´s in techno-anthropology. Additionally three students from different master´s programs also shared their impressions and interest in the e-course. Some suggestions were included in the final version of the e-course.

The public pilot was launched among new students enrolled in the master´s program in fall 2020. All the students, including those who graduated from the bachelor, received an invitation to follow, voluntarily, the e-course to prepare for the semester start. A total of sixty-three students enrolled both in Aalborg and Copenhagen. As was expected, only those who came from different disciplines finalized the course, twenty-three in total. The general impression of the students was very positive. In class, it was possible to identify those who completed the course because of their reflections, the use of some concepts and their confidence in group work with students with a background in techno-anthropology.

No quantitative course evaluation was made. However, we take notice of a suggestion by an anonymous reviewer to include a quantitative course evaluation in the e-course that must be answered to complete the course.

5 RESULTS

5.1 Public release and feedback

The final release of the e-course in the public platform for e-learning at Aalborg University was in late January 2021. As part of a campain to help student applicants to know if T-A would be the rigth choice for them.

The e-course was published in the master´s program's oficial web page, its facebook page, and the official profile of T-A at Linkedin. A total of ninety persons asked for enrolment, eigthyfive effectively enrolled in the platform and more than sixty followed the e-course. In the end, twenty-nine students completed the e-course and handed in a motivational letter to apply to the master´s program in fall 2021. Despite some slight technical issues that were corrected immediately, the feedback from all the students did not have critical remarks. In general, the experience of those who completed the course was very positive. This was mainly reflected in the inspiring motivation letters sent by the applicants and in several messages of gratitude that the course´s tutor recieved from different coutries around the world.

5.2 Replication of the idea

In the last year, the sibling program of T-A, the master´s program in Sustainable Design Engineering, decided to replicate the idea and implement an introductory course for their new students. In the last months, colleagues from other departments asked for guidance and support to implement the same initiative in other interdisciplinary programs that face the same challenge with students coming from different backgrounds. As part of a plan for facilitating the production and development of digitalized academic content, a business-oriented spin-off inspired by this experience was founded and is called Techno-Anthropology4U [www.TA4U.dk].

In the coming months, the initiative´s next level will be creating the Open Science and Responsible Innovation Teachers´ Academy. This project pretends to incorporate the experiences with this e-course into a hybrid course that will help and prepare higher education teachers to communicate their research in the framework of Responsible Research and Innovation (RRI). This initiative is supported by the COST Action EuroScitizen: CA17127 - Building on scientific literacy in evolution towards scientifically responsible Europeans.

6 CONCLUSIONS

In this paper we have shown how the problem with transition of students from specialized engineering or natural scientific bachelor degrees to a technical master´s program with anthropological an ethical content can be addressed through action research and e-learning. We have presented our inclusive co-creation action research process and the resulting e-course “Introduction to Techno-Anthropology”.

During the process we learned that engaging university teachers is key in digitalization of higher education. You can produce e-learning solutions almost from scratch if you have engaged teachers and some institutional support. We experienced that our e-learning project was easily accepted by both students and teachers because it solved the problem that conventional teaching did not addressed, and did not substitute existing conventional teaching.

We could not create an e-course that was 100% automated. It requires a minimal effort of human support and feedback to overcome students’ misconceptions and technical barrierers. Still, the e-learning solution turned into an effective use of resources. For instance, teachers´ time to assess applications to the program decreased.

The e-course made the students focus and align their expectations, which enabled better reflections and coherent group discussions once enrolled in the master´s program.

Starting almost from a low level, it was possible to build up to pedagogical, didactical and technical e-learning expertise within an action group, whose competences are now in high demands in other programs.

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Annex 1

Name and host institution	Key features	Good	Problematic
Course in philosophy of Technology / University of Twente.	• The course is allocated in a stable learning platform (Future Learning) • Very well explained content supported by visual resources • The course allows human-based feedback and peer interaction • Professional edition and production • The content follows a structure and clear script.	• Attractiveness • Clear message • Short and concrete • Clear language	• Performance depends on the presentation skills of the teacher • High demand of resources (time and money) for audiovisual production • The course demands human assistance for the reflection parts
Interview with Peter Paul Verbeek: blurring boundaries between man and technology / FastFacts Sciencetube.	• The material is a complete interview that present concepts and exemplarity cases • The interview is oriented to present areas of research and intriguing findings • Combines different academic, scientific and commercial contents	• The interview is structured and has a clear take-home message • The complementary content is illustrative • The time frame is short	• Requires video edition and production • Five minutes presentation can be enough. Depending on the topic it might be too short • The quality is relying on the fluency of the lecturer
Reinforcement Learning | Winter 2019 | Lecture 1 – Introduction / Stanford Engineering.	• Hybrid course: Virtual content combined with presence presentations • The lecture is recorded in the classroom with the support of a *powerpoint* presentation. • The presentation is complemented with closed-captions	• The changeable screen between the lecturer and power-point presentation helps with the dynamic of the presentation. • The resource of the whiteboard is very useful for improvisation during the class.	• The teacher gives the pace of the class; there is not enough room for interaction with students, or other dynamics. • A 1-hour lecture requires lots of time for edition. • After 20 minutes, despite the interesting topic the presentation turned monotonic. • The presentation is flat and with no design at all. • The language tends to be for a specialized audience.
Internet of the Things / Stanford Online.	• The online platform allows the participant to see the progression and the time spend in the course. • The platform has a feature to make a short tour through the basics of the platform before starting the e-course. • The course has not only video-lectures but also *powerpoint* presentations, literature and other tools. • The communication style is very clear and the language is very accessible for a non-expert audience.	• The features are very user-oriented and intuitive. • The same topic is presented and supported by different speakers. • Once the student open the video, the slides of the session appears in a pop up window. • The personalization of the speed to reproduce the video is enabled. • The course includes assignments to foster the learning process. • The teachers are very fluent in their presentation. • The presentations are very well-designed following coherence and standardization.	• The presentation tends to be very formal but maybe less attractive for young audience (standardized). • The background is white with only one camera, it turns into a static and flat presentation

Name and host institution	Key features	Good	Problematic
MIT open Course: Introduction to Machine Learning / MIT	• This is a lecture recorded in the classroom with the support of a *powerpoint* presentation. • It is allowed to have students' interventions and question • The presentation is complemented with closed-captions.	• The changeable screen between the lecturer and *powerpoint* presentation helps with the dynamic of the presentation. • The resource of the whiteboard is very useful for improvisation during the class. • The *powerpoint* presentation is more structured and include design features.	• The teacher gives the pace of the class. • 50 minutes lecture requires lots of time for edition.
SCRUM- Introduction Course. / Scrumstudy.	• The course is allocated in an in-house platform. • All the content and material is available in the sharing resources platform. • The evaluation takes place both during some parts of the lecture and in a special session. • The course allows participants to have access to complementary material • The interaction to peers is enabled in the collaborative platform.	• Allows discussions between peers. • Allows Q&A session with the facilitator of the course (it is a live session). • There is time for individual feedback at the end of the course.	• The time is very limited for Q&A and vary depending on number of participants. A next level of supervision is not included in the price of the basic course; the provider offers additional levels where they have more specialized guidance. • It becomes evident that the course has economic prevalence (cross-selling courses are related). • The limited access to additional material generates frustration and lead you to buy another level of the course. • The material lacks of design and a coherent visual structure.
Artificial Intelligence, the History and Future - with Chris Bishop. / RI (the Royal Institution).	• Lecture are recorded in an iconic theater • The conference involve a high film production that includes more than three cameras and full edition • The audience have access to a big screen with the presentation • The presenter has evident skills to perform in from of the camera and simultaneously in front of a big audience. • The production includes a selection of videos embedded in the presentation. • The lecture is full of smart jokes and engaging side stories connected with previous RI presentations	• The lecture format is very attractive and engaging. • The management and production of the images and change of camera is clean a very professional. • Usually the format of the lectures include experiments and some interactions with the public. • The tradition of the lectures transcends centuries, it started in 1825 with the inaugural lecture with Michael Faraday.	• The lecture demands many resources (filming, edition and production). • The quality of the presentation rely in the expert is not in the learning platform.

MIXED-MODE TEACHING: EMERGING FROM COVID-19 TO FUTURE PRACTICE

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Keywords: mixed-mode, flexible education, accessibility, professional practice

ABSTRACT

The COVID-19 disruption abruptly and significantly changed the way engineering and IT subjects were delivered. For our subjects, this meant a one-week turnaround from face-to-face teaching supported by an online learning management system (LMS), to a fully remote teaching model making use of the LMS and several collaboration platforms. Remote learning had to accommodate a common, quality learning experience for students in different locations, time zones and with different access to materials and technology in addition to the usual large class management tasks. The learning from this transition was invaluable in terms of effective, alternative ways to achieve our learning outcomes. We have now moved into a new phase where our students are eager and encouraged to be back on-campus, however, border closures and other concerns mean that there are students who cannot be physically on-campus. This gives us the option (and in some cases imperative) to deliver classes in mixed-mode. The challenge then is that those students who attend on-campus get the benefits of face-to-face teaching while still delivering an equally valuable experience to those not physically present. This paper reports on the experience of transitioning to mixed-mode delivery for professional practice subjects at an Australian university with a particular focus on a career management course for IT students. We believe that learning from this experience will be useful in the transition out of the COVID-19 disruption and can enhance future student experience by providing sustained flexibility and improved inclusivity and accessibility.

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1 INTRODUCTION

The COVID-19 disruption to teaching and learning resulted in a significant and sudden change to the way subjects were delivered to students. In Australia, the disruption occurred near the beginning of the academic year and resulted in a large number of students being unable to enter the country and others unable to travel to attend campus. The result was a move to remote teaching in a short time frame for the first teaching session of 2020. For subsequent teaching sessions over 2020, learning activities were improved and refined in line with the experience, feedback and outcomes for teaching staff and students.

Australian universities now find themselves in the position that students based within the country are free to attend on-campus classes with only a few intermittent restrictions, while a significant number of students are still unable to return to the country. There is a strong desire from universities, students, government and other stakeholders for on-campus activities to return. This presents a challenge of how best to provide equitable, quality educational experiences to both students who are able to return to campus, and those who in the short-term cannot.

This paper reports on the experiences of transitioning from remote teaching in 2020 to a current mixed-mode of teaching for professional practice subjects in engineering and IT. The paper focuses on a case study for IT students completing a subject that prepares them for internships and draws on the experience of other subjects which are currently facing the challenges of mixed-mode delivery. The learning from these experiences can inform future teaching practice as we transition out of COVID-19 and has implications for how we may support inclusive, accessible and flexible teaching and learning past this disruption.

2 BACKGROUND

The University of Technology Sydney (UTS) has a "Model of Learning" that guides curriculum design and provides a framework for practice-oriented learning. As one of its three key points, the model focuses on integrated exposure to professional practice which includes experiences such as internships and work-integrated learning [1]. In this context, engineering and IT have a stream of core subjects focussed on professional practice and support for student internships. UTS guides teaching staff to support this learning by making use of evidence-based best practice for teaching and learning, active and personal learning and authentic assessments [2].

In March 2020, one week into the semester, when the country locked down and university campuses were closed due to COVID-19, the university paused teaching for a week to rapidly redevelop all subjects for remote delivery. In line with the university model of teaching and learning the university mandated an interactive model of learning be implemented. That is, students should be given the opportunity to interact with others, opportunities to work in teams and build knowledge together. Classes remained synchronous and were largely conducted with the use of Microsoft Teams (Teams) or Zoom. The aim was to have no decrease in synchronous teaching time.

The research suggests that remote and on-campus teaching can lead to similar levels of academic performance but that students and teacher preferences vary for the type of activity that is best conducted remote or on-campus [3]. In addition, students with different learning styles will respond differently to various modes of teaching [4]. It has been acknowledged that the success of remote teaching is dependent on "pedagogy not technology" [4]. Experience in blended learning, flipped classes, and other modes of teaching and learning that mix synchronous, asynchronous, on-campus and remote teaching highlight the importance of teaching design and the integration of the technology rather than placing a focus on the teaching modality [3, 5, 6].

Courses in the professional practice and core streams at UTS faced challenges moving to remote teaching. They are typically large cohorts (up to 1000 students per semester), involve group projects or are focused on work placements, all of which required significant redesign with the COVID-19 disruption. A year of teaching in this mode resulted in a better understanding of how to facilitate remote, synchronous teaching including leveraging the use of collaborative tools such as Office365, Teams and Mural [7].

In late 2020, with COVID-19 locally under control, the university made the decision to start returning some classes to campus while still supporting students unable to attend campus such as offshore or vulnerable students. All subjects are required to support remote teaching while offering on-campus classes where safe and possible in line with the university's model of teaching and learning.

Some subject designers chose to have tutorial sessions that are run remotely but which include both students who are able to attend on-campus and those who cannot. In some of these sessions, locally-based students have chosen to log in from campus, physically meeting up with their project groups so that they can work in person. The result is that the teaching is done remotely and some of the students are remote and individually signed in, while others are physically together and signed in from a single device sharing the login. Our experience has been that the on-campus students enjoy this face-to-face collaboration with their teammates, however, it has an effect on the remote interactions. Activities have been designed for remote teaching where every student is individually present online and can contribute to discussions and collaborative tasks. With one representative out of four signed in for some groups who met on campus, interaction and collaboration is limited. In addition, these groups often meet in shared spaces on-campus so their communication is inhibited by the surrounding activity.

Other subjects have elected to conduct separate classes for on-campus and remote classes in this transition phase. However, this requires additional resources including developing separate activities and assessments that work best in each medium, additional staff and costs to run multiple classes, etc.

Transitioning from remote teaching to now supporting both remote and on-campus teaching, the designers of the subject Career Management for IT Professionals sought to trial mixed-mode delivery, where both on-campus and remote students are brought together at the same time and taught together in their preferred mode. The decision was made with the mind to minimise resource use while maintaining sound pedagogy.

The definitions of what makes a teaching mode "blended" is not definitive in the literature, however, they have in common that all students in the cohort receive similar instruction with components of on-campus and remote activities [8]. New conditions mean that teachers and learners are facing a scenario where the same cohort of learners may be synchronously exposed to different modes - what we will refer to as mixed-mode in this paper. Through exploring our experiences with mixed-mode delivery in one of our subjects, we hope to investigate ways in which we can bring the benefits of mixed-mode delivery to our larger subjects during this transition phase and beyond.

3 CASE STUDY

3.1 About Career Management for IT Professionals

Career Management for IT Professionals (CMITP) is a core subject for students enrolled in our combined Bachelor of Science in Information Technology and Diploma in Information Technology Professional Practice program. The program requires students to undertake subjects on career and placement preparation, a 9-month industry placement supported by work-integrated learning coursework, and a placement reflection subject in addition to their IT degree. CMITP has a cohort of between 40-125 students per semester and runs three times per year. The aims of the subject are to support students in developing their job-seeking skills (such as job searching and interview skills), developing job-seeking artifacts (such as cover letters and resumes), as well as developing their understanding of the IT industry and the realities of work including discussion on topics such as professional communication, company culture in Australia, wellbeing in the workplace, and time and task management.

Prior to the COVID-19 disruption, CMITP was taught wholly on-campus with the entire cohort in one large collaborative space. Classes were a mix of lecture and tutorial content where students would be introduced to material and concepts and would then, alone or in groups, work on activities such as skills stocktakes or peer review of others' resumes. As with all our subjects in 2020, CMITP transitioned to fully remote teaching for the first two sessions. Teams and collaborative documentation software such as Office365 and Mural were used to maintain a connection with students and continue delivering classes synchronously.

3.2 Transition out of COVID-19 Disruption

For the final session of 2020, it was apparent that classes could return to campus. In Week 1 of the session a poll of the 125 enrolled students was taken to gauge interest in returning to campus or staying remote. Approximately 25% of students wished to return. We wanted both on-campus and remote students to get the same value from their learning experience and there was no additional budget available to offer both remote and on-campus classes separately for this subject.

Drawing on the experience of teaching remotely for two semesters as well as the experience of colleagues who have taught in mixed-mode delivery prior to COVID-19, we looked into the practicality and suitability of mixed-mode delivery. All students - whether remote or not - were in the same timetabled class, taught by the same lecturer and connected through technology. This teaching method would allow us to bring remote and on-campus students together providing a more unified experience of the subject, and would ideally not cost anything additional to implement with a cohort this size. Some of the disadvantages of remote learning in the literature are that a lack of communication with peers and teachers, limited social contact or peer-to-peer interaction and lack of timely feedback may affect the development of oral communication and teamwork skills [8, 9]. It was important for us to consider these aspects in the subject design for mixed-mode and ensure we facilitate feedback, communication and interaction with remote and on-campus students to achieve the communication and teamwork learning outcomes for our professional practice subject.

3.3 Mixed-mode communication

The learning from fully remote teaching informed our use of Teams as a platform for students to use for collaboration. This gave all students, regardless of the mode of delivery, access to each other and to the same tools and information. In the classroom, a Teams meeting was used to bring the remote students in. The lecturer made use of an external webcam and a lapel microphone to provide audio and video from the classroom to the remote students. The content slides were shared in the Teams meeting which was projected in the classroom. This setup meant everyone could hear and see the same content at the same time.

Remote students were able to ask questions in a chat or speak into their microphones which would be output to the classroom speakers. On-campus students in the room could ask questions as they normally would in a physical space and could also use the Teams chat. Similarly, on-campus students could talk to each other face-to-face or use Teams to communicate with those not physically present.

3.4 Mixed-mode activity design

Rather than simply having on-campus students do "remote work", the activities for CMITP were redesigned to bring back the benefits of pre-Covid-19 face-to-face teaching for on-campus students while facilitating the learning of remote students based on our learning during 2020 remote teaching.

During remote teaching, we experimented with Microsoft PowerPoint stored in Teams as a whole class collaboration tool. Other tools such as Mural (a cloud-based tool for collaboration) have been used effectively and were included in the mixed-mode design. As all our students have devices (laptops, tablets, smartphones etc), those students on-campus were able to access the same digital platforms during class as their remote counterparts could. This was particularly useful for whole-of-class activities.

Whole-of-class activities are used in CMITP in order to develop an understanding of what the class as a cohort thinks and knows about a given topic before we discuss it further. In addition, students get to be inspired and learn from the input of others. Examples of these are activities where students are given time to reflect on their own and add notes to a Mural board before discussing it as a class.

Where smaller group or paired activities took place, on-campus students would be grouped together and remote students grouped together. This allowed on-campus students to make the most of being physically present, able to use materials such as paper and sticky notes and able to discuss work without the limitations of virtual calls (such as poor audio quality). Remote students also benefited from being grouped only with other remote students as it removed some of the problems found in other classes such as background noise of other teams and audio feedback from multiple microphones and speakers. We made use of Teams functionality of breakout rooms to accommodate smaller group activities for remote students.

4 DISCUSSION

4.1 Whole-of-class activities

PowerPoint slides shared through Teams had been very effective in remote classes of 30-40 students, particularly where groups are working together rather than each student needing their own slide. This however proved ineffective for the CMITP cohort of 100 students. The students found it confusing which slide was theirs and there were numerous occurrences of editing the wrong slides, additionally, for those students with slower computers or internet speeds the file struggled to be responsive and they could not see their changes or others' in real-time.

Mural proved to be a far superior tool for this purpose. Mural was able to handle this number of students without issue. In the mixed-mode classroom, it was useful for bringing the two cohorts together in a meaningful and engaging way. As all students had access to the Mural page, all were able to add their thoughts to it with no indication as to whether they were on-campus or remote. As changes happened all students could see them on their own device and the Mural board was streamed in the Teams call and on the in-room projector so we could discuss the results as a class.

4.2 Communication and Cognitive Load

During class all students had access to text chat functionality, this turned out to be popular with remote students who tended to prefer it to speaking on the microphone. In addition, on-campus students also made use of the chat, primarily to talk with other students while the teacher was talking. While some questions came through from on-campus students this way as well, most were verbalised.

There were differences in the management of questions and comments in the mixed-mode class that differed noticeably from both on-campus and fully remote modes of teaching. While not measured, the number of questions in the mixed-mode cohort of students appeared to the teacher to have increased compared with previous on-campus or remote-only cohorts, and more detailed comments were also made by students in the chat than previously. Students would often discuss what was happening with each other in the chat which was encouraging to note given the importance of peer-to-peer communication and collaboration.

Of significance was that, as the students now had multiple avenues to ask questions and make comments, the teacher was required to monitor these. Keeping apprised of what was happening both in the room and in the chat was an additional cognitive load and was at times disruptive as the teaching was paused to check if what is being discussed in the chat contained a question for the teacher.

There were occasions where guest lecturers were teaching in CMITP. In these cases the primary teacher was able to monitor the chat, calling out questions at appropriate times. This lowered cognitive load for both teachers and suggests that additional resources in order to monitor the different communication channels would be needed in future for a cohort of this size or larger. An alternative method is a "student champion" elected from the cohort to monitor the chat and raise any questions, but this has not been trialled in CMITP as of yet.

Finally of note is the disconnect between the method of questioning and method of teaching. That is, where students on-campus would talk, remote students could not hear them, and similarly, where students wrote questions in the chat not all on-campus students were watching the chat. In addition, when there was a lot of activity, some students were unclear about which question was being addressed. It became imperative that teaching staff repeat questions into the microphone no matter the mode the question was delivered in, to ensure all students heard the question and knew the context of what was being said. This is acknowledged good practice in face-to-face teaching of classes in large spaces or when recording classes, but usually not an issue in fully remote teaching. It is an important consideration for mixed-mode delivery so that all students benefit from the questions and answers.

4.3 Technological Issues

During class, Teams was projected to on-campus students as this meant we could share the slideshow in the meeting and all students would see the same content synchronously. Unfortunately during class midway through semester it was discovered Teams had pushed out a non-optional update which changed the presenter view to not show the slide show full screen. The slides were smaller and it was ineffective to project them in the classroom. Microsoft has since added options to use either view, but the experience illustrated how even with considered design and experience with technology, mixed-mode delivery is subject to disruptions out of the control of students and teachers.

Another technological issue that was a consequence of all students being included in the Teams meeting, was microphone feedback. During class, particularly early on when students were unfamiliar with consequences, it was not uncommon for an on-campus student to log into the meeting so they can see the chat without considering the ramifications of having their sound or microphone on. If either of these are on it causes high pitched disruptive feedback in the meeting. While students are now familiar with "muting" themselves, turning the sounds off on their devices is less intuitive and a "new problem". A solution is to setup a meeting where the chat can be seen without joining the meeting itself (which Teams allows) as well as providing housekeeping guidance to on-campus students around either not logging into the meeting or turning sound and microphones off.

Similarly to the microphone issue, if on-campus students log into the remote meeting the efficient use of breakout rooms is affected. Using randomised breakout rooms meant that all students logged in were placed into rooms, including any on-campus students who had logged in. Where students were required to work together there were three options: instruct on-campus students not to log into the meeting; instruct on-campus students not to join the breakout room (leaving the breakout room one person short); or manually fix the breakouts. Our preference was the option of not having on-campus students in the meeting itself as they could still access the chat and it also prevents other issues such as the audio feedback.

These technological issues all required the teacher to have flexibility and a suitable level of IT skills to manage the class. This is in line with many teaching experiences during the COVID-19 disruption and the dependence on the IT skills of educators and the importance of technology is acknowledged in the literature [8, 10, 11]. For teaching staff with developing IT skills, an additional staff member with IT skills and experience in mixed-mode delivery would be useful early on to support the transition to mixed-mode.

4.4 Remote vs In-class participation

One consequence of the transition out of the COVID-19 disruption is that any student was allowed to attend the remote meetings (regardless of whether they could attend campus or not) and as a result, not all students who could be physically present chose to attend on-campus or they chose not to do so every week. Students taking up this option illustrated the value they placed on flexibility. It may be that these students saw the remote and on-campus teaching as equally valuable, or that the remote mode suited their learning style better, and while this would be encouraging, it requires more research to understand student choices, which may not be made on the basis of improving their own learning outcomes.

5 CONCLUSION

Our experience in implementing mixed-mode delivery for a professional practice subject has demonstrated that this is a feasible solution that has the ability to support paired or small group activities, whole-class activities, class discussions and student communication with peers and teachers all of which are important for achieving the learning outcomes in professional practice subjects. In line with the research on blended teaching and learning, the successful implementation of mixed-mode delivery depends on intentional activity design in order to promote the best learning experiences regardless of the students' mode of accessing the subject and that this requires sound pedagogy as well as technical skills and institutional support to implement. Although there are requirements for additional support in order to effectively manage multiple communication streams, we found that the size of cohort has implications for the implementation of mixed-mode delivery rather than being an inhibiting factor. This paper contributes to our understanding of the implications and feasibility of delivering subjects in mixed-mode as we transition out of the COVID-19 disruption, and informs which practices may be useful in future. The ability to effectively deliver our subjects in mixed-mode improves accessibility for students with disabilities, carer duties or other life commitments which allows for greater inclusivity and diversity in our engineering and IT students.

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GROWING GAP BETWEEN SECONDARY EDUCATION AND ENGINEERING BACHELORS IN FLANDERS: SPECIFIC SHORTCOMINGS AND CAUSES

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ABSTRACT

Over the past decade, teachers in the first-year of the Engineering bachelor program at KU Leuven have experienced a decline in the incoming students prior knowledge and understanding of STEM subjects and mathematics in particular. To study the perceived growing gap between actual and expected prior knowledge, first year students and tutors at the KU Leuven Faculty of Engineering Science were questioned. 500 students completed an anonymous online survey targeted at their first semester results, prior education and experienced difficulties in the transition from secondary to higher education. Interviews with 7 tutors aimed at getting a deeper understanding of specific shortcomings in prior knowledge and understanding. Results indicate that particular mathematical topics, such as complex numbers and differential equations, are expected knowledge when enrolling in the Engineering program but are rarely treated at sufficient depth in Flanders secondary schools. While the majority of students indicate to be satisfied with their secondary education, many still point out a lack of exercises, applications and depth of understanding. Other significant factors are the acquired study approaches, and time and stress management skills. Both inquiries confirm the mismatch between expectations by Flanders Engineering faculties and what is achieved at the secondary level. Secondary curricula, teaching methods and academic environments are said to have a direct influence on this mismatch. This warrants further research into the underlying teaching methods, guidance and curricula at the secondary and university level.

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1 INTRODUCTION

1.1 Problem statement and context

Professors, teaching assistants, and tutors at Flemish faculties of Engineering Science have noticed a steady decline in the level of prior scientific and mathematical knowledge in first year bachelor students. This exposes a gap between Flemish secondary education and the Engineering bachelor in Flanders that has been noticed since 2008 [1]. Additionally, a similar gap is noticed in other higher education STEM (Science, Technology, Engineering and Mathematics) fields [1]. A lack of prior scientific and mathematical knowledge has negative implications for both students and faculty members. Students have to 'bridge' the gap, which takes time and negatively impacts their motivation [2]. Tutors, on the other hand, receive increased requests for counselling, which is increasing their work load and forces them to explore increasingly creative methods to provide qualitative guidance to all students who are in need. Considering the relevancy and severity of this issue, the different Faculties of Engineering Sciences in Flanders, initiated dialogues with the Flemish secondary educational organisations and local teacher training departments. The aim of this cooperation is to decrease the gap between both secondary education and university engineering education. Within this context, the need for a clear description of the problem arises. Both higher edcucation institutes and secondary education schools require a clear definition of the problem related to the gap between both educational levels. This exploratory study aims at providing such a clear description, focused on mathematics and interdisciplinary projects. Mathematics has a significant role in all major STEM fields. Interdisciplinary projects combine application of theoretical concepts and integration of multiple subjects, which characterizes most engineering disciplines. The presented research scope is limited to the KU Leuven Faculty of Engineering Science. This faculty hosts two principal bachelor programs: Engineering (Ir.) and Engineering-Architecture (Ir.-Arch.), along with a multitude of specialized master programs.

1.2 Research questions

The aim of this research is to accurately describe the discrepancy between Flemish secondary education and the first year of local Engineering bachelor programs. Specifically, the mismatch with regards to mathematical course contents and problems regarding study methods and attitudes are studied in order to answer the following questions. How do students experience the transition from secondary school to an engineering bachelor? What problems, in terms of study methods and attitudes, are experienced by students? What mathematical topics do students struggle with? How do these problems relate to prior secondary education? What are the underlying causes at higher levels of education?

2 METHODOLOGY

In order to answer the questions put forward, this paper uses an exploratory approach. To this end two groups were surveyed: first year students and academic tutors at the KU Leuven faculty of Engineering Science It is expected that tutors' viewpoints potentially allow to observe an evolution in time, especially considering the long-term employment contracts of the tutors, whereas student experience may only offer a snapshot building on their own experience.

Seven tutors of the KU Leuven Faculty of Engineering Science were interviewed in a one-on-one setting. All tutors were involved in the support of different first-year Engineering and Engineering-Architecture courses and across the seven tutors, all first-year classes of the faculty were covered. Tutor interviews took place in a period of one month before the student survey was presented.

During the interviews, the discussion was left open as much as possible but four key questions guided all conversations:

1. When students consult you, what problems are you approached with?
2. What are, according to you, their principal challenges that students encounter?
3. How can KU Leuven help to remedy these problems?
4. How can Flemish secondary institutions help remedy these problems?

Notes were taken during these interviews and tutor's answers were subsequently compared to each other. Close attention was paid to highly similar and directly contrary opinions.

First-year students at the KU Leuven Faculty of Engineering Sciences were questioned in the form of an anonymous online survey. The survey was presented in the first week of the second semester of 2020-2021. This timing offered students time to reflect on their results of the first semester, the study techniques they applied, and any difficulties they may have encountered. Additionally, this survey questioned them about their prior experiences in secondary education, including: prevalence of (interdisciplinary) projects in these past years; specific mathematical subjects; studying techniques; time and stress management; and personal appreciation for their secondary formation. Subsequent processing of the results was aimed at:

1. Relating the hours of mathematics students had in secondary education with their scores during the first exam period.
2. Relating the presence of certain math topics in secondary curricula with their scores during the first exam period.
3. Exploring overall student satisfaction with regards to their secondary education and specific contributions to this satisfaction.
4. Exploring students' perception on studying methods and attitudes.

The anonymous survey was filled in by 500 students, henceforth referred to as the sample group. This group consisted of 425 students enrolled in the Engineering (Ir.) bachelor and 75 students following the Engineering-Architecture (Ir.-Arch.) bachelor. These numbers correspond to approximately 90% of first-year students for both programs.

3 RESULTS

3.1 Tutor interviews

None of the seven interviews revealed any conflicting viewpoints or opinions. All results and answers are summarized in the following paragraphs. The tutors perceive a significant mismatch between the level that is achieved in Flemish secondary education and what students are expected to master at the start of the Engineering(-Architecture) bachelor program at KU Leuven. Different tutors also note that, even if current secondary curricular goals are fully achieved, a gap between both levels still exists. The existing gap is, at least partially, due to high expectations in Flemish university curricula. The root causes here are believed to be twofold. On one hand, tutors feel that university teaching staff is not sufficiently aware of secondary education curricula, especially if they have been subject to changes. On the other hand, professors and engineering programs as a whole are often reluctant to make changes or additions to university curricula as this would reduce the available time for what currently are principal engineering subjects and taking into account the expectations of the work-field of graduating engineers.

Tutors indicate that students struggle to gain sufficient insight in these engineering topics, possibly due to lack of abstract reasoning skills and a lack of contextualized examples. A multitude of potential causes are stated by tutors. First, there is the evolution of Flemish secondary curricula away from theory and towards alternative assignments and teaching methods. Consequently, secondary education textbooks contain less theory and a lower level of abstraction. Specifically, textbooks are also stated to contain very few contextualized examples, i.e. exercises in the context of a real life application. Secondly, teachers in secondary education face serious challenges due to strict limitations of teachers' classroom instruction and evaluation to not exceed course curricula. Thirdly, heterogeneous class groups, make it difficult to challenge all students in a single class, while providing sufficient time for support. Finally, the training of younger teachers puts a greater emphasis on newer, less theoretically strict teaching methods.

Tutors also note that, as the scope of study narrows in the academic bachelor, course contents become more profound. The accompanying (mathematical) concepts are also more complex and students allegedly have trouble understanding and discerning between these concepts. According to tutors, the increased complexity is not the only problem. Available learning materials at this level are often written in a more rigorous, scientific manner, which is in contrast to more didactic materials in secondary education. Specifically, the contrast between closely related concepts is not sufficiently emphasized in university textbooks and lectures, leading to confusion among students.

Time and stress management also present challenges to students. Higher education presents the students with relative freedom and independence as many students move away from home and to the university city. In addition, the pedagogical structure, including frequent evaluation, provided by secondary education, is mostly replaced by planned but non-mandatory lectures and fewer evaluation periods per academic year. Sufficient discipline is required from students and this is not always cultivated in the prior context of secondary schooling. This is believed to be especially problematic for students who are above average in intelligence, e.g. many students starting at Engineering faculties. Many of these gifted students rarely had to exert themselves during secondary education and hence, may lack the discipline to study independently or to constructively cope with academic setbacks. For these students, failure to achieve a given goal may be new and this may prove to be very demotivating and stressful. Hence, some of the tutors again point to the importance of sufficiently challenging all students in secondary education but also to the importance of cultivating discipline and motivation in this context.

Students are observed to adopt relatively superficial study methods. Tutors believe that this is closely related to the point mentioned in the previous paragraph. Deep understanding of a subject requires sufficient theoretical study along with repeated exercise. Students often neglect to go through the steps of reflective problem solving and prefer to consult existing solutions for similar problems. This may be due to lack of discipline, lack of time, or both. Superficial strategies used by students only require a minimum of profound understanding. Tutors state that their advice often underlines the importance of solving problems step by step and (semi-)independently. The rise of social media and online document sharing platforms have worsened this issue, as solutions can be exchanged more easily.

A final issue noted by the tutors, stems from students and parents ignoring advice related to academic pathways. Starting in Flemish secondary education, students receive recommendations with respect to their academic level and potentially, other disciplines that may be better suited for the given student. However, students are often still enrolled in disciplines that are more renowned or perceived as prestigious, like STEM fields of study and those intended to prepare them for a higher education. Such programs do not always match the students' interests and competences and such status-driven orientation is rarely to the benefit of the student. A similar attitude is appearing at the KU Leuven faculty of Engineering Science where students in a remedial academic track may choose to ignore tutor advice with respect to re-orientation or lower course enrolment. Again, the image of certain programs and personal pride play a significant role in these decisions.

3.2 Student survey

The majority of enrolled students, i.e. 479 students indicated that they had completed general secondary education (GSE), specifically meant to prepare students for higher education. The remaining 21 students followed a technical (TSE) program. Within both groups, students may have had between 4 to 8 hours of mathematics per week. However, programs with 6 to 8 hours of mathematics dominate the sample group, with 493 students.

When reviewing their secondary education with regard to the extent to which it prepared them for the first semester in the Engineering(-Architecture) bachelor, students were fairly satisfied. Results, displayed in figure 1, show that almost 70% of all students at least agreed that secondary education had prepared them sufficiently for the bachelor. In comparison with students in the Engineering bachelor, students in the Engineering-Architecture bachelor seemed to be less satisfied with their secondary education. During the tutor interviews, an idea surfaced that may explain this small difference. Generally, students starting in the Ir.-Arch. bachelor, expect this program to be less difficult than the Ir. program. This is however not the case as engineering architecture requires good abstract mathematical and scientific reasoning and design skills.

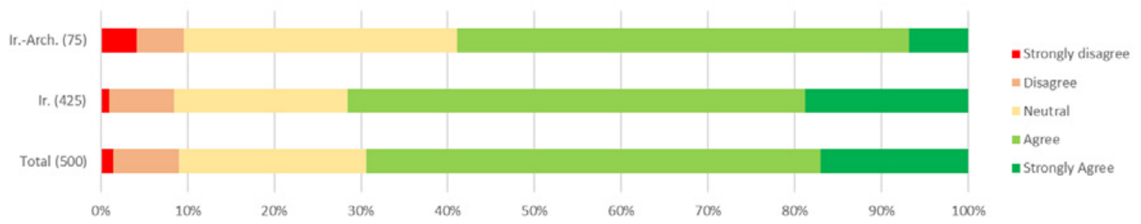
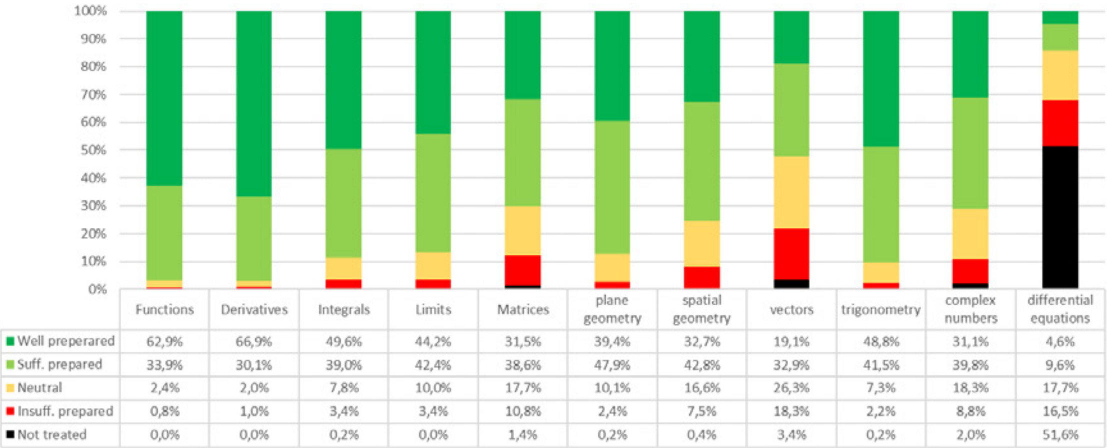


Figure 1: Extent to which secondary education prepared students for an Engineering(-Architecture) program, as indicated by students

Students were presented with open questions about what specific factors influence their satisfaction with their secondary education. Two categories were considered: a first set of factors, related to course contents and hard skills on one hand and a second set of factors related to student attitudes and studying techniques on the other. With regard to course contents, students were overwhelmingly positive about their acquired basics in mathematics, approximately 40% of students list their secondary mathematics training as a direct positive contribution to their preparation for higher education. Other positive contributions are said to be: developing abstract reasoning skills; developing a mindset for (mathematical) problem solving and presence of good teachers. Do note however, that this is in contrast to tutor opinion. Student opinions were mixed with regards to other scientific subjects. An approximately equal amount of students list secondary physics and chemistry courses as either positive or negative contributions to their preparation for the engineering bachelor. Students reflect negatively on: an insufficient depth of understanding that is developed and offered at the secondary level; a large difference in pace between secondary and university levels; and a substantive difference between what is taught in secondary and higher education. These remarks aligned with comments by tutors.

When considering other factors, students mostly indicated that proper time management skills were acquired during secondary education. Overwhelming praise was also attributed to both cooperative skill and independence in an academic context. Opinions were mixed related to studying techniques and work ethics. A part of the sample group showed awareness of poor working discipline or superficial study methods.

Mathematical knowledge and treated topics were questioned in more depth in the survey. Results indicated that students may feel under-prepared for certain engineering topics. Specifically: differential equations, vectors, matrices, spatial geometry, and complex numbers were less covered in Flemish secondary education. Figure 2 shows this indication by students, ranging from "not treated" to "very well prepared", for the listed topics.



	Functions	Derivatives	Integrals	Limits	Matrices	plane geometry	spatial geometry	vectors	trigonometry	complex numbers	differential equations
Well preperared	62,9%	66,9%	49,6%	44,2%	31,5%	39,4%	32,7%	19,1%	48,8%	31,1%	4,6%
Suff. prepared	33,9%	30,1%	39,0%	42,4%	38,6%	47,9%	42,8%	32,9%	41,5%	39,8%	9,6%
Neutral	2,4%	2,0%	7,8%	10,0%	17,7%	10,1%	16,6%	26,3%	7,3%	18,3%	17,7%
Insuff. prepared	0,8%	1,0%	3,4%	3,4%	10,8%	2,4%	7,5%	18,3%	2,2%	8,8%	16,5%
Not treated	0,0%	0,0%	0,2%	0,0%	1,4%	0,2%	0,4%	3,4%	0,2%	2,0%	51,6%

Figure 2: Extent to which secondary education prepared students for mathematical topics, as indicated by students

First semester results for the engineering bachelor in 2021 were in accordance with previous academic years and their distribution is shown in figure 3. A distinction was made between the following grade categories: intolerable (0-7), failed but tolerable (8-9), sufficient (10-13), very good (14-20). Results for Calculus and Applied Mechanics were rather poor with well over 50% of students failing these subjects. Results for Applied Chemistry show just below half of the students failing. Students performed better in Algebra and the project course, with 78% and 90% passing rates respectively.

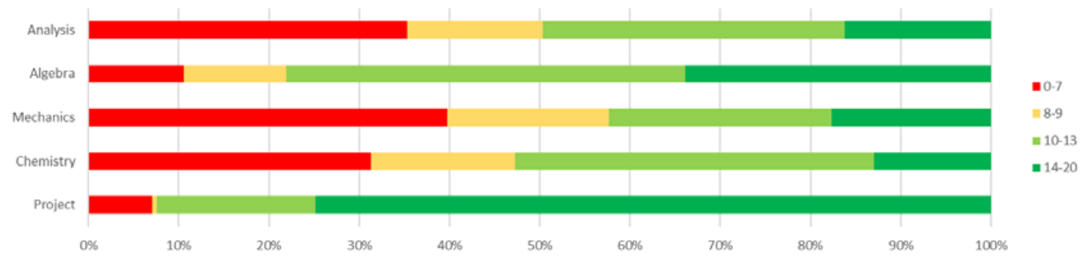
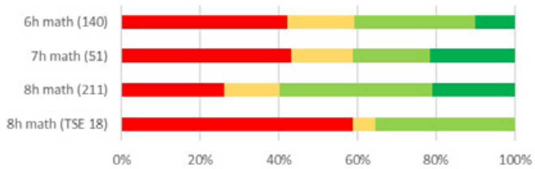


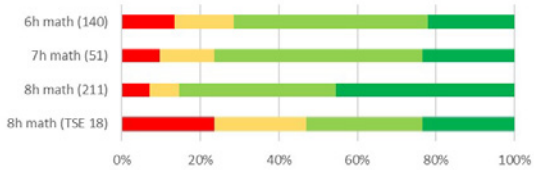
Figure 3: 2021 First semester results as reported by students, for Engineering bachelor

When accounting for prior education, differences in score arise. Here, results for the Ir-Arch. bachelor are neglected as it leads to insufficient student numbers per category to be statistically relevant. Figure 4 shows the distribution of scores per Ir.-bachelor subject, for all students with a history in TSE and 8 hours of mathematics or GSE and 6-8 hours of mathematics. The data shows that students coming from a GSE program with 8 hours of mathematics performed better than their peers in all engineering bachelor subjects. Similarly, former TSE students perform relatively worse in all subjects, even when compared to former GSE students who had less hours of mathematics. Their poor scores in math and science subjects were remarkable and may be due to a different focus in TSE math classes. Additional factors, such as different attitudes and science subjects in secondary education warrant further exploration.



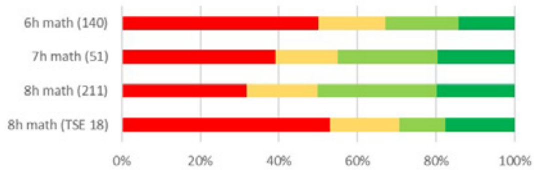
	8h math (TSE 18)	8h math (211)	7h math (51)	6h math (140)
≤7	58,8%	26,1%	43,1%	42,1%
8-9	5,9%	14,2%	15,7%	17,1%
10-13	35,3%	38,9%	19,6%	30,7%
≥14	0,0%	20,9%	21,6%	10,0%

(a) Calculus



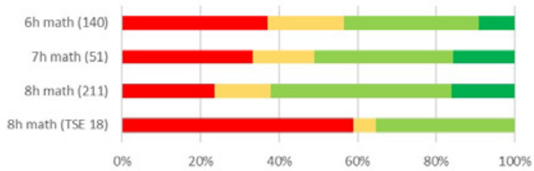
	8h math (TSE 18)	8h math (211)	7h math (51)	6h math (140)
≤7	23,5%	7,1%	9,8%	13,6%
8-9	23,5%	7,6%	13,7%	15,0%
10-13	29,4%	39,8%	52,9%	49,3%
≥14	23,5%	45,5%	23,5%	22,1%

(b) Algebra



	8h math (TSE 18)	8h math (211)	7h math (51)	6h math (140)
≤7	52,9%	31,8%	39,2%	50,0%
8-9	17,6%	18,0%	15,7%	17,1%
10-13	11,8%	30,3%	25,5%	18,6%
≥14	17,6%	19,9%	19,6%	14,3%

(c) Mechanics



	8h math (TSE 18)	8h math (211)	7h math (51)	6h math (140)
≤7	58,8%	23,7%	33,3%	37,1%
8-9	5,9%	14,2%	15,7%	19,3%
10-13	35,3%	46,0%	35,3%	34,3%
≥14	0,0%	16,1%	15,7%	9,3%

(d) Chemistry

Figure 4: 2021 First semester results as reported by students, for the engineering bachelor, per subject and number of hours of mathematics per week in secondary education

When looking at the prevalence of interdisciplinary and group projects in secondary education, it appeared that only 13% of students had project work in secondary education, yet scores for the Ir. bachelor project course were exceptionally good when compared to other first semester courses. It should be noted however that this course followed very different teaching and grading methods than the more conventional non-project-based courses.

4 DISCUSSION AND FUTURE RESEARCH

Within the scope of broader dialogues between Flemish secondary educational and KU Leuven's and engineering faculty, the gap between both levels of education is identified through interviews with university tutors and a survey of first-year university students at the KU Leuven Faculty of Engineering Science. Students and tutors confirm the existence of a gap between Flemish secondary education and programs at the KU Leuven Faculty of Engineering Science. We believe that the results from this exploratory study can be extended to apply for enrolling students in other Flemish Engineering faculties. In relation to the transition from secondary schooling to higher engineering education, students indicate to be satisfied with their secondary education. Many students state that they have a strong mathematical basis although this is not entirely reflected in their first semester bachelor results. Students and tutors indicate that students experience a structural pedagogic difference between both levels of education. Support is reported to be less available and evaluation is less frequent in higher education Engineering programs as compared to secondary education. It is concluded that this cultural and structural transition, along with more complex and profound course contents present a steep learning curve for first-year students With regards to differences in pedagogic structure, students' learning methods and attitudes play a significant role. Students do note shortcomings with regard to study methods and study attitude. Applied study methods are often deemed too superficial by tutors and both tutors and students note that discipline, to tackle the challenges of higher engineering education, may be problematic for students. Hence, tutors believe that emphasizing the cultivation of proper studying techniques and discipline could be of great benefit for many students. This potential is further supported by previous findings [3], stating that learning skills and motivation are a necessary condition for success in STEM fields. Student survey results are further interpreted to imply that students with a technical secondary background especially suffer from this pedagogic transition. Hence additional attention to this group may prove to be promising, even if these students currently only comprise a small part of all first year students at Engineering faculties in Flanders. The student survey indicates relatively low scores for the first semester Engineering bachelor courses. We believe this is closely related to the reportedly treated topics in secondary mathematics education. According to students, differential equations, vectors, matrices and complex numbers are,often not sufficiently treated in secondary education. These topics hold a significant role in first year Engineering faculty courses, specifically in Calculus (differential equations, complex numbers) and Mechanics (vector and matrix manipulation), and more generally in modelling and problem solving applications. Tutors did not significantly comment on specific topics but do agree that mathematics on a secondary level remains too superficial. There is said to be insufficient attention for abstraction in terms of theory and exercises are said to lack practical and realistic context. Students do not report this shortcoming when questioned but may possibly not realize that a lack of contextualized exercises is part of the underlying problem.

Further conversations will be organized with education experts, specifically in the field of student tutoring and professional teacher training, to explore ways to close the gap between expectations in secondary education and those in university Engineering programs. We believe that an effective and sustainable way to equip students with the required knowledge and attitudes, is to focus on professional development of STEM teachers in secondary education [4]. As suggested by this study, such professional development should address teaching practices with regard to mathematical and scientific topics that are important in engineering, as well as practices regarding contextualized problem-solving and abstract thinking. In the broader scope of this ongoing research, further discussions between secondary and higher education teachers may uncover other strategies on how to match these desired practices with secondary STEM curricula

The Flemish secondary education system is currently also undergoing a reformation, with the introduction of new programs, also in STEM fields. This includes the development of technical, STEM oriented programs that also serve as preparation for higher education. This evolution is monitored closely by Engineering faculty staff and may prove to be an effective way of improving students' prior knowledge and college readiness.

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TAKE-HOME LABORATORY KITS FOR PRACTICAL CLASSES IN THE HOME

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ABSTRACT

With the rapid move to fully online teaching brought on by COVID-19, educators scrambled to redesign and adapt their curricula to ensure that students would receive an educational experience at least on par with what they would receive in an on-campus setting. A major concern with shifting to online delivery, particularly for engineering, is being able to replicate the benefits of experiential learning, usually supported by laboratory classes involving specific technical equipment, in an online environment. Furthermore, due to lockdown conditions and travel restrictions, students would be confined to their homes and unable to attend campus to use any laboratory equipment.

An initiative was devised to send out a laboratory kit out to all students, both domestic and overseas, enrolled in a third year electronics subject that could be used to perform the laboratory exercises in their own home. Synchronous, scheduled online classes provided the necessary structure for the learning activities and demonstrators were trained to supervise these sessions and remotely perform assessment of student tasks. Technical equipment was provided to the demonstrators to specifically support this mode of teaching.

This paper presents and discusses the creation of the take-home laboratory kit, the logistics involved in distributing the kit to students, the management of health and safety issues, and how the laboratory classes and tasks were modified to facilitate the take-home laboratory kits in an online environment. Results have shown an overwhelmingly positive student response to the initiative, supporting a continuation of the scheme into the future.

1 INTRODUCTION

Laboratory-based courses play a critical role in scientific and engineering education. Traditionally, such laboratories have comprised hands-on, face-to-face teaching and learning activities, where students are actively performing experiments, doing design work, gathering data and interacting with specific technical laboratory equipment. In this manner, laboratory classes can be seen as embodying the philosophy of experiential learning [1], which shifts the learning from being teacher-centered, where the teaching is largely transmissive to an approach that is semi-structured and requires students to cooperate and learn from one another through direct experiences tied to real world problems. As technology has improved, in particular computing power, internet bandwidth and video quality, the academic community has embraced alternative methods to deliver these laboratory classes and attempt to provide equivalent experiential learning opportunities through virtual and remote laboratories.

Virtual laboratories utilise software packages to simulate the experiments ordinarily performed in the laboratory class. These types of laboratories do not completely replicate the associated in-class teaching and learning activities but typically provide instruction without any human-to-human interaction and often do not support group work [2]. While there are arguments for their usefulness, particularly in terms of low-cost, ability to be self-paced and opportunity for repetition, their effectiveness compared to learning from undertaking real experimental work is not clear [3]. In particular, positive student outcomes and observed increases in motivation are potentially based more on novelty than design and the effects of reduced social learning are not included in most comparative studies [2].

Remote laboratories aim to address some of the limitations associated with virtual laboratories by incorporating real laboratory equipment in a simulation environment. Typically, students remotely access laboratory equipment to perform experiements and are able to observe the results via a camera or remote interface to the equipment without having to be physically present in the laboratory. Having a direct connection to a real-world piece of equipment in this way can help add to the authenticity of the laboratory experiment. In a similar way to virtual laboratories, remote laboratories support students' autonomous learning activities, however they come at an increased cost in terms of equipment, laboratory space and ongoing maintenance and support [4].

Recently, augmented reality (AR) has offered to improve the experience of virtual or remote laboratories and in some cases has been shown to improve student outcomes [5], however the cost and time to set up such a system could be prohibitive, particulalry in courses with large student numbers or when rapid development and deployment is required.

The debate over these different approaches is made ever more confusing by the use of different educational objectives as criteria for judging the laboratories. On-campus advocates tend to emphasise design and build skills, while remote laboratory advocates tend to focus more on conceptual understanding. The presence of computers in all three of these approaches blurs the boundaries even further [6].

This paper details an approach that is somewhat of a hybrid of the traditional notions of virtual and remote laboratories described above, which was motivated by the need to deliver classes wholly online due to the COVID-19 pandemic. A specially-prepared laboratory kit was sent out to all students, both domestic and overseas, enrolled in a third year electronics subject that could be used to perform the laboratory exercises in their own home. Synchronous, scheduled online classes provided the necessary structure for the learning activities and demonstrators were trained to supervise these sessions and remotely perform assessment of student tasks. Evaluation of the use of the take-home laboratory kits is ongoing and will be the subject of a larger study, however some preliminary feedback thus far is presented.

2 DEVELOPMENT OF THE TAKE-HOME LABORATORY KIT

The COVID-19 pandemic necessitated many universities world-wide to rapidly migrate their teaching programs to a wholly online environment. This forced educators to redesign and adapt their curricula to ensure that students would receive an educational experience at least on par with what they would receive in an on-campus setting. Due to lockdown conditions and travel restrictions, students would be confined to their homes, possibly overseas, and unable to attend the university campus to use any laboratory equipment. Furthermore, strict restrictions on staff attending the campus would mean that all laboratories were shut down and laboratory equipment was unable to be supported or maintained. Under these conditions, the Department of Electrical and Electronic Engineering developed an initiative to provide take-home laboratory kits to all students enrolled in a particular set of subjects in order for them to complete the laboratory classes in their own home, in a synchonrous online learning enviroment. This paper focuses on one of those subjects, a third-year electronics subject, and details the kit compositions, necessary changes to the curriculum, assessment activities, class format and logistics and health and safety regulations.

2.1 Online laboratory class format and logistics

Prior to the migration to wholly-online teaching, each week, students would attend their scheduled on-campus laboratory session and design, build and test a circuit on breadboard, under the facilitation of two demonstrators, who would assess their work during the class. Students worked in teams of three, and each laboratory class comprised of approximately thirty students. With the move to online teaching, this model was preserved through the use of the Zoom video conferencing platform which also supported peer interaction within teams. Synchronous classes were timetabled as usual and students would simply log in to the session they were enrolled in by following a hyperlink. Similar to the on-campus class, the demonstrators would discuss the class activities with the entire class using a webcam and then students would break into their small groups to complete the class tasks, with small group work being supported online through the use of Zoom breakout rooms.

2.2 Take-home laboratory kit contents

The subject previously utilised standard bench-top electrical engineering test and measurement equipment in the laboratory classes – signal generators, oscilloscopes, multimeters, as shown in Figure 1. In order to have students perform the experiments in their own home, the heart of the kit would need to be a suitable platform that would be low-cost, portable and able to replicate the laboratory test equipment. The Analog Discovery 2, shown in Figure 2, was chosen due to its ability as an oscilloscope, waveform generator, power supply, voltmeter, spectrum analyser, impedance analyser, its USB interface and its free, multi-platform interface software. It is highly portable as it can fit in the palm of one's hand and, for the laboratory exercises considered in this subject, could be powered through the USB interface without the need for an external power supply, which could be problematic in other countries with different socket and voltage standards.

Fig. 1. In-class laboratory equipment

Fig. 2. Analog Discovery 2

One of the major limitations of the Analog Discovery 2 is its inability to measure current. Several laboratory exercises required this to be done, so instructions had to be modified to incorporate a test resistor as part of the measurement process, and the current determined by measuring the voltage across the resistor and using Ohm's law.

The passive (resistors, capacitors and inductors) and active components (ICs, op-amps) used in the laboratories were all supplied as part of the kit as well as breadboard for protyping and hook up wire to make interconnections. The contents of the kit are shown Figure 3.

Fig. 3. Take-home laboratory kit contents

For the digital laboratories, a small DE0-Nano Development Board replaced the much larger DE1-SoC Development Board used on-campus, albeit with a reduced feature-set. This required a redevelopment of the corresponding digital laboratories, however some of the larger board's functionality, for example the seven-segment displays, could be replicated through the Analog Discovery 2.

2.3 Health and safety considerations

As students would be performing the laboratory exercises in their own homes, it was vital that they were able to assess any risks present and ensure that they were operating in a safe environment. The STAR (Stop, Think, Act, Review) process is a method for students to ensure that they are adeqeuately planning their tasks and have considered the necessary safety pertinent to the laboratory. The Environment, Health and Safety (EHS) team, along with academics in the Faculty of Engineering and Information Technology, devised an online survey, called the Take 5 Risk Assessment, that provided a simple, structured way for students to complete the STAR process. Students were required to complete a Take 5 before every class that involved the take-home laboratory kit. This not only had the benefit of ensuring that they had the appropriate procedures and controls in place before commencing the tasks but also gave them insight into considering the risks associated with the particular laboratory, something which would ordinarily only be covered by a single, generic laboratory induction at the commencement of semester.

2.4 Take-home laboratory kit distribution

The lockdown conditions prohibited students from attending campus to pick up the kits. Furthermore, restrictions on travelling ourside the home meant that the only way to distribute the kits would be to mail them directly to all enrolled students, both domestic and overseas. The Faculty of Engineering and Information Technology requested bills of materials for each subject employing take-home laboratory kits which were then passed on to an electronics distributor, along with student postal addresses. Students were asked to complete an online form to indicate the most suitable address to receive their kits, as their circumstamces may have changed from when they initially enrolled at the university. The distributor assembled the kits for each subject and mailed them out to the students over the course of several weeks. Due to postal delays, it was essential to begin the mailing out process early so that students would have their kits early in the semester. Students were required to confirm the inventory of the kit they received via an online form and any issues were resolved by mailing out replacement parts.

3 IMPLEMENTATION OF THE LABORATORY CLASSES

The take-home laboratory kits were used in synchronous, online, small-group learning actvities with two facilitators (demonstrators). Each class had some individual, assessed preparatory work to be completed beforehand that largely focused on familiarity with how the Analog Discovery 2 was going to be used in the class. Short videos were incorporated into online support modules to visually assist students with setting up their circuits, and to also act as a motivator to get them to prepare for their class.

During the classes, the demonstrators would move between the group breakout rooms on Zoom and provide assistance or explanations as required. Demonstrators were provided with USB webcams, small tripods and headset microphones in order to be able to effectively communicate with the students. When students would complete a task, they would signal the demonstrator to be assessed through raising their hand (virtually) or by sending an instant message. Typically students worked together in their teams and were assessed at the same time as the team. These assessments required students to either be able to show their constructed circuits via a webcam, experimental results via screen sharing, or a verbal explaination of the phonemenon they were observing. This would be expected to take additional time to perform than on-campus classes and therefore was streamlined and simplified where possible.

Instead of a physical sheet of paper to record student marks as was done on-campus, a shared online spreadsheet was used, which provided rapid, real time updating of results and removed one less administrative task for the demonstrators in having to transcribe the marks from paper to the online learning management system.

4 RESULTS

While detailed results investigating the effectiveness of the take-home laboratory classes are still forthcoming pending the completion of the semester, some initial observations can be made:

- Students have reported that they have interacted with the take-home kits more often and for longer than for the total duration of the laboratory classes, as would be the case if they were on-campus. Increasing students’ exposure to experiential learning through regular access to the kits in their own time is a significant positive and can lead to improved engagement and better learning outcomes.

- Demonstrators and students commented that webcams, particularly those integrated in laptop devices, were difficult to manipulate to ensure that they were angled correctly to demonstrate constructed circuits while also keeping the screen visible.
- Students utilised their webcams more often in subjects employing the take-home laboratory kits, even for tasks not requiring direct assessment such as peer discussion, than in subjects that purely relied on virtual laboratories. This is likely due to instilling the use of the webcams as a normal part of the class dynamics from the beginning.
- Debugging incorrectly functioning circuits has been perceived as being more difficult than in-person classes due to the demonstratiors having to instruct students remotely via the webcam and not being able to physically verify elements themselves.
- Students interacting with the take-home laboratory kits in their own environment led to some ad hoc exercises in the laboratory classes and lectures where students were asked to locate and incorporate an object in their environment into the class tasks. In particular, the lecturer leveraged the presence of the take-home kits in students' study spaces to have them perform exercises with the kits in real time during scheduled, synchronous online lectures. This is something that is not possible to do on-campus in a standard lecture theatre environment due to space considerations and requiring students to physically carry their kits to every lecture class.
- Students have reported that they felt a sense of ownership and pride over the completed circuits as they did not need to tear them down immediately after the class ceased.

These obervations are expected to be strengthened through student surverys performed at the end of semester and an analysis of student results.

5 DISCUSSION AND CONCLUSION

The debate about the value of hands-on versus simulated laboratories has been on-going for some time and will likely continue, particularly now that educational institutions have had to radically reconsider how to deliver their programs. Virtual and remote laboratories each have their own sets of strengths and weaknesses, however take-home laboratory kits could be seen as spanning the gap between these approaches. Such kits provide accessibility, opportunities for experiential learning and motivation to demonstrate self-directed learning and experimentation. With an uncertain future in terms of travel restrictions and the nature of delivery of university courses, it is envisaged that take-home kits will remain a permanent part of the course, providing sufficient flexibility to students to seamlessly participate remotely if the need arises. Even with a wide-scale return to campus, take-home laboratory kits could be distributed to all students to provide an equitable experience for those who are still unable to travel or who require flexibility in their learning arrangments and to those coming on campus who are able to attend a facilitated laboratory class.

The ready availability of webcams, typically standard on a laptop device, and wide accessibility of high-speed internet across the world has created a simple, yet effective environment for delivering classes in such a manner. Preliminary results have shown an overwhelmingly positive student response to the initiative, supporting a continuation of the scheme into the future.

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CREATING THE CONDITIONS FOR AN ONLINE CHALLENGE-BASED LEARNING ENVIRONMENT TO ENHANCE STUDENTS' LEARNING

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ABSTRACT

In addition to relevant knowledge, today's graduates also need problem-solving skills, interdisciplinary skills, communication skills (also termed 21st-century skills) and the ability to identify and acquire the new knowledge necessary to solve problems. Therefore, we require an educational framework that provides enough freedom and flexibility for students to choose their own focuses and, at the same time, enough structure and direction to ensure the institutional-wide quality of education. Challenge-based learning (CBL) is a promising innovative educational approach that combines these desirable features. However, experience from previous pilots has also revealed some limitations; for example, the lack of structure sometimes seems far outside the comfort zone of students and teachers. In this paper, we show how our experience from the Autumn Challenge Programme at the University of Twente, offered fully online, led to some promising suggestions for a CBL course design in which students had to take control over their own learning processes in a structured learning environment, with a coach playing a prominent role in ensuring that the learning outcomes were successfully achieved.

1 INTRODUCTION

1.1 Why a New Educational Approach for Engineering Education

The needs of society and industry are changing rapidly—at such a pace that it is becoming increasingly difficult for engineering education, in its current form, to adapt at the same speed [1]. Thus, the time has come to reconsider the format in which we offer education. Technological developments, among other things, have opened up more and more ways of transmitting knowledge [2]. For example, the physical

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presence of a lecturer is no longer necessary when lecturing; this provides the opportunity to teach larger numbers of students at the same time and creates space and time for the teacher to focus on parts of the curricula where students benefit most from the physical presence of a lecturer [3]. Universities must examine how education can be designed in such a way that students still graduate with a solid knowledge base but have also developed the so-called transferable and lifelong learning competencies industry, and society wants them to develop. Challenge-based learning (CBL) offers a framework that can support the transition to future-proof higher education without compromising quality. Universities that implement the necessary changes in this phase are therefore likely to gain a strong competitive edge [4].

1.2 Challenge-Based Learning

The CBL framework was developed to help students gain a fundamental understanding that would last longer. Even though CBL addresses this specific need, it is also based on educational theories, such as social constructivism [5] CBL has some specific features that make it a pedagogy on its own. A main feature of CBL is that students get to work at a real-life problem; according to experiential learning theory, skills are learned best if the learner can practise the skills in an environment that resembles the real-life situation [6]. Although this idea is not new in education, with CBL, the purpose goes beyond the intended learning effect; the assumption is that students can actually contribute something substantial right now. Furthermore, the focus is on the development of so-called transferable skills whereby the skills are deliberately taught, including interdisciplinary collaboration skills. In summary, CBL is an approach in which students are involved in their learning through formulating questions (essential and guiding), investigating widely in cooperation with stakeholders and collaborating with different disciplines to build new understanding, meaning and knowledge, all while working towards a solution that is environmentally, socially, and economically sustainable. Sustainability is not just another topic to be added to the curriculum to build awareness, as building awareness will not automatically lead to change. The CBL model makes learning meaningful, offering students large enough challenges to learn the new insights and skills to solve them while at the same time

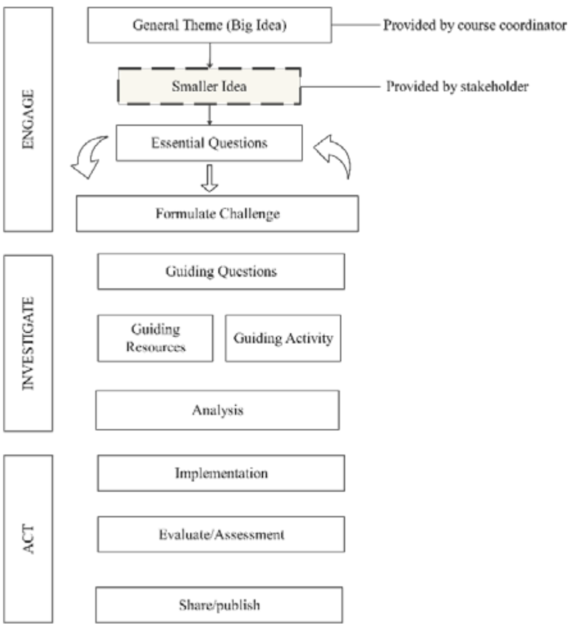

Fig. 1. Cbl framework based on the framework proposed by apple inc. (2010) adapted for use during the Autumn Challenge

allowing students to be close enough to the problem to come up with a worthwhile solution [4]. An advantage of allowing students to co-design the learning process is that they can individually build on prior knowledge and experience, which allows them to learn more effectively and individually throughout the process. In addition, students will be much more motivated when they have determined for themselves what knowledge and skills they need [7]. However, CBL does not encourage a curriculum defined by individual students; the curriculum, as well as the learning environment, must be flexible, as does the teaching approach. Yet, there seems to be a missing link between the flexible and customisable framework CBL promises to be and its practical implementation.

1.3 Curriculum Design for Engineering Education

Given the newness and distinctive features of CBL, there is limited knowledge concerning suitable learning environments and supportive systems to achieve desired learning experiences for CBL, and many aspects require further investigation. Furthermore, all other programme characteristics, such as the online, interdisciplinary (ID) and multicultural nature of the programme, must be considered in curriculum design. Therefore, three broadly used curriculum frameworks, namely Biggs, van den Akker and the 4TU framework for ID education were reviewed, and shared elements were identified and referred to in this paper as rationale, learning, assessment and support (Figure 2). The reasons for establishing the programme and its main goals are referred to as rationale. The success of learning, and in turn participant development in CBL and ID programmes, is based on the constructive alignment between learning goals, learning activities and well-designed assessment tools [8]. Unlike in other educational designs, the focus in CBL should be on how to use flexible learning goals so that the students are encouraged to determine their paths to achieve them. To offer a fully experiential learning experience a major project that is challenging and relevant to the learning is an essential component of a programme, as it sets a clear goal for the learners . All learning activities should be directly related to the project and offer learners autonomy to steer their learning paths [9]. This will create a learning environment in which learners can develop 21st-century skills, such as critical thinking and teamwork, and be prepared for the future and constantly changing world. Yet, it is still relatively unclear how to assess 21st-century skills, and assessment is considered crucial in any context, including in CBL [10]. Assessment in CBL should

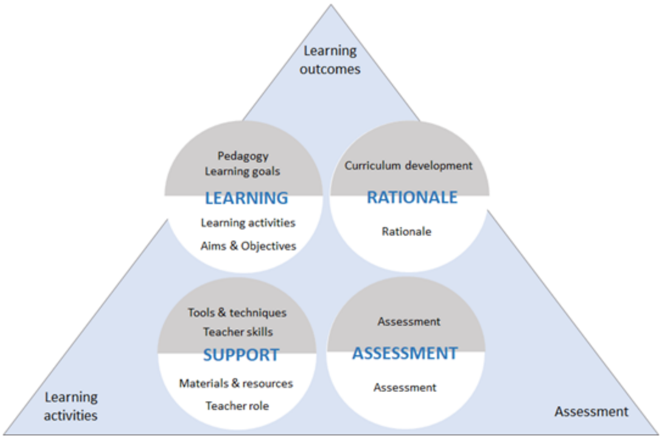

Fig. 2. Identified elements of curriculum design that are shared by three frameworks: Biggs, van den Akker and the 4TU

not only focus on its summative format but also on a formative one to guide learners towards self-regulation. Including metacognition in the assessment as a form of reflection on the learning process that the students co-designed themselves is vital. To ensure uniformity in terms of the assessment criteria that are important for motivation, well-designed assessment rubrics are essential [8]. Support, including initial structure and guidance, in an ID learning environment with open-ended problems, plays an important role in helping learners towards self-regulation [11]

2 IMPLEMENTATION

The Autumn Challenge Programme2 is an extracurricular and short-term CBL programme organised and offered by the University of Twente. This programme was the first of its kind to be piloted by the UT in a completely online setting between October 2020 and January 2021. The programme offered seven different problems (small ideas) under the wider UN SDG's. There were a total of 33 students enrolled in the programme, of which the vast majority were engineering students (64%) from five different universities and eight nationalities. Table 1 shows the number of students per discipline.

Table 1. Overview of students per discipline who enrolled in the Autumn Challenge

Discipline	N
Public Administration / Political Science / Sociology / Law	5
Civil engineering / Sustainable Energy / Spatial Engineering	5
Mechanical Engineering / Industrial Design	4
Business / Finance / Management	4
Psychology	3
Statistics / Data Science	3
Liberal Arts & Sciences	3
Chemical Science / Physics	2
Geosciences / Earth Observation	2
Aeronautical Engineering	1
Biomedical Engineering	1

International, Interdisciplinary online setting

The reasoning behind piloting the programme was to create a learning environment whereby students could work together in a fully online setting, actively learn with each other and from each other in an international and intercultural context and create societal impact. As a result of the Covid-19 outbreak, many students were struggling with shifting to a completely online model of education and had difficulty

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https://www.utwente.nl/en/autumn-challenge/

interacting with peers and co-learning. Furthermore, the opportunities to have a physical experience abroad were diminished, which also created a gap in terms of available learning activities to fill their study programme. An innovative programme that could bridge these gaps created by the pandemic and give students a new purpose and motivation to learn, connect and socialise was, therefore, necessary, and because the CBL framework was developed for flexible learning paths, it was the most likely choice. Admitted students were asked to choose an overarching project (challenge) and had to work with various stakeholders, such as the challenge provider and other social groups (i.e., certain communities), to formulate the challenge and design a potential solution. The student teams were formed on the basis of transdisciplinarity and intercultural diversity after the admitted students were asked to choose their preferred challenge topic by ranking them (one to seven). Most teams were formed based on the students' first choice and some on the second choice. The programme was opened to second-and third-year bachelor and master students from all universities[3], as well as strategic partners of the University of Twente. The workload for learners was estimated to be 5 ECTS (5*28 hours = 140 hours), which were divided among various activities.

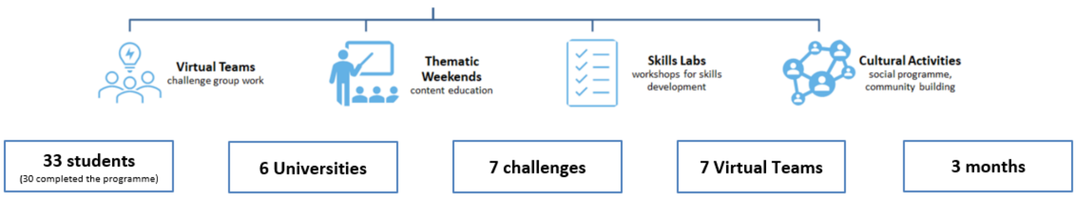

Fig. 3. programme curriculum organogram

2.1 Curriculum design components

The intended learning outcomes were formulated broadly, as shown in Appendix A, to give autonomy to the students to co-design their learning paths [12]. To ensure that the learning outcomes could be achieved, the programme was structured on the basis of four learning activities: Virtual Teams (organisation), Thematic Weekends (content knowledge), Skill Labs (skills) and Cultural Activities (engage). Assessment criteria were communicated with the students via thoroughly yet broadly structured assessment rubrics (Appendix B). Additionally, there was a formative assessment in which student teams presented their progress to all interested stakeholders. The students were assessed in a non-traditional grading system using a pass-fail standard. To ease communication (i.e., sharing assessment rubrics and syllabus) with the student and at the same time support, self-regulated learning, a learning management system (Canvas) was used. Throughout the programme, the teams

[3] https://www.eciu.org/member/eciu

regularly consulted on their progress with the problem providers, and the teams' development was also monitored at weekly sessions with team coaches. Based on the outcomes from these sessions, the coach guided the students in reflecting on how it was going, if they did all they could and if they needed additional support, knowledge, or information. Ad hoc scaffolding in terms of additional workshops or support was offered.

3 RESULTS

Developing, implementing and evaluating the CBL approach as a leading educational pedagogy for the Autumn Challenge has led to several insights that may benefit not only UT and ECIU but also other universities in future educational innovation. In the next section, we report the choices made regarding designing a CBL learning environment.

Table 2. The curriculum design component Learning activities, aims and objectives interpreted to CBL-related activities and objectives used in the Autumn Challenge

Learning activities, aims and objectives	
CBL Features [13–16]	**Applied in the Autumn Challenge design**
• Stakeholder collaboration • Students can determine how they wish to achieve the learning outcomes • Failure is part of the learning process • Learning happens in learning communities • Real world wicked problems connected to societal challenges • Self-directed learning • Applicable solution • Critical and higher-order thinking skills • Ethical awareness • Synthesise multiple perspectives	• Weekly meetings with the problem provider (students plan meetings themselves under the supervision of the coach) • Pre-planned thematic lectures (content) • Pre-planned skill labs • Students can indicate whether they need additional knowledge or skills • Broad learning objectives to let students choose their own learning paths • Include the development of academic skills, such as higher-order thinking, enterprise or transferable skills, in the learning objectives • Educating students about the CBL approach regarding their own role (taking responsibility for the learning process)

Table 3 shows that the learning activities were highly appreciated by students. In particular, *Virtual Teams*, which include the organisation, setting and guidance of the teamwork, was highly valued.

Table 3. Student evaluation in terms of how these components contributed to achieving the learning outcomes.
(1 = very poor, 10 = excellent)

	N	M	SD	Min	Max
Skill Labs	24	7.54	1.66	3	10
Thematic Weekends	24	7.20	1.69	4	10
Virtual Teams	24	9.12	1.07	6	10
Cultural Activities	18	7.83	1.97	3	10

Role of the coach

Coaches can help guide students throughout the learning process, which should be tailored to the dynamics and composition of the different student teams [20]. Although teachers should have less control over the learning process and allow learners to make mistakes, the teachers' role in CBL requires a different time commitment and flexibility in comparison to traditional pedagogies [10]. Together with coaching, milestones can serve as a tool to monitor team progress [21], and if any issue is identified, new scaffolding strategies can be implemented. Online learning environments became the new norm during the Covid-19 outbreak, and they introduced more complexity into curriculum design. In addition to using learning management systems, interpersonal relationships—which can be built by providing collaborative and networking opportunities that in turn can support self-directed learning and develop productive life-long learning communities—are important in an online learning environment [22]. The role of the coach was essential. The coaches created a safe and motivating (Table 4) environment while simultaneously guiding the students in their individual learning processes. The three main coaching activities (Table 4) included asking questions, coordinating the learning process and motivating.

Table 4. The most mentioned coaching activities that contributed to the learning experience.

Coaching activities	**N**	**%**
Guiding/coaching/tutoring	8	24%
Planning, coordination and organising	6	18%
Motivating	4	12%

Stakeholder involvement

Students indicated that their intensive collaboration with stakeholders led to improved skills in defining the real problem, asking the right questions and gaining specific content knowledge (Table 5).

Table 5. The most mentioned learning gains related to stakeholder interaction.

Learning gains	N	%
Learned to ask the right (number of) questions	6	18%
Understanding the root problem and the challenge	5	15%
Gained specific knowledge about the subject matter	4	12%
Gained interdisciplinary knowledge	4	12%
Networking with professionals	4	12%

Students were given little structure. For example, as to what the solution should be, they were told that it was quite possible that the outcome would not be a product or solution but only a refined problem statement. This was not something to which students were accustomed. Therefore, while it did take more time than expected, it is a crucial step when teaching students how to become learners. Students saw the added value afterwards, but during the first weeks, it was a challenge to stop them from rushing towards a solution, as they had in the past. Table 6 shows how this approach to teaching contributed to the students' learning process.

Table 6. Learning experiences related to the lack of a fixed outcome.

Learning experience	N	%
Better understanding of the root of the problem	8	24%
Taking responsibility for our choices	6	17%
Gained understanding of the learning process itself	5	14%
Became more focused	3	9%
Became more organised	3	9%
Highly motivated	3	9%
Learned how to prioritise	3	9%
Opportunity for better relationships with stakeholders	1	3%
Too difficult if you have no project experience	1	3%
Does not work when the stakeholder has a fixed idea about the outcome	1	3%

Authentic learning

Authentic learning is most beneficial if it fully reflects the real world [17]. Part of the real world is learning how to deal both with and from failure. The literature shows that students who do not get the expected result become more determined to succeed the next time [18,19]. Table 7 shows that 22% of the students indicated that they did not experience any failure. Although the students were educated about CBL in general and about how learning occurs within CBL, it seems that there was still some unclarity as to what failure exactly entails.

Table 7. Percentages of students that experienced failure as part of the learning process.

Failure/no failure	N	%	Comments
Failure	18	78%	'We had to take a step back to rethink our design process'. 'We had to really understand that our solution did not have to be perfect but rather meaningful'. 'We took more responsibility'. 'We experienced our boundaries'. 'Helped to get more clear vision of the challenge'. 'Failure made us grow with more ideas'. 'Helped us understand our limits and errors'. 'After failure, we really understood the mistakes we made'.
No failure	5	22%	'Feels more like we learned a lot'. 'Can't comment on this'.

Materials and Resources

Giving students more ownership of their learning will have the greatest effect when they are able to oversee all aspects of the learning process. Providing them with the learning outcomes followed by having them think about ways in which they can demonstrate that they have achieved those learning outcomes will lead them to consider what knowledge and skills are required to achieve those outcomes successfully. In turn, this will lead to them thinking about the materials and resources needed to gain this knowledge.

Table 8. The curriculum design component Learning activities, aims and objectives interpreted to CBL-related activities and objectives used in the Autumn Challenge

Materials and resources	
CBL Features [13–16]	**Autumn Challenge design**
• Open data and information • Materials and resources from other parties can be used • Learning outside the classroom • The real world is the learning environment	• Encouraged the use of open data • Encouraged students to search for relevant learning materials themselves (literature, textbooks, data) • Encouraged students to think about what knowledge and skills they needed to work successfully on the challenge • Provided a network of content specialists and encouraged the students to contact and share their own network • Helped students share their own disciplinary knowledge and skills with the rest of the group

This worked well for some student teams. For example, one group asked for a workshop on how to write scenarios, and another group asked for project management training. The scenario writing workshop was organised by the problem provider. However, the question is whether we can provide students with the necessary facilities on an *ad hoc* basis. Another challenge we encountered was getting students to explore open data and other resources due to the combination of having an international group of students and using local companies as problem providers. Most of the data and materials were only available in Dutch.

Summary

The engineers of the future will play a pivotal role in working towards solutions to the challenges that industry and society face. To prepare students well for their future responsibilities, engineering education will have to reorganise their curriculum in such a way that students are still equipped with a solid knowledge base while at the same time focussing increasingly on developing transferable skills to aptly tackle these challenges. As in the current curriculum, the educator plays an important role in the amended curriculum. CBL provides a learning environment in which teachers do not 'just' provide the content knowledge; students are guided (by the coach, whether or not the teacher) towards thinking for themselves about what knowledge they need and why. This capability will lead to students not only learning during their time at university but also teaching them how to educate themselves, thus laying the foundation for them to become lifelong learners.

Coaching for learning

Imagine a plane crashing down in the Amazon rainforest. A multicultural group of people, all with their own prior unique knowledge and skills sets, survive the crash, and now have to find their way out of the unknown jungle. It seems there are no roads, no lights, no signs of civilisation. The first step they must take is to find out what every person can contribute to the team. One team member knows which berries edible and which ones are poisonous, another team member is very good at scouting and mapping the area, yet another team member is very good at making fires. However, due to the group's small size, they do not have all the skills and knowledge necessary to survive and get out of the jungle. What would such a team, in such an open, free and lawless environment, need to survive, find their way, and redo it if they ever get into a situation like this again? The answer to this question is two-fold: the group needs to work together well, and the members of the group need to acquire the skills and knowledge they lack to survive in the wild and pave their road to civilisation. If this group manages to get out of the jungle on their own without the help of a guide who tells them which way to go and what to eat, but rather a guide who keeps them on their toes and asks them to think carefully and make strategic choices. Then this group not only survived the jungle, but they learned how to look for new knowledge and new solutions in an unknown, complex situation based on existing skills and knowledge.

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APPENDIX A

Learning goals

Learning goals

The most important learning experience for a student in this programme, is the ability to work on solving a complex societal problem in a multicultural and multidisciplinary environment. In order to be able to achieve this main learning objective, six other learning goals are defined on the basis of which this course is designed:

After finishing this programme, the student

1. discusses the UN Sustainable Development Goals (SDGs) and can place them into real life context, connecting their education and knowledge to real life local situations and challenges stemming from the locations of the participating universities (knowledge and comprehension);
2. is able to analyse and critically assess societal challenges in the framework of the UN SDG 11, "Mak[ing] cities and human settlements inclusive, safe, resilient and sustainable" (analysis);
3. can co-design and conceptualise solutions for [given] societal challenges (synthesis);
4. can present these solutions in a suitable format, taking into account their skillset, innovation and the various stakeholders dynamics (societal leadership);
5. has acquired knowledge of different disciplines around the main thematic;
6. has developed intercultural competences through communicating and functioning effectively in a multicultural team

APPENDIX B
Assessement rubric

Criteria	Pass			Fail	Assessment	Feedback (motivation for the given assessment score)
	Excellent	Good	Satisfactory			
Interdisciplinary collaboration	Reflects on every important aspect of how differences in disciplines affected (positively and/or negatively) the team collaboration. Provides many specific examples on how the team dealt with them.	Reflects on the most important aspects of how differences in disciplines affected (positively and/or negatively) the team collaboration. Provides some specific examples on how the team dealt with them.	Reflects on some aspects of how differences in disciplines affected (positively and/or negatively) the team collaboration. Provides a few not very specific examples on how the team dealt with them.	***Absent or very limited reflection on how differences in disciplines affected (positively and/or negatively) the team collaboration (No examples how the team dealt with them are provided)***		
Multicultural collaboration	Reflects on every important aspect of how multicultural differences affected (positively and/or negatively) the team collaboration. Provides all the necessary examples on how the team dealt with them.	Reflects on the most important aspects of how multicultural differences affected (positively and/or negatively) the team collaboration. Provides some examples on how the team dealt with them.	Reflects on some aspects of how multicultural differences affected (positively and/or negatively) the team collaboration. Provides a few examples how the team dealt with them.	***Absent or very limited reflection on how multicultural differences affected (positively and/or negatively) the team collaboration.***		
Team Decision Making	Reflects extensively on the team decision-making process (how, as a team, they applied each team members competences in the work). No additional explanation is needed to understand team decision-making process.	Reflects not extensively on the team decision-making process (how, as a team, they applied each team members competences in the work). Some additional explanation would be needed to understand team decision-making process.	Reflects loosely on the team decision-making process (how, as a team, they applied each team members competences in the work). Substantial additional explanation is needed to understand team decision-making process.	***Absent or very limited reflection on the team decision-making process.***		
Communication and contribution	Reflects extensively on the effective exchange of ideas among team members. It helps to understand the full extent of	Reflects not extensively on the effective exchange of ideas among team members. It helps to understand to some extent	Reflects loosely on the effective exchange of ideas among team members. It helps to sufficiently understand	***Absent or very limited reflection on the exchange of ideas among team members.***		

	their communication.	their communication.	their communication.			
	Reflects on a workload distribution that was extensively based on the disciplinary and cultural background of the various team members.	Reflects on a workload distribution that was not extensively based on the disciplinary and cultural background of the various team members.	Reflects on a workload distribution that was loosely based on the disciplinary and cultural background of the various team members.	The workload distribution was not based at all on the disciplinary and cultural background of the various team members.		
Interpersonal relationships	Reflects on every important aspect of the interpersonal team engagement. Provides all the necessary examples of positive situations (e.g., everybody feels respectful) and/or conflicts that were resolved (e.g. a compromise between opposing views).	Reflects on the most important aspects of the interpersonal team engagement. Provides some examples of positive situations (e.g., everybody feels respectful) and/or conflicts that were resolved (e.g. a compromise between opposing views).	Reflects on some important aspects of the interpersonal team engagement. Provides a few examples of positive situations (e.g., everybody feels respectful) and/or conflicts that were resolved (e.g. a compromise between opposing views).	***Absent or very limited reflection on the interpersonal team engagement. Only negative examples (e.g., competitive and individual atmosphere) are provided and/or conflicts has been left unresolved.***		
	Reflects extensively on how individual strengths and weaknesses of the team members affected team collaboration.	Reflects not extensively on how individual strengths and weaknesses of the team members affected team collaboration.	Reflects loosely on how individual strengths and weaknesses of the team members affected team collaboration.	***Absent or very limited reflection on how individual strengths and weaknesses of the team members affected team collaboration.***		
Report length	The report length is within the given word count (1250-1500 words, excluding references)	The report length slightly violates the given word count (by <150 words, excluding references)	The report length violates the given word counts (by >150 but <300 words, excluding references)	The report length is largely outside the given word count (by >300 words, excluding references)		

CAPACITY BUILDING OF RUSSIAN UNIVERSITIES STAFF FOR THE DESIGN & DELIVERY OF PROSPECTIVE IT-ORIENTED ACADEMIC PROGRAMS

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ABSTRACT

The paper presents the results of the implementation of a pilot project for a large-scale professional development of 1000+ academics from 100+ Russian Universities at the International Computer Science CPD Center in National Research Tomsk State University. The training was fully implemented online in three educational areas: “Research & development in IT", "Advanced teaching & learning technologies", and "Academic programs of a new generation”. In addition, the workshops called “End-to-End Digital Transformation Days” and two International Conferences on IT were organized. The programs on each track included the performance of individual and group projects. A special course "Key faculty competencies in the context of the academic program life cycle: Foresight-Forecast-Conceive-Design-Implement-Operate" was offered. The idea of the course is borrowed from the evolution of well-known CDIO approach to engineering education. The course objective was to develop competencies of academic staff of various positions for productive teamwork in university system of division of labor.

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1 INTRODUCTION

In accordance with the National Program for the development of the Digital Economy, launched in Russia in 2017, the number of students enrolled in higher education programs in the field of IT (mathematics, computer science, digital technologies) may triple by 2024. This requires a substantial increase in a number of faculty members whose competencies are not inferior to the best international standards in these subject areas and meet the requirements to mastering up-to-date teaching & learning technologies.

Meeting this challenge the International Computer Science Continues Professional Development (CPD) Center was established in National Research Tomsk State University (TSU), one of the leading universities in Russia (http://en.tsu.ru/).
The purpose of the CPD Center is to concentrate the research and educational potential in the field of mathematics, computer science and digital technologies for the development and implementation of advanced training programs for academic staff of universities in Russia and neighboring CIS countries. The idea is to achieve the goal by collaboration and networking with other Russian and foreign universities, research institutes and IT companies, as well as inviting well-known and respected IT experts.

Initially, it was planned to implement faculty training with the use of blended learning mode rotating on-campus and online sessions. However, restrictions due to the COVID-19 pandemic prevented the organization of on-campus sessions. Initial plan had been revised, and faculty training in 2020 was implemented fully online. This added work to create more online teaching & learning materials. At the same time, it allowed to expand the geographical area of universities participating in the pilot project and attracting more academics to the online training. As a result, the initial plan to train up to 200 faculty members was exceeded by five times. More than 1000 faculty members from 100+ universities were enrolled. The location of the universities participated in the pilot project on the geographical map is shown in Fig 1.

2 METHODOLOGY

2.1 Section 1

Within the framework of the pilot project faculty training was realized in three tracks: "Research & development in IT area" (R&D), "Advanced teaching & learning technologies" (T&L), and "Academic programs of a new generation (AP)". Trainees had the opportunity to build individual educational paths within the tracks.
The idea of R&D-track was to develop faculty competencies in research & development to create a meaningful basis for academic programs in cooperation with IT companies. The main topics of lectures and master classes were the following: innovations in IT, immersion in a problem, terms of reference for a project, concept and project life cycle, group work methodology, creative thinking and

generation of new ideas, Agile project management according to the Scrum method, choosing the best project solution, communication with the customer, MVP and feedback, project presentation, support institutions and sources of project funding at the university, etc. The objective of the T&L-track was to master the advanced methods and technologies of teaching & learning at a modern university. Faculty members have got acquainted with the best practices of using such pedagogical techniques as Backward Design, Flipped Classroom, Gamification, Blended Learning, Peer Assessment, etc., as well as applying of various digital tools and LMS for online education, MOOCs development, etc. The aim of the AP-track was the comprehensive preparation of university faculty members for the design, implementation and quality assurance of IT-academic programs of three levels (undergraduate, graduate, postgraduate) at all stages of the program life cycle.

The training programs on each track included the performance of individual or group projects by the faculty members as trainees. As part of R&D-track, the trainees created a new scientific & technological foundation for a new educational product (discipline, interdisciplinary module, etc.) in IT area. Within T&L-track, the trainees developed new educational products applying new teaching & learning technologies. As part of AP-track, the trainees designed new academic programs most competitive in today's IT higher education market. The focus of all tracks was directed at the priorities of the selected end-to-end digital technologies (AI, Machine Learning, AR/VR, IoT, Big Data, Cybersecurity, etc.). This was realized, among other things, through field-specific master classes, as well as methodological and consulting support available to each trainee.

2.2 Section 2

The complete cycle of training lasted for 5 months from July to November 2020 according to the schedule shown in Fig 2. In the intervals between online training sessions, the trainees' self-study was organized, including project work. The methodological material for teaching & learning within each track was developed and implemented in the logic of project work according to the classical scheme: Analysis – Specification – Design – Development – Implementation. In parallel there were organized three online workshops called “End-to-End Digital Transformation Days” with active participation of representatives of leading IT companies. Remote interaction of trainees with each other and with instructors was carried out on the basis of the following principles: integration of personal and institutional virtual learning environment, flexibility of educational trajectories, the ability to check the educational results of trainees through the analysis of their digital footprints.

To enrich personal virtual learning environment, trainees had access to educational activities through organizers, messengers, network communities (WhatsApp, Facebook), and communicative tools for group interaction (Mirro, Trello, Mindmap). In parallel with the use of open Internet services, digital tools of institutional systems for support of distance learning technologies, including LMS, were used. Work in the LMS included the performance of assignments, consolidated into a single schedule with deadlines, assessment criteria, examples, comments and other materials. A number of assignments were assessed with peer review made by trainees based on criteria and matrices prepared by the instructors.

3 RESULTS

For participation in the pilot project 1,012 trainees from 116 universities have been registered. The contingent of trainees was rather diverse. Majority (70%) of trainees were mainly engaged in teaching, and 30% were mainly engaged in research and management in IT departments at universities. The trainees included 64% of experienced instructors and researchers with academic degrees and 36% of young faculty members. It should be noted that two thirds of the trainees (66%) were female and only one third (34%) were male. Following various priorities, 63% of trainees registered for T&L-track, 20% for AP-track, and 17% for R&D-track.

Totally, 827 trainees mastered the training programs (more than 80% of registered trainees). About 40% of the trainees completed the full training cycle. The main results, i.e., the updated and developed trainees competencies, were demonstrated by them while working on R&D and educational projects carried out in the interests of their universities. On the R&D-track, 66 trainees (about 40% of those registered for the track) successfully completed program cycle and carried out 18 group projects. The relatively small number of R&D-track graduates is due to the fact that only 6% of all registered trainees were researchers and, therefore, directly involved in R&D activity. However, this is not the only explanation. The relatively low interest in the R&D-track on the part of the main contingent of trainees (teaching staff - 70%) is explained not only by the labor input and complexity of R&D projects, but also by the fact that research and development are still not very much popular among faculty in Russian universities.

The majority of trainees (63%), mainly teaching staff, has initially chosen the development of advanced educational technologies as a priority track in order to update courses and other curriculum elements. The attractiveness of the T&L-track is obviously due to the fact that the introduction of new technologies, especially online learning, is caused by the trends of the digital transformations in higher education, and, more recently, by a vital necessity in the face of the forced transition to distance learning during the COVID-19 pandemic. The full training cycle was completed by 289 trainees (46% of those registered for the track), having completed 52 group projects.

The AP-track has been chosen as a priority by 20% of trainees, mainly faculty members. Within the framework of the track, it was required to design (or deeply upgrade) an academic degree program as a whole, not a separate curriculum element. The full training cycle was completed by 48 trainees (24% of those registered for the track), having completed 11 group projects. According to the trainees, the AP-track was the most difficult and time consuming, as it involved the design of the program taking into consideration all stages of its life cycle.

For those who moved along the AP-track program, the course "Key faculty competencies in the context of the academic program life cycle: Foresight-Forecast-Conceive-Design-Implement-Operate" was offered. The idea of the course was to systematically outline all stages of the life cycle of a degree program as the main product of a university and to focus on those competencies needed for academic staff at each stage of creating and delivering programs.

The idea of the course is borrowed from the evolution of well-known CDIO approach to engineering education [1]. The CDIO approach was initially developed for basic engineering education focused on Bachelor's training to complex activity at Conceive-Design-Implement-Operate stages of the engineering products life cycle [2]. As a result of evolution, the approach has been adapted to Master programs focused on graduate's training to innovative engineering activities at the stages of Forecast-Conceive-Design-Implement (FCDI) and to PhD programs oriented to postgraduate's training to engineering research at the stages of Foresight-Forecast-Conceive-Design (FFCD). The extensions of FCDI and FFCD of the CDIO structure are due to the need to take into account the system of division of labor in the engineering profession when developing competencies of Bachelors, Masters and PhD-holders in the three-cycle system of engineering education and training to complex, innovative and research activities, respectively. The absence of "Operate" in FCDI structure indicates that this kind of engineering activity (operation and maintenance of products, processes, systems, and services) is not a priority for Masters. The presence of "Forecast" emphasizes the importance for them of predicting potential needs of society in new products, processes, systems, and services. The absence of "Implement" in the FFCD structure indicates that participation in manufacturing is not a priority for PhD-holders. The presence of "Foresight" underlines the importance for research activity of a long-term vision of the society's needs and technological foresight to create a scientific basis for conceiving and designing new products, processes, systems, and services.

By analogy with engineering activities, in scientific and educational activities, there is a system of division of labor between academic staff of divers position in HEI, corresponding to various stages of the life cycle of educational products. Research activities on the creation of scientific basis of educational products and related FFCD stages are a priority for full professors. Methodological activities for the design and development of educational products and related FCDI stages are a priority for associate professors. Teaching activities for the implementation of educational products and related CDIO stages are a priority for assistant professors. For sure, there is no strict division of responsibility and authority between the academic staff of divers positions at the university. However, the priorities do exist and they are known.

The objective of the course "Key faculty competencies in the context of the academic program life cycle: Foresight-Forecast-Conceive-Design-Implement-Operate" was developing competencies of academic staff of divers ranks and positions (assistant, associate and full professor) for productive and high-quality research and teaching in university system of division of labor.

The course has been offered to trainees by 6 specific modules. The “Foresight” module is devoted to the analysis of promising research & development trends in the subject area; methods of integration of research, innovation and education (knowledge triangle); global trends in STEM higher education. The “Forecast” module is dedicated to forecasting the most demanded educational products based on the analysis of the higher education market, the needs of employers, and the interests of other stakeholders. The “Conceive” module is focused on planning the most competitive academic programs; assessing their feasibility and life-cycle; realizing up-to-date strategies for STEM:IT higher education. The “Design” module is devoted to the design of three-cycle STEM:IT academic programs based on the CDIO-FCDI-FFCD triad [3]. The “Implement” module is dedicated to the creation of teaching & learning materials for rational combination of on-campus and online education and training. The “Operate” module is focused on the delivery of academic programs with the optimal use of PBL, Case Study, and other active learning methods. The results of the course implementation in terms of the demand for modules showed the priority of FFCD modules for full professors, FCDI modules for associate professors and CDIO modules for assistant professors and instructors.

New knowledge and skills acquired by the trainees as the course outcomes allowed them to have designed (or updated) academic programs in IT based on up-to-date STEM:IT strategies and international standards of engineering education adapted to STEM:IT including the latest version of CDIO Standards [4]. After completing the teamwork on the group projects, the trainees were asked to give a self-assessment of the compliance of the newly developed IT programs with the CDIO Standards (Fig. 3) and the ABET accreditation criteria (Fig. 4). The diagrams in the figures are built on the basis of averaged data of self-assessment of developed academic degree programs by the trainees who participated in the development.
To assess the compliance of the developed Bachelor programs with the CDIO Standards, the trainees were recommended to use the 6-level scale Rubrics [5]. From the diagram in Fig. 3 it follows that the trainees managed to get closer to the recommendations of the Core CDIO Standards 3.0 in terms of context for IT higher education (Standard 1), intended learning outcomes (Standard 2), integrated curriculum (Standard 3), design-implement experiences (Standard 5), integrated learning experiences (Standard 7) and enhancement of faculty teaching competence (Standard 10). Less success achieved in terms of introduction to IT higher education (Standard 4), learning workspaces (Standard 6), active learning (Standard 8), enhancement of faculty IT-competence (Standard 9), learning assessment (Standard 11) and program evaluation (Standard 12). Based on the self-assessment results, trainees identified areas for further development and improvement of the IT programs to better comply with CDIO Standards.

To assess the compliance of the developed IT programs with the ABET Criteria, the trainees were recommended to use 2020-2021 Criteria for Accrediting Computing

Programs (https://www.abet.org/accreditation/accreditation-criteria/). The programs were assessed on a 3-level scale: 0 - the criterion is not met, 1 - the criterion is partially met, 2 - the criterion is fully met. When self-assessing the developed IT programs, the trainees applied General Criteria for Computing Programs and Program Criteria for various specializations (Computer Science, Cybersecurity, Information Systems, Information Technology).

From the diagram in Fig. 4 it follows that the newly developed IT programs only partially met the ABET accreditation criteria. At the same time, the trainees managed to approach the requirements of the criteria in terms of planning student outcomes (Criterion 3), designing curricula (Criterion 5), developing of faculty qualification (Criterion 6) and providing classrooms, offices, laboratories, and associated equipment (Criterion 7). Unfortunately, the trainees achieved less success in defining the objectives of IT programs (Criterion 2), planning their continuous improvement (Criterion 4) and providing institutional support (Criterion 8). Anyway, as a result of the self-assessment, trainees identified areas for further improvement of the IT programs to better comply with ABET accreditation criteria.

3.1 Figures

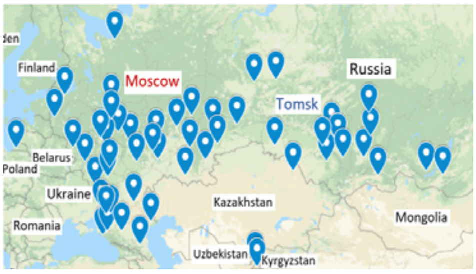

Fig. 1. The location of the universities participated in the project

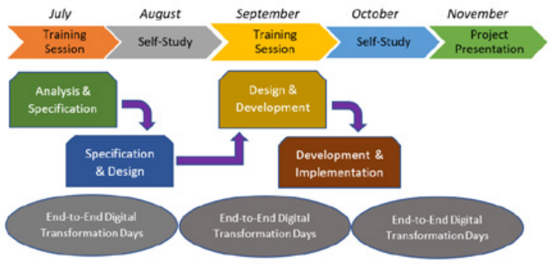

Fig. 2. The complete cycle of faculty training

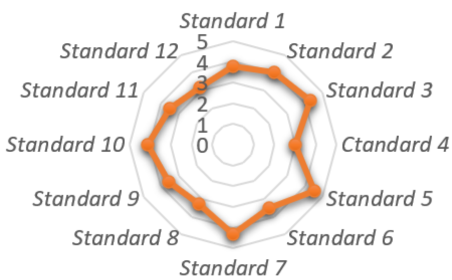

Fig. 3. Compliance of the developed IT programs with the CDIO Standards

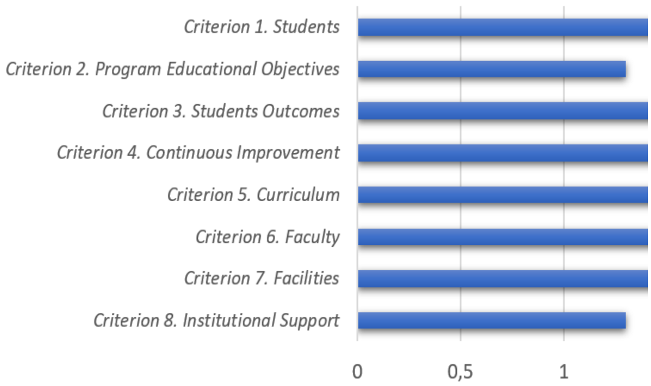

Fig. 4. Compliance of the developed IT programs with the ABET Criteria

4 SUMMARY

In conclusion, it should be stated that despite the unfavorable conditions of the COVID-19 pandemic, the pilot project on online training of a large number of academic staff at the International Computer Science CPD Center of Tomsk State University on a wide range of key issues of IT higher education improvement was successful. The project can be considered as one of the best practices for mass advanced online training of academic staff of Russian universities working in IT sector of higher education. The results of the pilot project will be further studied with the aim of further development and improvement of online teaching & learning materials, as well as technologies for the implementation of training programs. However, after the restrictions associated with the COVID-19 pandemic are lifted, it is planned to run faculty training with the use of blended learning. This mode will improve the quality of the trainees teamwork on R&D and educational projects, and overall results of the faculty training.

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WHAT IS QUALITY IN ENGINEERING EDUCATION? AN EU PROJECT CASE STUDY

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ABSTRACT

Focusing on the case of a current project funded by the EU ERASMUS+ Programme, this paper will explore the question - *what is quality in engineering education?* The project called EXTEND is seeking to develop the next generation of Engineering Educators in the Russian Federation and Tajikistan and is supported by partners from Romania, Latvia, Portugal and the UK.

It is very apparent that when we explore quality in engineering education it can mean different things to different people. As the diversity of higher education increases in terms of students, teachers, courses, modes of delivery etc, now is an appropriate time to revisit and explore this topic as it is invariably the engineering educators who are tasked with reconciling the, often competing, requirements.

Using data collected during the course of the EXTEND Project and considering the wider engineering education context, the authors will seek to offer suggestions as to how the ideas of what constitutes 'quality' can be embedded within courses aimed at developing the next generation of engineering educators. This will help to ensure that when designing and delivering courses the outcomes for all stakeholders are realised.

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1 INTRODUCTION

Building on some of the ideas explored by Clark et al that focused on the features of quality in funded engineering education projects [1], this paper uses a current EU Project as the case within which to explore the quality of engineering education itself. By understanding what constitutes ‘high quality’, the aim of the work is to start to formulate a framework within which institutions wishing to develop their engineering education expertise can systematically address the key areas that will have the most impact. The Capacity Building Project that forms the subject of this work is focused on the development of engineering education in countries that are not as mature in their understanding of what ‘high quality’ requires.

2 BACKGROUND LITERATURE

In earlier work it was stated that to understand what we mean by quality, the context we are considering is of considerable importance. In this paper we are focusing on the engineering higher education context in the global space which often separates into two dominant considerations, Quality Assurance and Quality Enhancement. Williams argues that they are ‘integral parts of the same process’ [2] although their purity is increasingly contaminated as quality becomes associated with measures such as rankings [3] or content [4]. This perceived ‘tension between QA and QE’ has been explored in the literature with measures to capture the synergy Williams alludes to being proposed through self assessment [5] and collaborative QE [6].

Quality improvements can be prompted through many channels other than policy and process – students [7], alumni [8] and industry [9] are three such examples. It needs to be acknowledged that each of these stakeholder groups will likely have different perspectives as to what constitutes quality and how important each element is [10].

Despite the structured QA approaches in many western countries [11] [12], challenges exist across the world. On the positive side, in seeking to improve the quality of higher education in Afghanistan, a QA framework is seen as being integral to ‘organisational sensemaking’ and the all important support of senior leadership [13]. Russia (one of the partner countries in EXTEND) has been grappling with the challenges with respect to engineering education for many years. Debates about a ‘National Doctrine’ in 2012 [14] have struggled to realise significant change with recent authors suggesting there remain ‘quality and relevance’ issues in Russian institutions [15].

Acknowledging the need for change to improve quality is an important first step. The passive approach to engineering education in India is being challenged by models such as flipped learning [16]. In Nigeria, the recognition that quality will improve only with better able teaching staff is similarly important [17]. The recent work by Campbell et al suggests that an important feature of student success in engineering education is the development of a ‘growth mindset’ [18]. A mindset that is flexible and resilient in the face of change. Much engineering education today remains didactic in nature and far removed from the high quality, active and engaging approaches that will aid the development of such a mindset.

3 CONTEXT

The context of this paper is an EU funded ERASMUS+ project that is in the last year of its work. The EXTEND project is focused on modernising the approaches used in teaching engineering in Russia and Tajikistan and, through this, developing the educators engaged in the teaching [19]. The quality of education is central to this project, especially when the objective is to develop in each of the Russian and Tajik universities (4 in each country), an active, respected and sustainable Centre for engineering educator training. The challenge is what form the Centres and their work should take in order to be effective in realising high quality engineering education in each of the institutions. Following the events of the last 2 years, the latter stage of the project will also seek to capture the role of blended learning in each Centre and the associated quality considerations.

4 APPROACH TO THE STUDY

Data collection has been taking place throughout the project in various forms and this paper draws together two threads of this work. At an early stage of the project the Centres were asked to complete a Business Model Canvas [20] and develop a clear and compelling vision that would focus on excellence and sustainability. This initial work conducted in 2018 has been revisited throughout the project and will be contrasted with the data collected for the last face-to-face project meeting in 2020.

The data collection is being guided by the Quality Plan for the project. The current phase of the work is focused on establishing the quality and value of the EXTEND Centres and will draw on a range of data sources. To date these have been the Project Team Members who have been with the project since its outset. It is this work that is reported here.

In completing this work over the next year these data sources will be extended to include, but not be limited to, interviews with Centre staff, users and beneficiaries (e.g. students and university administration), usage data for the Centres, a review of the Centre spaces and the facilities they offer, scrutiny of the documentation and resources produced as part of the Centres' operation, evidence of the Centres' visibility and reach both within the host institution and on the national stage and finally observations on how the individual EXTEND Centres are co-operating with each other.

5 RESULTS

5.1 5.1 Data Collection Point 1 – Bucharest 2018

Prior to and during the Project Meeting in Bucharest in 2018, each Centre was asked to complete a Canvas. An example for one of the partner universities is shown in Figure 1.

Business Model Canvas of Partner University`s EXTEND Center				
Key partners	Key activities	Value Proposition	Customer relationships	Customers segments
✓ Industries ✓ Ministry of Education and Science ✓ Ministry of Industry ✓ Employees/Companies ✓ EXTEND Partners ✓ Local Authorities ✓ Ministry of Labour Migration and Employment	✓ Teaching ✓ Consulting ✓ Training ✓ Programming ✓ Connecting, ✓ Analyzing and Publishing results	✓ Recognition ✓ Placement Opportunity ✓ Unified Centre ✓ Increase research opportunities ✓ Distance Learning ✓ MOOCs ✓ Virtual Mobility ✓ Designing New Courses ✓ International Visibility and Mobility ✓ Authentic Practices that will benefit Students	✓ Ministry`s permission ✓ Rector`s instructions ✓ Volunteering ✓ Involving interested and motivated Staff	✓ Teachers ✓ Students ✓ Industries ✓ Partners ✓ Universities ✓ Community
	Key resources		Channels	
	✓ Intellectual Capital ✓ Advanced Equipment ✓ Unified Centre ✓ Significant Technical Opportunities		✓ Website ✓ Mass Media ✓ Social Media ✓ Former Students ✓ Student Union ✓ Conferences and Seminars ✓ Personal interaction / Networks ✓ Journals	
Cost structure		Revenue Stream		
✓ Fixed cost ✓ Variable costs ✓ Software Development ✓ Space for the Centre ✓ Equipping and Maintaining the Centre ✓ Time ✓ Opportunity cost		✓ Project funding and extension ✓ Co-funding from University ✓ Licensing ✓ Outsourcing ✓ Partnerships		

Fig. 1. Sample Business Model Canvas

Many of the elements identified in this sample Canvas were replicated in those produced by the other Centres. During the meeting these documents were critiqued and the Centres were challenged to explore their ideas further with a particular focus on 4 questions that would help to realise excellence and sustainability for each Centre. The questions were:

WHY? What is the purpose of the EXTEND Centre, particularly its vision?

WHAT? What will be the portfolio of activities for the Centre?

HOW? How will the Centre achieve its objectives? What are the resource requirements?

WHO? Who will be essential in making the vision a reality?

A thematic analysis was performed on the Canvas' and the results of the critique. In doin this, with the focus on excellence and sustainability, 4 main themes were identified – People, Portfolio of Activity, Place and Supporting Environment. These will be explored one by one.

All of the Centres viewed the project as a significant opportunity for their institutions and country. In terms of **People**, the key aspirations were to create a motivated, high quality and recognised teaching workforce. Linking the benefits to ongoing employability and lifelong learning were highlighted, as was the need to explore a form of certification to accompany the activity taking place within a Centre.

In terms of the **Portfolio**, the Centres took a very broad view of what would be needed. Key features were the need for virtual offerings as well as classroom based, courses that were relevant and authentic and delivered using a variety of teaching approaches. Quality Assurance was mentioned but for most the view was that the Centre should be about Quality Enhancement and should have a scholarly and ‘scientific’ basis, not be too practice focused. The opportunity to introduce latest thinking in learning and teaching along with an industry view was also viewed as important. Experience sharing was singled out for particular mention.

Having a dedicated and appropriately equipped **Place** was seen as essential. Each Centre saw this as a way to create visibility and to make a statement about the importance of the work to the wider institution. This was extended to suggest the need for a variety of communication strategies on an institutional, national and international level to enable the Centre to connect to a wider network of possibilities. These possibilities were seen as an important feature for the Centre sustainability.

The final theme is that of a **Supporting Environment**. It was felt that the support of University Administrations and Government Ministries was particularly important for sustainability and for the Centres to be influential. This would enable future funding to be explored and realised extending to industry and other partners who may wish to co-create and engage in activities with a Centre.

5.2 Data Collection Point 2 – Warwick 2020

For the Warwick Meeting the Centres were asked to explore the progress made in the setting up of their facilities and their steps towards providing an environment for quality engineering education to be realised. Each Centre had focused on the setting up of one teacher education course as its core activity. Around this the supporting activities to create the Centre and realise the vision were being actioned.

The focus of this data collection activity were 3 questions:

What have been the positive points of the work so far?

What points have you identified that will be the focus of improvements?

What are your ideas for the future in order to make your Centre sustainable?

Focusing on these questions, the responses from the different Centres have been analysed using the 4 themes identified from the work in 2018. It should be stated at the outset that at the point of this data collection each Centre had been established and the initial course design had been created and piloted.

The **People** attending the courses clearly viewed the work in a positive light. Teacher training based on latest thinking was a new experience for many and their engagement was positive in all cases. The enthusiasm came through in the post-course reviews with participants having their ‘eyes opened to many new possibilities’. There were challenges in getting some ideas accepted yet the idea that the Institution was consciously investing in its staff and the opportunity to share experiences were welcomed. Some universities have sought to embed the courses in a formal teacher development programme but this was the exception. It also became apparent that mixed cohorts of teachers and PhD students were a challenge as each had a different starting knowledge.

As may be expected, with the focus on course development, the **Portfolio** theme was most dominant in the responses. The teachers developing the courses for their colleagues to experience worked hard to embrace the latest ideas from across the globe, making the learning authentic, active, relevant and of high quality within the cultural environment they were used to. All saw the piloted courses as a first step and embraced the idea of continuous improvement. What was clear was that in order for the courses to be taken seriously by the learners, they needed to be developed on a solid ‘scientific’ base and at times this deflected the resulting design away from its pedagogical objectives until the review process highlighted the challenge. Obtaining appropriate supporting and reference materials in the native language was also a commonly referred to problem.

One of the features of the project was the realisation from the outset that a physical **Place** for the Centre would be essential for its success. All of the Centres had achieved this presence by the time of the data collection and it was clear that this had created a real excitement within the Project Team for each Centre as well as in the wider institution. The associated visibility on the institution website and the scheduling of Opening Events had all helped to embed the Centre and what it is about into the institutional environment.

Of the 4 themes it is perhaps the **Supporting Environment** where there was least evidence of the success that will be needed to ensure the Centres are sustainable. There is still anxiety about funding, the support of the Administration and the ability to create a place for the Centres within the individual institutional cultures. Where the Centres had linked into wider institutional initiatives such as teacher development programmes, e-learning projects and quality enhancement drivers, the possibility for longer term success are more likely. The Centres all intend to create a network in which sharing and co-operation will be enabled that will help to sustain the life of the individual Centres. It is this last point that will form the final stage of the work to ensure quality engineering education is realised in each of the 8 partner universities in Russia and Tajikistan.

6 DISCUSSION

The analysis has identified 4 themes around which the development of quality engineering education can be enabled in the 8 partner universities, each with a newly formed EXTEND Centre. Although progress was made with respect to the development of the course and event portfolio in the designated spaces the Centres had been allocated, much work needs to be undertaken to ensure the path to high quality engineering education is maintained. This will, to a large extent, be facilitated by the local Administration, as the success of each Centre and the realisation of its vision will require top level support. The Centres are a new idea within both Russia and Tajikistan and the prevailing culture is likely to not be fully supportive. That suggests the value of the courses, the networking and the impact on people needs to be captured to provide evidence to support cases for funding and resource.

Even in EU countries, Centres like the EXTEND Centres often experience cycles of support and threat that undermine attempts to enhance teaching quality. Engineering as a subject often experiences challenges either due to its attractiveness to potential students or its relevance to industry employers. Against this backdrop, it is even more important that engineering education develops a reputation for being both engaging and high quality if universities are to develop for the engineering talent for the future. Hence the success of teacher development and Centres like those discussed here is crucial.

In considering a potential framework within which to establish the success and sustainability of an individual Centre, the initial thoughts are around exploring the following 7 criteria

- Clarity of Purpose
- Funding
- High level Support
- Space
- Partnerships
- Innovative ideas
- Capable Teachers

These are consistent with the results of the thematic analysis but presented in a slightly different way to capture a little more of the detail from the responses. The final evaluation work will consider a rating statement for each EXTEND Centre based on these criteria as a way to helping them to develop a sustainable future.

7 CONCLUSIONS

This is a work in progress that is exploring how to create the right environment for quality engineering education. The benefits and challenges of setting up dedicated Centres are being examined as the project progresses. The culture and academic traditions of the institutions where the Centres are located are an important consideration and one that will be explored further as the sustainability of the Centres is studied.

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CHALLENGE-BASED LEARNING AS A PRACTICE FOR ENGINEERING EDUCATION TO DEVELOP STUDENTS' ENTREPRENEURIAL MINDSET

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ABSTRACT

This paper aims to investigate the implications of Challenge Based Learning programs on entrepreneurial skills, mindset and intentions of university students using a quantitative approach. Using an original database, we analyzed pre and post levels of entrepreneurial skills, mindset and intention of 127 students who attended a Challenge Based Learning program. Results show a positive and significant effect of Challenge Based Learning programs on entrepreneurial mindset and skills – such as

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financial literacy, creativity and planning – of the students. Moreover, results show a positive but non-significative effect on entrepreneurial intention.

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1 INTRODUCTION

Besides education and teaching, since the end of the XX Century universities have expanded their roles with the introduction of the “Third Mission”, devised to contribute to cultural, social and economic development through knowledge and technology transfer activities (Etzkowitz et al., 2000). In this framework, universities today perform a broad range of entrepreneurial activities, including entrepreneurship education (EE) and support to the creation and growth of new ventures (Ricci et al. 2018). Entrepreneurship education has thus become an important activity from the perspective of professors, researchers as well as university managers (Kuratko, 2005) and a dramatic increase in the number of curricular and co-curricular offerings in entrepreneurship have been observed across the globe (European Commission 2008; Kuratko 2005; Morris et al., 2013).

Given its increasing importance, EE has more and more become the objective of academic research (Barr,2009; Duval-Couetil et al.;2021). Within the stream of the literature on EE, an increasing number of works have been devoted to the identification and definition of different teaching methodologies and learning approaches and to the analysis of their effectiveness (Dickson et al., 2008; Matlay, 2008; Oosterbeek et al., 2010). Results have shown that EE may improve entrepreneurial skills, mindset and the career ambitions of students (Sánchez, 2011; Cui et al.,2021). Moreover, experiential methodologies have proven to be particularly effective in the entrepreneurship domain (Rasmussen et al.;2005). Among such methodologies, Challenge Base Learning approaches have taken momentum.

Challenge Based Learning is a learning methodology in which students learn in a real context, dealing with challenges and real problems proposed by them or by existing firms (Chanin et al. 2018). Although the increasing diffusion of the Challenge Based Learning approach, evidence on its effectiveness is still limited (Johnson et al. 2009; Martinez and Crusat 2020; Palma-Mendoza et al. 2019;), particularly in the Entrepreneurship Education field. Moreover, previous evidence are mainly descriptive and drawn using qualitative approaches (Martinez and Crusat; 2017).

The present paper aims to empirically assess the effectiveness of Challenge Based Learning programs in improving students’ entrepreneurial mindset, skills and intentions. The empirical analysis is based on an original dataset of 127 students who took part in a Challenge Based Programs proposed by a technical university in Italy.

The remaining part of the paper is structured as it follows. The theoretical background is discussed in Section 2. Section 3 describes the challenge based program in entrepreneurship under scrutiny and the methodology design. Finally, results and implications are discussed in Section 4 and Section 5.

2 Theoretical Background

The Challenge Based Learning approach is an experiential learning methodology that allows students to learn dealing with real challenges, such as founding a startup or solving real problems proposed by existing firms, supported by professors or external stakeholders. The peculiarity of this methodology is that students can apply the knowledge and competencies gained during their university career in a real context - unlike methodologies like Problem Based Learning or Project Based Learning (Membrillo-Hernández; 2019) - and develop new skills, mindset and career aspirations thanks to these experiences.

So far, the objective of the academic research on Challenge Based Learning approaches has been twofold. First, previous studies on Challenge Based Learning have focused on how to design these kinds of programs and have identified best practice in different domains (Camino et al.,2019; Membrillo-Hernández and García-García, 2020). Second, recently a still limited strand of the literature has been devoted to the understanding of the effects of Challenge Based programs on participants (Johnson et al., 2009; Palma-Mendoza et al.;2019; Putri et al. 2020)

As far as the design of Challenge Based programs is concerned, scholars and practitioners agreed that Challenge Based Learning programs should follow a framework composed of three stages: Engage; Investigate; Act (Apple Inc, 2012; Nascimento et al.,2019). The Engage stage requires participants to start with a big idea, usually the main topic of the challenge, and try to figure out possible solutions to it. At the end of the Engage stage, participants move to the Investigate stage, in which they are asked to frame the proposed solutions in tasks, draw an implementation journey and understand what is needed in order to realise the solution. In the last stage, the Act stage, participants start to implement the solution and to verify whether the solution is suitable to address the challenge or if it needs to be revised. During these stages, participants must be tutored by educators and other stakeholders, in order to guide them through the process of generation and implementation of the solution.

As for the effect of Challenge Based programs on participants, the literature has shown that Challenge Based Learning improves soft skills, entrepreneurial intention and university performance of participants (Johnson et al., 2009; Palma-Mendoza et al.;2019; Martinez and Crusat 2020). In particular, Johnson et al. (2009) investigates the effects of Challenge Based Learning approaches on a sample of 312 high school students from 6 U.S. high schools. Students involved in the study were asked to work for some months on different real and global problems – such as, for example, Sustainability of Food - in order to propose a solution to be implemented in their schools. At the end of the project, students reported that they had improved their soft skills, such as critical thinking, creativity and problem-solving. Although the study shows a positive impact of the program on students' skills, these evidence are built on self-reported information and do not allow to verify whether students’ skills have improved with respect to the pre-challenge levels. In another study, Palma-Mendoza et al. (2019) analyses the effectiveness of the I-semester program led by Tecnologico de Monterrey. The paper reveals a clear positive effect of the challenge based approach on students who participated in the program, but limited to the performance achieved in related subjects and the communication skills. Finally, an interesting evidence on the effectiveness of the Challenge Based Learning approach on the mindset and entrepreneurial intention of university students is provided by Martinez and Crusat (2020). By focusing on the Innovation Journey Challenge Based program, in which 20 teams of mechanical and electrical engineering students work on innovative solutions to real problems proposed by municipalities, startups and firms, the paper shows that the program positively affects participants' propensity to become entrepreneurs.

Building on this, Challenge Based Learning methodology seems to improve soft skills, performance and entrepreneurial intention and mindset of the participants. However, previous studies have mainly focused on generic skills and other measures of performance of participants, such as university grades, neglecting possible effects on entrepreneurial skills. Moreover, evidence on entrepreneurial intention and mindset are drawn using qualitative methodologies and do not allow to measure the extent to which students' entrepreneurial skill have improved after the program.

Building on this, this paper aims to quantitively assess whether Challenge Based Learning methodologies improve students' entrepreneurial skills, mindset, and intentions.

3 METHODOLOGY

3.1 The program

The challenge based program analysed in the paper is carried out by the CLICK university Technology Transfer Laboratory. This experimental teaching laboratory was born in September 2017 and conceived as an essential part of the university's strategy to foster innovative education and entrepreneurial culture.

After an initial settling-in period, in January 2019 CLIK organised the first Challenge_by Firms while in September 2020, the first two Challenge_by Students were added.

The Challenges, both "_by Firms" and "_by Students", are real challenges to find the most innovative idea: up to 30 Master's Degree students, divided into multidisciplinary teams with different backgrounds, look for new solutions to solve the challenges proposed. The challenges last a semester, i.e. 14 weeks, and take place in two defined teaching periods, October/January and March/June, of each academic year.

Students are divided into teams of 5-6 people and work hard to overcome the challenge by developing the most promising idea. Professors and mentors, both from a technical and business point of view, support the Teams. Also, multidisciplinary workshops are organized during the challenges to provide educational content.

The main difference between these two tracks is the following:

- Challenge_by Firms: a company or an association proposes a challenge that tackles a real problem the organization faces.
- Challenge_by Students: the Board of the Technology Transfer Laboratory identifies macro-topics (e.g. climate change, circular economy, artificial intelligence) and teams of students develop business ideas within the identified macro-topic.

This challenge based program's objective is manifold and relates to two targets: students and the local ecosystem.

The aims concerning students are the following:

- Equip students with soft skills: problem-solving, lateral thinking, team working, project management, team management;
- Promote the "Learning by doing" approach
- Promote entrepreneurial culture and behaviour;
- Promote entrepreneurship;

The objectives concerning the ecosystem are the following:

- Bridge the gap between universities and companies/ecosystem;
- Sustain local economic development;
- Support local SMEs;

3.2 Sample

This study was carried on using a sample composed by former participants of a challenge based program. The period analysed goes from January 2019 until January 2021, for 11 challenges that involved approximately 300 students. The sample includes 127 students who answered a questionnaire administered before and after participation in the Challenge Based program.

The sample includes mainly students who took part in "by Firms" challenges. In particular, Figure 1 reveals that the 89% of the sampled students participated in "by Firms" challenges, while only 11% of sampled students took part in a challenge "by Students".

Figure 2 shows the sample distribution by gender and reveals a prevalence of male students compared to female students: while males represent 66% of the sample, females are 34%. The challenges are proposed to all the students of the university, thus belonging to three different fields of studies: engineering, architecture, and design. The distribution of students in these three fields (Fig. 3) is skewed toward the engineering area (91%), compared to the other two areas, which count only the 9% of the sample.

Finally, since the challenges are proposed in English, it may be useful to observe in Fig. 4 the distribution of students by nationality: 78% are Italian, against 22% of other nationalities.

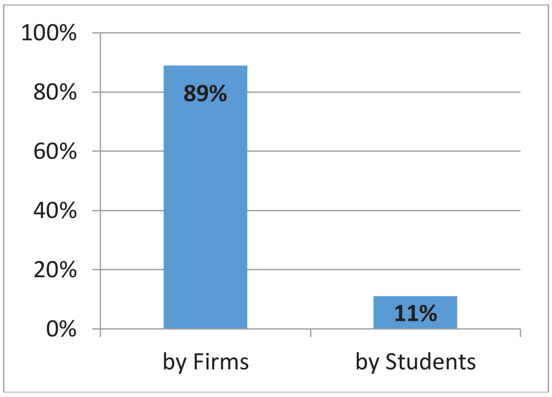

Fig. 1. % distribution of challenges by type

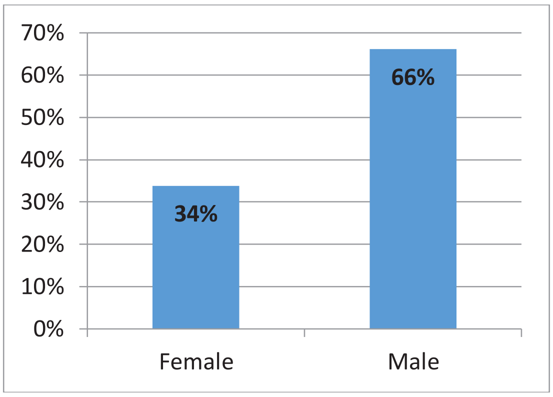

Fig. 2. % distribution of students by gender

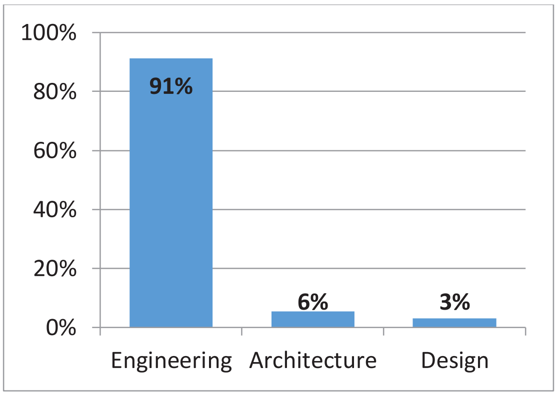

Fig. 3. % distribution of students by faculty

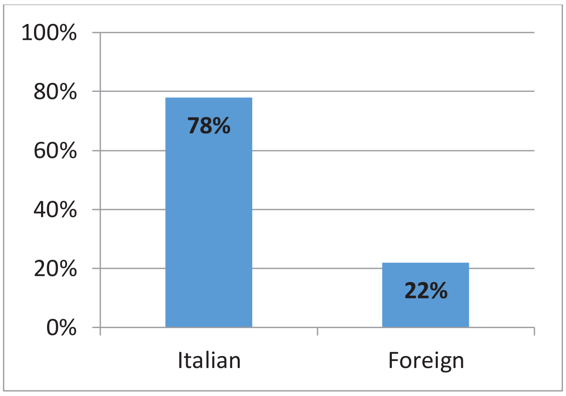

Fig. 4. % distribution of students by nationality

3.3 Description of variables and analysis

A survey was conducted on the sample presented in the previous section. Specifically, the survey aimed to assess the entrepreneurial characteristics of the students before and after participation into the program.

Entrepreneurial characteristics were measured through scales validated by Moberg et al. (2014). The variables considered were grouped into the following three domains (Table 1):

- ***Mindset***: The first domain aims to measure the entrepreneurial mindset. This variable is important to capture the respondent's sense of initiative and attitude towards challenges.
- ***Entrepreneurial skills***: The second domain variables included within this domain are *creativity*, *planning*, *financial literacy*, and *managing ambiguity*.
- ***Connectedness to labour market***: The third domain focuses on the importance for students to connect the knowledge and skills acquired to their future career. It is measured through *entrepreneurial intention*, i.e. the intention to start a business in the future.

Measurement of the variables in Table 1 was accomplished through the administration of a questionnaire to students. The questionnaire was administered once before the challenge and a second time after the challenge. This allowed for the measurement of variation in the variables due to participation in the challenge.

The choice was made to use perceptual measures of the benefits of the Challenge-based learning program. This choice could be criticised, as perceptions often differ from reality and also the use of self-reported measures invites statistical problems of common method variance (CMV) and response trends. CMV refers to false conclusions that result from “variance that is attributable to the measurement method rather than to the constructs the measures represent” (Podsakoff et al., 2003, Williams and Brown, 1994). To preempt these concerns, perceptual measures have been validated through econometric tests and factor analyses that have demonstrated satisfactory reliability.

In addition, the questions in the survey are a combination of validated constructs and constructs developed or adapted by Moberg et al. (2014). The development of these measurement tools was performed in a step-by-step process that included pre-studies and pilot testing. This increased the precision, validity, and reliability of the measurement tools.

Moberg et al. (2014) referenced the framework developed by Heinonen and Poikkijoki (2006) to develop their indicators and subsequently construct the questionnaire. This framework, which is recognised at EU level by the Directorate-General for Enterprise and Industry (DG Enterprise and Industry), illustrates the dimensions that educational initiatives should focus on to develop enterprising individuals, such as students' mindsets, attitudes, and career aspirations.

The questionnaire has a set of questions for each variable. Each question allows for the measurement of a single item of the considered variable and each question can be answered on a Likert scale from 1 to 7 (1=totally disagree, 7=totally agree). The arithmetic mean of the item values was calculated to obtain the value of a variable for a student.

Consequently, for each student, the values of the individual pre and post challenge variables were collected. For each variable in Table 1, it was possible to develop a statistic by calculating the average pre challenge value of the sample of students and comparing it with the respective average post challenge value.

Factor Analysis were conducted to verify the appropriateness of the items for the individual variables. The Factor Analysis revealed six factors that explain 80 per cent and 76 per cent of the variation of the items, respectively for the pre and post challenge surveys. Cronbach's α for the six factors, both pre and post challenge, were more than 0.68. After the Factor Analysis and processing of statistics, a t-test was conducted for each variable to test for the presence of a statistically significant impact of the challenges on students' entrepreneurial characteristics. Results are presented in Section 4.

Table 1. Variables, and their respective domains, to measure students' entrepreneurial characteristics

Domain	**Variable**
Mindset	Entrepreneurial Mindset
Entrepreneurial skills	Creativity
	Financial Literacy
	Managin Ambiguity
	Planning
Connectedness to labour market	Entrepreneurial Intention

4 RESULTS

As anticipated in the methodology chapter, statistics were initially developed to compare the average values of students' entrepreneurial variables before and after participation in the challenge (Fig. 5). In Fig. 5, it can be observed that before the challenge the average value of students' entrepreneurial mindset was 5.29, while this value grew by 0.25 to 5.54 after participation in the challenge. Similar growth can be observed for creativity and planning. Regarding financial literacy, participation in the challenge allowed for a greater increase than the previous variables. Instead for the variables managing ambiguity and entrepreneurial intention, a smaller increase in average values can be observed.

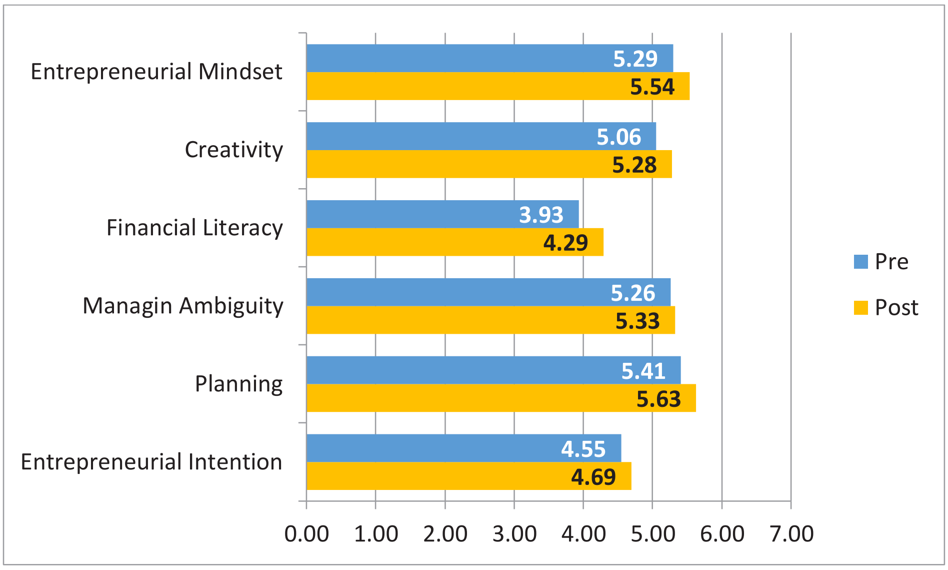

Fig. 5. Average value of entrepreneurial characteristics, pre and post challenge

After these initial statistics, a t-test was conducted (Table 2) to test the effect of the program on students' entrepreneurial characteristics. A significance level of 5% is considered.

Results show that the difference between the post and pre challenge of the entrepreneurial mindset is statistically significant and positive, so participation in the challenge increases the average value of this variable.

As for entrepreneurial skills, it is possible to note (Table 2) that the difference between the post and pre challenge is positive for all variables. However only creativity, financial literacy and planning are statistically significant. Finally, also entrepreneurial intention reveals a positive difference between the post and pre challenge, although it is not statistically significant.

In sum, results in Table 2 show that the challenge based program positively affect the entrepreneurial mindset and skills, like creativity, financial literacy and planning, of participating students.

Table 2. Output t-test

Variable	Average pre challenge	Average post challenge	Ho: diff = avg post challenge – avg pre challenge	p-value Ha: diff>0	p-value Ha: diff!=0
Entrepreneurial Mindset	5.293963	5.538058	.2440945	0.0196	0.0391
Creativity	5.055118	5.279528	.2244094	0.0366	0.0733
Financial Literacy	3.934383	4.288714	.3543307	0.0256	0.0512

Managin Ambiguity	5.257874	5.326772	.0688976	0.2976	0.5951
Planning	5.411417	5.629921	.2185039	0.0376	0.0752
Entrepreneurial Intention	4.545932	4.690289	.144357	0.2567	0.5135

5 LIMITATIONS OF THE STUDY

The study addressed student attitudes and intentions before and after the Challenge, but not actual student behavior in the periods following Challenge participation. It is echoed by the suggestion that longitudinal studies that follow subjects for years after graduation is the only way to accurately prove the intention-behavior link (Kolvereid, 1996a). In future research on entrepreneurial education, the effect of Challenge-based learning programs could be longitudinally tested, by investigating and analyzing the eventual creation of ventures.

6 CONCLUSIONS

This paper presents the results of a research project to assess the effectiveness of challenge based programs on students' entrepreneurial skills, mindset, and intentions. The paper contributes to the increasing but still limited stream of the literature on Challenge Based Learning approaches. The project has involved 127 students who answered to a questionnaire administered before and after participation into the challenge base program. Results reveal that the program positively and significantly affects the entrepreneurial mindset and skills, like creativity, financial literacy and planning, of participating students. The empirical evidence also shows an increase in students' entrepreneurial intention, although the effect is not statistically significant.

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EVALUATING THE IMPACT OF REMOTE LEARNING ON ENGINEERING REPORT WRITING SKILLS USING ACADEMIC ASSESSMENT AND AUTOMATIC NATURAL LANGUAGE PROCESSING

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Conference Key Areas: *• Competence development for engineering professions, Changes beyond Covid-19*
Keywords: *writing skills, automatic readability assessment, natural language processing*

ABSTRACT

Written communication skills are considered an important yet underdeveloped skill in student engineers compared to those studying humanities. Motivated to evaluate existing techniques to automatically measure writing skills and discover their relationship to the academic grades awarded by engineering educators, this paper reports an analysis of an individual engineering research report writing exercise that all students complete after one semester in their first year engineering degree programmes. The exercise has been taken by 1360 students from 2017 to 2020. The performance is compared across the four year-cohorts via academic assessment and automatic readability assessment. While the first three-year results are from students who are taught on campus, the last cohort is taught exclusively online with no opportunities for students to meet in person due to the restrictions under the COVID-19 pandemic. To evaluate whether there is any marked change in the qualities of student report writing skills very early in their university studies due to the lack of cohort interaction and shared physical experience, eight classic readability assessment measures are calculated for each report and compared with the grade awarded for the report. We find that two classic readability measures - Coleman Liau and Dale Chall - have a higher correlation with the academic assessment and complement each other due to low correlation with each other. We combine them and further improve the correlation with the academic grade. The work highlights the potential of using readability assessment in engineering education as a learning support tool and to improve assessment reliability.

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1 INTRODUCTION

Is it possible to automatically assess the readability of an engineering student's technical writing, and how would this automatic readability assessment correlate with an academically-assessed grade, which would take into account technical quality and context? Moreover, has the covid-19 pandemic affected, on average, students' report writing compared with recent years? In this study we answer these questions by examining research reports from four successive first-year general engineering cohorts and consider different methods for automatically assessing the reports' readability.

1.1 Report Writing Skills

Written communication skills are an important skill for engineering students [1]. They are shown to influence career choice and success [2]. However, it is still a widely-held view that modern engineering curricula does not place significant emphasis upon them [3]. By the virtue of the type of secondary school focus of their studies in numerical and scientific subjects in order to enter engineering higher education in the United Kingdom, students do not develop writing skills explicitly further than English language secondary school level, with which they communicate their ideas and research in the scientific subjects.

In the particular report writing exercise considered in this paper, the instructor reminds students that writing skills are important because they are likely to produce many reports as engineers. A report is "a statement of the results of an investigation or of any matter on which definite information is required". They are introduced to an engineering report as having a very formal structure, that leads the reader through the information efficiently and that makes it easy for non-experts to glean information. They are expected to structure the report under the headings of title page, acknowledgements, content, abstract or executive summary, the main body, references and appendices.

1.2 Impact of Covid 19

The impact of the COVID-19 pandemic is likely to be studied for many years to come. In higher education, there was an almost immediate move to online teaching and assessment because students could not attend in person with many residing in different countries and in different time zones. The lack of social interaction between students online, particularly any cohort that was coming together for the first time as in the case of first year undergraduates, raised additional challenges to cohorts that had come together prior to the pandemic and in which friendships and face-to-face group work had taken place which formed and deepened acquaintances. The lack of these interactions between students and their instructors could have an impact on learning and skills development.

In this paper, the authors choose to focus on report writing skills for first year undergraduate students to assess whether online instruction versus in-person instruction and tutoring could have impacted on the report writing skills of different cohorts. To achieve this, reports produced under the same instructions but covering four cohorts are assessed and compared. Only the last of the cohorts are taught online. The readibility of the reports, assessed automatically due to the sheer volume (1360) is investigated to identify any possible trends arising from the different type of instruction and a lack of personal interaction between students.

1.3 Automatic Readability Assessment

The quest to find a reliable automatic measure of text comprehension is an active research area that spans almost a century [4]. Applications in the education domain include assessing reading age level, automated essay scoring, and providing student feedback [5]. Readability Assessment (RA) involves parsing text to extract quantitative measures, from which a score is calculated. Parameters used to compute the score are determined empiricially to match a gold standard recorded in a text corpus. This standard is typically a score derived from human judgement and/or demographic information, such as age.

Hundreds of RA methods exist. In a recent review of the field [6], methods were described as classical formulas that compute a score based on frequency and length of text units such as words and sentences, and methods that use more advanced linguistic and semantic features from Nautral Language Processing (NLP). These advanced features are combined with statistical and machine learning methods to determine the best feature set.

Despite the promise of recent advances, classical formulas persist due to their ease of comprehension and application. In the Engineering domain, recent applications of classical formulas include assessing design standards [7] and distinguishing academic abstracts [8].

1.4 Structure

This paper proceeds as follows. Section 2 outlines the data, methodology for analysing the correlation between report readability and grade, and the three experiments performed. Section 3 presents our results and findings, including follow-on work to combine automatic readability measures to improve correlatio with academic assessment. Section 4 finishes with discussion and future work.

2 METHOD

2.1 Text Corpus

Reports from the same assignment taken by different students over 4 years from 2017-2020 are collected together with the grade awarded, which is an academic assessment of the quality of the report taking into account the technical quality and knowledge understanding of the topic, rather than notions of general readability. Text from each report is extracted and frontmatter and backmatter removed. In total 1360 reports are processed. Cohort numbers are comparable between years, ranging between 315 and 398. The mean word count for reports is 1684 with a standard deviation of 437. The normalised mean grade is 0.69 with a standard deviation of 0.11. There is no significant difference between grades awarded each year, as show in the frequency histogram in fig. 1.

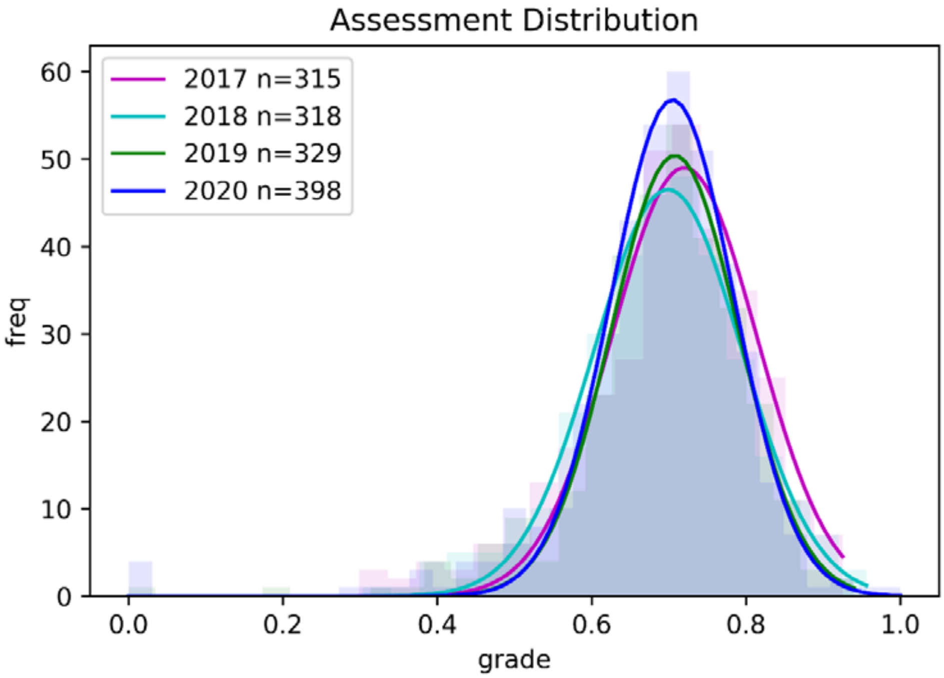

Figure 1 Frequency histogram comparing grade distribution normalised to 1 across years, overlayed with a normal distribution curve fit for each year.There is no significant difference between distributions.

Classic Readability Assessment (RA) measures are computed for each report. These methods are summarised in Table 1. All RA methods typically apply an estimated linear function to produce a readability score, where the inputs are a subset of counts of sentence, word, syllable and letter. In some algorithms, word counts are further distinguished by taking into account word complexity using either grammatical analysis or usage estimates.

Table 1 RA method comparison of input features (counts)

RA method(year introduced)	Sentence	Word	Letter	syllables	complexity
Flesch-Kincaid Grade Level (1975)	x	x		x	
Flesch Reading Ease (1948)	x	x		x	
Dale Chall Readability (1995)	x				x
Automated Readability Index (1967)	x	x	x		
Coleman Liau Index (1975)	x		x		
Gunning Fog (1952)	x	x			x
SPACHE (1952)	x	x		x	
Linsear Write (1966)	x				x

2.2 Experiments

Three experiments are conducted with the RA measures extracted from the reports:

Experiment 1: Correlation between RA measures and grade. The linear and monotonic relationship between measures and grade for each report is explored by calculating the Pearson and Spearman correlation coefficients respectively.

Experiment 2: Correlation between RA measures. These are compared to identify those which can be considered complementary or redundant. The relationship is similarly explored with the Pearson and Spearman correlation coefficients.

Experiment 3: An optimum RA measure is proposed to predict grade. A selected number of measures are combined to doscover a readability measure which has a higher correlation with academic assessment than others.

3 RESULTS

3.1 Experiment 1: Correlation between RA measures and grade

Correlation of RA measures with academic assessment (Table 2) reveals that all measures are weakly correlated with grade. CL has the highest correlation when considering the linear case, while DC has the highest correlation when considering the monotonic case. Scatterplotting these two methods to visualise these relationships with grade (Fig. 2) illustrates this.

Table 2 Correlation of readability measures with grade including ours (see section 3.2)

Method	Pearson (linear)	Spearman (monotonic)
Flesch-Kincaid	-0.012	-0.077
Flesch Reading Ease	0.020	0.065
Dale Chall Readability	0.084	0.281
Automated Readability Index	-0.012	-0.091
Coleman Liau Index	-0.126	-0.062
Gunning Fog	-0.012	-0.074
SPACHE	0.007	0.084
Linsear Write	-0.010	-0.057
Ours	**-0.154**	**0.320**

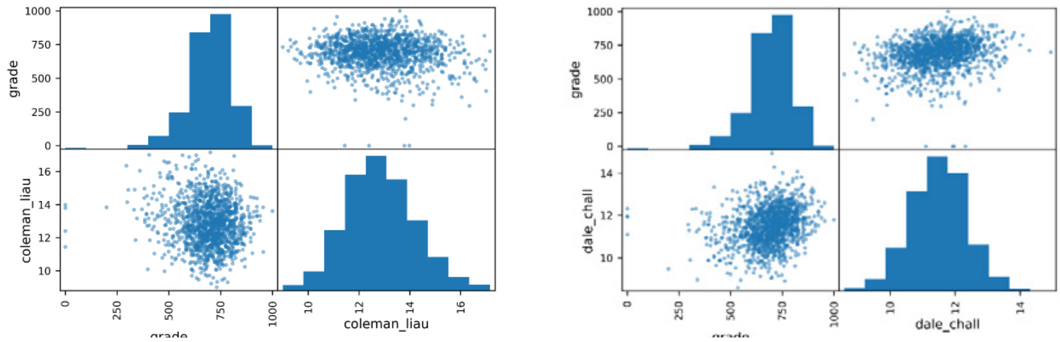

Fig. 2 CL weak linear relationship (left) DC weak monotonic relationship (right)

3.2 Experiment 2: Correlation between RA measures

Fig. 3 shows the linear and monotonic correlations respectively between readability methods for all text (*n=1360*) in heat-map form. Most methods have high correlations (either positive or negative) with the exception of Coleman Liau (CL) which does not correlate with any other measure. This suggest that CL may be useful in combination with other measures, and that the other methods are relatively interchangeable. For the monotic (ordinal rank) relationship, the comparison also reveals that CL does not correlate with other measures. Furthermore, the Dale Chall (DC) method also has a low-correlation with other methods. This highlights the possibility that these two measures may complement each other.

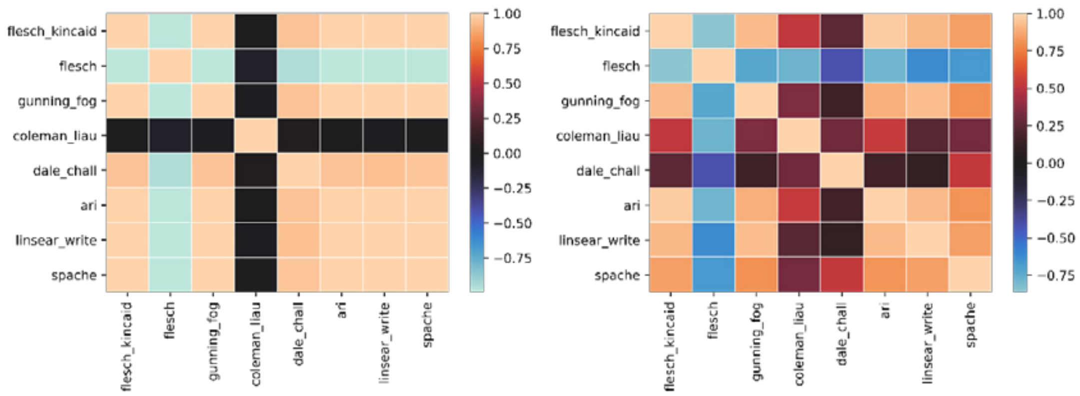

Fig. 3 Pearson (left) and Spearman (right) correlation coefficient heatmaps for RA measures

3.3 Experiment 3: Optimum RA measure to predict grade

The discovery of higher correlations with grades for DC and CL (experiment 1), and their low correlation with other methods (experiment 2), invites the possibility that combining the two could yield a higher correlation with grade. Their scores, R_{DC} *and* R_{CL} respectively, are combined for each report using linear weighted interpolation to produce our new measure R_{ours} :

$$R_{ours} = \alpha R_{DC} - (1 - \alpha) R_{CL}$$

R_{CL} is negated due to its negative correlation with grade as revealed in table 2. The interpolation weight, α, is empirically determined to maximise either the pearson and spearman correlation coefficient. $\alpha=0.8$ gives the highest value for spearman correlation coeeficient (*0.32*) while $\alpha=0.2$ has the highest value for pearson correlation coefficient (*0.15*). These findings show some value in combining these two complementary measures to predict grade. This is likely due to relatively fewer overlapping features that they share (sentence counts) whereas other measures share more counts (notably word and letter). Finally, for completeness, our formula combining DC and CL using weight α is:

$$R_{ours} = \alpha\left(15.79\frac{N_{dw}}{N_w} + 0.0496\frac{N_{dw}}{N_s}\right) - (1-\alpha)\left(5.88\frac{N_l}{N_w} - 2.96\frac{N_s}{N_w} - 15.8\right)$$

Where counts N_{dw}, N_w, N_s, N_l are for difficult words, words, sentences and letters respectively.

4 DISCUSSION AND SUMMARY

Motivated to improve engineering students report writing communication skills through technology, and to assess the impact of remote learning, we found no difference between previous years for grades awarded and the classic readability measures for students who have experienced only remote learning and those who interacted face-to-face with peers at their beginning of study. This is not altogether unexpected – compared to skills that may require greater interaction with apparatus and other people, writing can be a skill mostly practiced alone with feedback provided asynchronously.

We found a limited use for these classic readability measures; most are highly correlated with each other and are only weakly correlated with grade. Given that the grade used in this study is an academic assessment that is not directly assessing readability, we believe the weak correlation is acceptable. Strikingly, two measures – Dale Chall and Coleman Liau - stand out with significantly stronger correlations. This suggests that these measures could be more useful to engineering educators than the more common go-to measures found in the literature: Flesch-Kincaid, Flesch Reading Ease and Automated Readability Index. In the case of multiple assessors, as is common in large faculties assessing capstone reports, these measures could be used to improve assessment reliability by including a machine-generate component into the mark scheme. However, their weak correlation suggests they are no replacement for human judgement.

Future work includes using our preferred readability measures to demonstrate progression through years of study. There is also potential to employ newer techniques of natural language processing with machine learning to devise an engineering education-specific automatic readability assessment measure which could support learning for specific engineering writing contexts. This would necessitate collecting a corpus with a sufficient number of samples to robustly train and evaluate any algorithms.

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ASSESSMENT OF PROJECT-BASED LEARNING AS A WORK METHODOLOGY FOR AIR NAVIGATION STUDENTS.

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Conference Key Areas: *Lab courses and projects blended and online; Competence development for engineering professions.*
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ABSTRACT

Motivation is considered to be a crucial factor in the teaching-learning process in Aerospace Engineering, especially due to the difficulty of the courses taught. The application of active methodologies, focused on student learning, can increase students' motivation, and improve their learning, helping them to persevere through a challenging workload. In this regard, previous studies have shown how the implementation of the Project-Based Learning methodology as a working tool in various disciplines is motivating and facilitates the integration of courses and their success in student learning. This work presents the results, in terms of student satisfaction, of the application of this methodology in various courses of the module Air Navigation Specific Technology, consisting of the development of an airport project considering its associated infrastructures and procedures. The results of the global data collection survey are analysed in order to identify trends. We included open-ended questions in a questionnaire where the students could express their impressions, problems, suggestions for improvement, etc. Through these techniques, in addition to students' satisfaction, other features such as dedication time or problems in developing the project are also analysed to complete the project appraisal.

1 INTRODUCTION

1.1 Context

The bachelor's degree in Aerospace Engineering from the *Universitat Politècnica de València* (Technical University of Valencia) completes the training of students with a focus on a specific technology (Aeromotors, Aircraft or Air Navigation), which qualifies students for the profession of technical aeronautical engineering. The courses offered in the module Specific Air Navigation Technology provide students with a complement that will allow them to develop their professional work in the general field of technical aeronautical engineering and, in particular, within this particular area. The courses involved in the development of this work are the following (Table 1):

Table 1. PBL Courses on Performance Based Navigation.

Name	Sem.	ECTS	Nº std.
Planificación y Desarrollo de Aeropuertos (Airport Planning and Development)	5	6	14
Navegación Aérea, Cartografía y Cosmografía (Air Navigation, Cartography and Cosmography)	6	4,5	26
Infraestructuras para la Navegación Aérea (Air Navigation Infrastructure)	7	6	22
Gestión del Espacio Aéreo I (Airspace Management I)	7	6	26
Ingeniería de los Sistemas de Navegación Aérea II (Air Navigation Systems Engineering II)	8	6	27
Gestión del Espacio Aéreo II (Airspace Management II)	8	6	31

In the starting situation, the organization of these studies involved the accomplishment of multiple tasks in the different courses, which facilitated the acquisition of the knowledge and competences required for the professional development of students, and which were part of the final evaluation of the courses, together with the completion of open-ended written tests. The diversification, and sometimes overlap, of these tasks required a work overload of the students, who faced these tasks with little motivation.

In the case of training in Aerospace Engineering, motivation is considered as a crucial factor in the learning process and academic performance of students, especially due to the difficulty of the courses taught [1]. It is therefore important to identify the active methodologies that can increase students' motivation and improve their learning, helping them persevere through a challenging workload [2]. Active learning methodologies are based on activities that involve students in such a way that they perform the tasks with a clearly applied focus on the task they carry out, thus achieving a combination of action and reflection that improves the learning capacity of students. Unlike traditional learning approaches, in which the teacher leads the work of students through the teaching of theory lectures and targeted practical sessions, the leading role of students in the teaching-learning process is increasingly required, without ignoring the importance of lectures at the beginning of any process, along with teamwork and students' autonomous work.

The application of new practice-based models particularly benefits engineering education for its essential practice component. In addition, courses in the advanced semesters, in particular those of specific technologies, which have a very technological and systematic nature, are better suited to implement active learning methods such as Project-Based Learning (PBL), which will be the fundamental tool for this process [3]. PBL enhances not only the acquisition by students of the specific competences of each course, but also the development of skills or abilities such as problem-solving, critical thinking, adaptability, capacity for data collection, teamwork, proactivity, among others, increasingly appreciated in the professional field of aviation and aeronautics [4].

In fact, among the benefits of this method it stands out that it fosters autonomous learning, prepares students for qualified jobs, increases motivation, strengthens self-confidence, establishes a connection between academic learning and the real world, offers opportunities for collaboration to build knowledge, improves social and communication skills, increases problem-solving skills, etc. If we also consider the added benefits of collaborative work in terms of increased interaction and critical-thinking skills in the negotiation of solutions, PBL appears to be an ideal strategy for improving the quality of learning [5,6].

The integration of the tasks to be carried out as part of the different subjects involved in the development of this work will enable the students to lead and manage their own project, requiring their own decision-making while constantly having the support of the teachers. The teachers will start the process by identifying the requirements and competences to be acquired through the specified content and skills, yet students will be autonomous in learning the contents and developing the skills. Additionally, project teamwork will also be encouraged using requirements lists as an interface between teams.

1.2 Objectives

The main objective of this project is to improve the teaching-learning process of students of Specific Air Navigation Technology, using the PBL methodology. To do this, students will develop the design of an airport in accordance with its infrastructure and associated procedures.

The specific objectives, which are intended to be achieved through the application of this didactic methodology, are:

- To increase the motivation of students through the development of an integrated project that implements and contextualises the acquisition of specific competences.
- To improve the ability to apply course content to the professional world, thus expanding the vision of the professional future of students.
- To facilitate the acquisition of skills such as collaborative work and working time management.
- To know the degree of satisfaction of the students regarding the effectiveness of the PBL methodology in the learning process.

With regard to students, it is expected that, upon completion of the airport design project, they will be able to:

- Collect the necessary information in the bibliography and the regulations applicable to airport and infrastructure design.
- Identify the basic functional components of an air navigation system and the needs of on-board and ground equipment for proper operation.
- Apply the theoretical knowledge of the courses involved to professional practice, through the design of the ground side and air side of an airport.
- Calculate the elements required for the development of an airport: runway parameters, electrical networks infrastructure and specific air navigation systems.
- Prepare the report of the design of an airport, including all the necessary documentation, for presentation in oral communication format (presentation or poster).

2 METHODOLOGY

In order to achieve the objectives of the airport designin project, the teachers have scheduled some planned open learning activities, based on real cases, associated with the delivery of the project and coordinated between subjects, using the project as a link among them. These activities are intended to facilitate and improve the learning and evaluation process of general, specific and cross-curricular competences. The work of students has been assessed, analyzing and evaluating the achieved results, both in terms of satisfaction with the PBL methodology as a working tool, and regarding the attainment of the learning outcomes.

The work presented here aims to assess students' perception of the development of skills, and the usefulness and effectiveness of an airport design project.

2.1 Activities

The activities carried out by students throughout the two years of the project are briefly discussed below, indicating the methodology used for their completion, the cross-curricular competences (CTs) developed and their percentage in the final grade of the courses, taking into account that the activities A3, A4 and A5 are carried out in the same courses and activity A9 distributes its 20% weight between activities A7 and A8:

- A1: Airport installation and runway project report (5th semester). Teamwork including an oral presentation through the MICROSOFT TEAMS platform. Involves CT06 – Teamwork and CT08 – Effective Communication. Weight: 30%.
- A2: Study of the reception of radio signals from satellites (6th semester). Teamwork including an oral presentation through the MICROSOFT TEAMS platform. Involves CT08 – Effective Communication and CT11 – Lifelong Learning. Weight: 40%.
- A3: Beaconing project (7th semester). Individual project. Involves CT05 – Design and project and CT07 – Ethical and environmental responsibility. Weight: 10%.
- A4: Electrical installations project (7th semester). Involves CT05 – Design and project and CT07 – Ethical and environmental responsibility. Weight: 10%.
- A5: Radio Navigation project (7th semester). Individual project. Involves CT05 – Design and project and CT07 – Ethical and environmental responsibility. Weight: 10%.
- A6: Radar installations project (7th semester). Individual project. Involves CT09 – Critical thinking and CT10 – Knowledge of contemporary problems. Weight: 20%.
- A7: Communications project (8th semester). Individual report. Involves CT01 – Comprehension and Integration and CT03 – Problem-solving. Weight: 40% (30% + 10% of A9).
- A8: Aeronautical Charts with the design of procedures for approach to the airport (8th semester). Individual report. Involves CT02 – Application and practical thinking and CT13 – Specific instrumental skill. Weight: 50% (40% + 10% of A9).
- A9: Presentation and final evaluation of the airport project (8th semester).

2.2 Instruments

Twenty-six students have participated in the project. Although this is not a very large sample, it is the number of students usually registered in these specific technology courses, so we can consider that the results are reliable. In order to know their evaluation of the project carried out, a survey has been used with a validated questionnaire [7] for assessing their perception of the effectiveness of active participation methodologies in the development of technical and non-technical competences, and in particular of PBL. The aim of this questionnaire has been to assess specific competences of the training profile of the courses taught: general skills, i.e. instrumental in learning and training; systemic competences, to properly manage the entire task; and interpersonal competences, which allow to keep a good level of social relationship. The 25 items comprised in the questionnaire cover basic skills that any graduate student must achieve, and are answered through a Likert scale including 5 answer options (1 - Strongly disagree; 2 - Disagree; 3 - Neutral; 4 - Agree; 5 - Strongly agree). In addition, three open-ended questions were included in which students could express impressions, problems, difficulties, suggestions for improvement, etc.:

- What aspects could you point out regarding the usefulness of this methodology in improving your learning process?
- What difficulties have you faced when carrying out the different activities of the airport design project?
- Have you found the development of this airport design project motivating? Briefly comment on your answer.

3 RESULTS

Regarding the results obtained in the assessment of students' perception, in this work we deal with those directly related to the objectives of this project. Of the first 5 items of the questionnaire, related to the development of the specific competences of the courses integrated in the project, it is worth pointing out that all participants (26 students) have considered, with the highest score, that the PBL educational methodology helps to contrast the knowledge learned in the classroom with its application in real situations (item 1) and manages to bridge the gap between theory and practice (item 2). 92.3% of students (24 students) completely agree that this methodology facilitates the learning of the course (item 3) and 88.5% of students (23 students) fully agree that it involves participants in their own learning (item 4) and creates an attitude of active participation (item 5).

With regard to the development of cross-curricular competences of the instrumental, systemic and interpersonal categories, the results are presented below for the assessment of the skills: management (items 6, 9 and 16) (Fig. 1), problem solving and critical thinking (items 7 and 8) (Fig. 2), communication (items 12 and 13) (Fig. 3), data collection and instrumental (items 10 and 11) (Fig. 4) and social skills (items 19 and 22) (Fig. 5). These are the items that best represent the competences that have been directly addressed in this project.

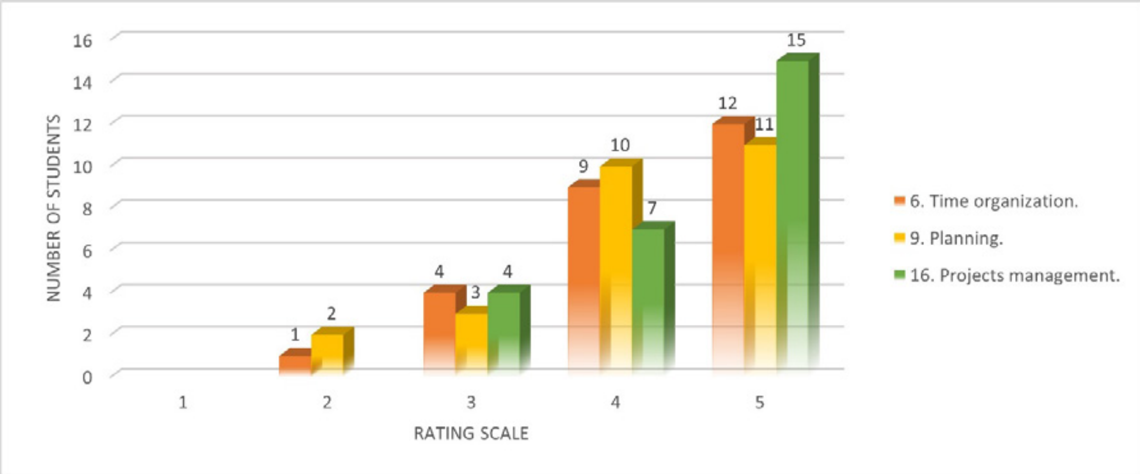

Fig. 1. Management skills assessment.

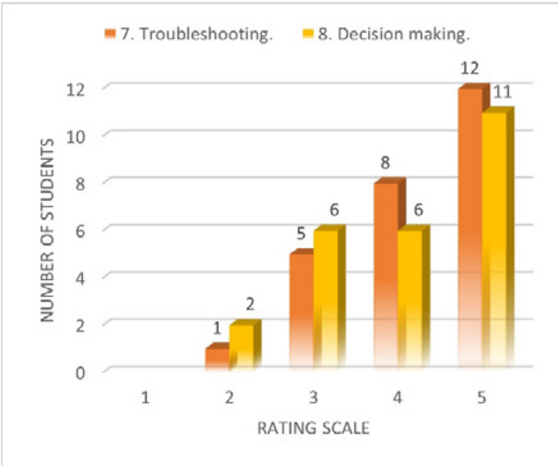

Fig. 2. Problem solving and critical thinking skills assessment.

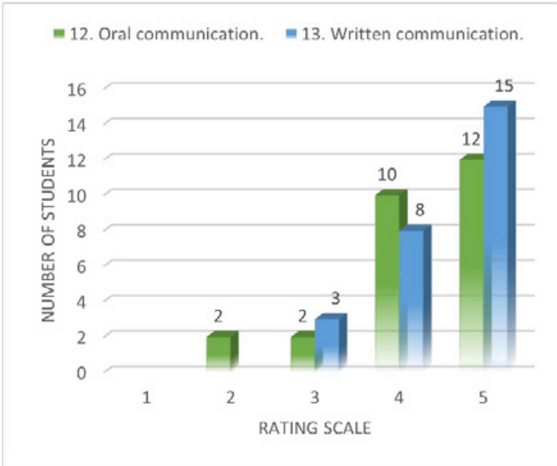

Fig. 3. Communication skills assessment.

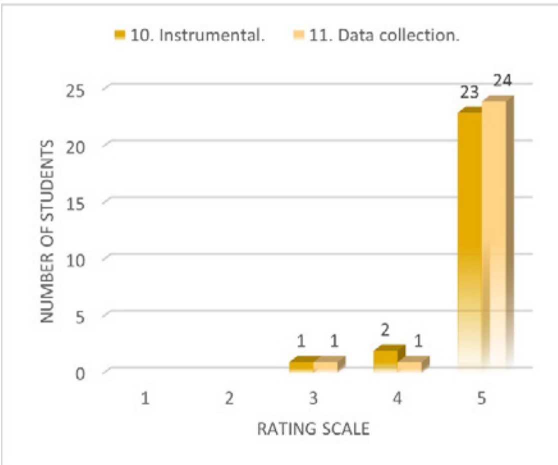

Fig. 4. Instrumental and data collection skills assessment.

Fig. 5. Social skills assessment.

4 CONCLUSSIONS

Bearing in mind that the ultimate goal of this project is to facilitate the learning of specific Air Navigation technology subjects, throughout the use of the ABP methodological tool, and to motivate students in the learning process of these subjects; two features have been distinguished. On the one hand, the integration of the competencies provided by different subjects to ensure that the students see them as part of a whole and not in isolation, and look for solutions to their project in such a way that its theoretical components are assimilated; and on the other hand, it is intended to work on full projects development, which will help them to achieve useful competencies for their future professional life as engineers.

In view of the results of the questionnaire, and with the support of the comments provided in the open-ended questions, it can be concluded that the application of the PBL methodology for improving the teaching-learning process of students of Specific Air Navigation Technology has been successful.

Most students have highlighted, above all, the link between courses within a single project and their similarity and connection to their professional future, which has resulted in an increase in motivation. They also stressed that the high level of difficulty of some activities, which could be seen as a negative factor, has motivated them in the problem-solving process. On the other hand, a few students have not found this methodology motivating or effective and have expressed that it has been a great additional workload, and that they have found it difficult to meet the completion deadline of some of the activities, which has caused them a feeling of dissatisfaction.

It is important to highlight the assessment of collaborative work that has been carried out in some of the activities. Although most participants (16 students) have positively assessed the achievement of this goal, many others (10 students) have not considered that the acquisition of this skill has been facilitated. Comments on this have dealt with the current health situation, which does not allow us to perform group tasks in the way we were used to. In this sense, the TEAMS platform has been fundamental to the development of meetings and the presentation of works, and students consider that it has facilitated oral communication by reducing the embarrassment usually associated with speaking to an audience.

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HOW TO ADD INNOVATION AND DESIGN INTO INTRODUCTORY ELECTRICAL ENGINEERING CLASSES

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Conference Key Areas: *Engineering Skills, Curriculum Development, Engineering teaching*
Keywords: *Curriculum, Design, Electrical, Projects*

ABSTRACT

It is becoming more commonly acknowledged that effective methods for educating engineers is through active learning strategies such as Design Projects. What is more challenging is developing these active strategies that are focused on broader accessibility, participation, and inclusion. This curriculum development paper will describe specific activities, design projects, and strategies that have been developed and revised in introductory Electrical Engineering classes. The projects develop engineering competence through students utilizing technical concepts, analytical reasoning, practical skills and professional judgement to solve open-ended design problems. All activities place priority on student experience and competency development as compared to a faculty centric approach.

INTRODUCTION

To develop the engineering student of today into the engineer that we will need tomorrow it is vital to build a curriculum that is relevant, applied, challenging and inspires students to apply the knowledge to new and different applications [1, 2]. To accomplish this it is important to shift some of the current curriculum focus away from traditional lecture format. A pair of studies from 2005 by Shuman [3] and Loui [4] focused on the ineffectiveness of the traditional lecture format for teaching ABET professional skills and argued that a modern engineering education should focus on active and cooperative learning approaches. Sheppard adds, “In the Engineering Science and technology courses, the tradition of putting theory before practice and the effort to cover technical knowledge comprehensively, allow little opportunity for students to have the kind of deep learning experiences that mirror professional practice and problem solving” [1]. Rather than focusing strictly on theory and technical laws, engineering education needs to broaden its scope and include curriculum that develops the spirit and the professional practice that we are also seeking [2].

Goldberg offers some guiding questions to consider in improving Engineering education:

1) How do we produce the innovators that are needed for our times?
2) How do we inspire students to become intrinsically motivated to learn?
3) How do teachers step down off the stage and involve themselves as coaches inside and outside the classroom?
4) How do we renew the culture of engineering education to make it relevant, creative and fulfilling? [2]

Engineering is inherently a creative enterprise. While scientists ask “Why?” engineers must ask “why not?” Engineers are responsible for imagining what has never been and then doing whatever it takes to bring visions to reality. In the fundamental sense, “to engineer” is “to make.” Making requires more than the analytical mind. It also requires the design mind [2].

Design is widely considered to be the central or distinguishing activity of engineering [5]. It has also long been said that engineering programs should graduate engineers who can design effective solutions to meet social needs [6]. Despite these facts, the role of design in engineering education remains largely as stated by Evans, “The subject of design seems to occupy the top drawer of a Pandora’s Box of controversial curriculum matters, a box often opened only as accreditation time approaches. Even ‘design’ faculty—those often segregated from ‘analysis’ faculty by the courses they teach—have trouble articulating this elusive creature called design” [7, 8].

Design is hard to learn and harder still to teach [8]. Cobb states the term design-based learning has been broadly applied across the many fields of Science [9]. In a 2002 study Edelson defines design as open-ended, reflective and relying on creativity. He goes on to state, “In Challenging or innovative design, decisions can be complex, interdependent, requiring extensive investigation, experimentation and iterative refinement on the part of the designers. In these cases, the designers inevitably acquire substantial new understanding.”[10]. Design faculty across the country and across a range of educational institutions still feel that the leaders of engineering departments and schools are unable or unwilling to recognize the intellectual complexities and resources demanded to support good design education [11].

This author’s journey down the path of adding more design to the curriculum started with the desire to better engage students in the enjoyment of a real metacognitive challenge, the kind of challenge only attained by a true open-ended engineering design project. Initially, concern was for asking too much of the students and the potential for a failed experiment. Maybe an 18-20 year-old student wouldn’t have the maturity, creativity and drive to overcome the many challenges they would face. I couldn’t have been more wrong! Right from the start the students impressed me with how much they embraced the idea of getting to create something. It was as if they had been waiting for me to wake up and finally give them a real engineering challenge! It’s been over 15 years now with steadily increasing complexity of projects, and the students have never disappointed in their ability to rise to the challenge. In fact, many times student prevailed with better solutions than their instructor. What follows is a description of four projects that have been used in the introductory electrical engineering sequence of classes.

The projects are presented in the order that this author typically uses them. In the development of electrical comprehension, as with most areas of engineering, it is vital that the concepts are presented in such an order that it promotes student understanding. In the study of electricity it is also important to build a basic understanding, comfort and belief that electricity makes sense and can be predictable. The first project presented, the battery project, is not a design project. It is however, a great project for a student's first electrical class that builds a strong foundation for future design work.

THE DESIGN PROJECTS

Battery Project – Physics 2 Class

A group of students is given 7 to 8 different AA batteries and asked to determine which battery is the "Best Bang for the Buck". Instruction is given on how to measure battery capacity in ma-hr. A visit to a leading battery manufacturer's website will help to answer some questions (Energizer.com has a nice technical info section link at the bottom of the home page). This research will reveal how critical discharge rate is to determining battery capacity. This instructor uses an average discharge rate of 200 mA. This is a good average discharge rate and will allow for the discharge to be done within a reasonable 8 -12 hours of data taking. For 1.5 volt AA batteries, a good size resistor to use to attain a 200 mA discharge rate is 4.7 ohms. Students' record voltage every half hour until battery voltage is below 0.8 volts, the industry standard. The voltage data is then put in to a spreadsheet program to graph volt vs time and current vs time. The students find the area under the mA vs hours graph then divide the area by the cost per battery. This will give them mAhr/$ or energy per dollar, "Bang for the Buck".

The batteries should be purchased locally and purchased in the largest package available to attain the lowest price per battery. Purchase an assortment of battery chemistries like lithium, manganese dioxide (alkaline) and zinc chloride. This will give more interesting results and also show students the significance of the Chemistry involved. It is also educational to add on a few extra questions pertaining to batteries. Questions like: How does temperature affect battery performance? What is battery memory? What are some recent battery developments? How can I tell how much energy is left in a battery? Does discharge rate effect overall battery capacity? How do Alkaline, NiMH, Ni-Cd and Li ion batteries compare?

This project tends to be a great introductory electrical experiment. It answers a very relevant question, "What is the best battery?" It builds confidence with electricity and provides opportunity for practice with a voltmeter. The project also puts students in groups to learn from each other, helps to clarify the difference between current, voltage, energy and power (four concepts that students often confuse), lets students use a spreadsheet and apply basic Calculus in a real-world problem. All of this helps to build a solid foundation which prepares them to succeed in future classes.

Circuit to Meet a Need in Society - Circuits 1 Class

For this project students are given the very open-ended task of building a circuit to meet a need in society. Grading is based on originality of need met, difficulty of circuit design, creativity of solution and quality of manufacturing.

The first two weeks of the class are very lab intensive. Students learn and build many different types of electrical circuits with an assortment of devices and sensors that will become the components of their final project. Each of the concepts taught connect and build upon the previous concepts. The circuits, devices and sensors taught include astable and monostable circuits, 555 timer, pulse-width modulation (PWM) circuits, servo-motors, potentiometers, photoresistors, thermistors, transistors, photo-transistors, hall-effect sensors, infrared detectors, relays … etc. Preliminary challenges are assigned during the first two weeks to ensure students can build the circuits applying all of the devices and sensors. Challenges may include set off an alarm to trip on increasing darkness/brightness, trip on lowering/rising temperature or trip when a laser beam is broken.

This design project provides a number of significant benefits for student learning. Students are learning many new electrical concepts and applications. Students are learning how to apply technical solutions to a real world design where they actually have to build the solution. Students also have to, maybe for the first time, find their own problem to solve. Often in a class the instructor chooses the problem to solve; design a bridge, build a windmill…etc. This design project however, asks the student to assess their environment and find the problem to solve themselves. This methodology takes student learning and involvement to a whole new level. The student is no longer a passive member in their own education but are beginning to discover problems and direct their own solutions. This is the very essence of engineering, recognizing a need, evaluating the need, applying technical knowledge to resolve the need, thus improving society.

The open-ended nature of this project allows students to push their limits of creativity and to more effectively learn circuits through genuine application of the concepts. Students often achieve a high level of personal accomplishment and take a great deal of pride in their project. This project results in a wide spectrum of products such as ice fishing tip-up alarms, laser activated burglar alarms, light follow circuits for solar panels, automatic cat feeders, entertaining games of skill with flashing lights and buzzers… the list goes on and on. Students are given six weeks for this project.

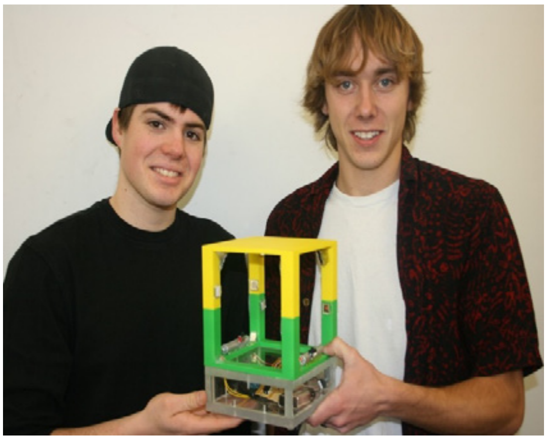

Fig 1: Laser beam protected Jewelry box alarm.

Fig 2: Salt dispensing snow shovel.

Submarine Flood Alarm Project – Digital Logic Class

The earlier part of this author's life was served on a submarine. So this project is modeled after the flood alarm system found onboard a naval submarine. The project is pitched to the students as a government contract their company is trying to win. The contract is to design a flood alarm system that will be used on all Navy and Coast Guard ships to be operated in saltwater and freshwater. Students are to design, build and test all physical and electrical components. The alarm system is to include a caution alarm and a danger alarm. The caution alarm activates at a lower water level. The alarm system requires both a loud auditory alarm and a flashing yellow light. It should also have a cutout switch which will silence the auditory alarm but also line up a circuit to sound the auditory alarm again if the cutout switch is still activated after the water level has lowered. The danger alarm activates at a higher water level but all of the other features are exactly the same as the caution alarm. This helps provide the redundancy required for any piece of safety equipment on a naval ship.

At the start of this project students are taught the basic logic gates (invertor, And, Or, Nand, Nor, Xor, Xnor). They are encouraged to use these gates to solve this problem. They will also have to use past knowledge to build the 555 astable circuits to drive the auditory alarms and the flashing lights. For the design of the actual flood sensor they are given a 5 gallon bucket along with Styrofoam, wood dowels, aluminum foil, steel washers, PVC piping and wire. Students are encouraged to build their own switches for this project. Switches can be easily built using the supplies provided. Students will need to be taught how to use pull-up and pull-down resistors to send a high or low when a switch is open or closed.

This project provides a very student centered way to teach logic gates. Often the process of learning digital logic gates involves more of an exercise in memorization and a quiz. This project forces students to think about problem needs and how and which combination of logic gates could match those requirements. In addition, students are required to build their own sensor. The problem of measuring water level will require students to figure out how to change a rising float into an electrical voltage than can be understood by a digital logic chip. This project also requires students to recall old knowledge and combine it with new knowledge to solve a very open ended problem. The 555 timer circuit in astable configuration will need to be applied to create the alarm tone and the flashing LEDs.

Grading is based on reliability of operation and creativity of circuit and flotation construction. Each group is asked to present and explain their circuit operation for the class. Students are given one week for this project.

Fig 3: Flotation system

Fig 4: Flotation and circuit

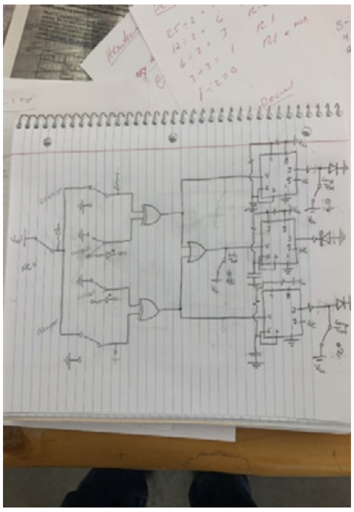

Fig 5: Submarine alarm circuit

Motor Design Project - Circuits II

Students are to design, build and test either a DC motor or a brushless motor. They are given magnets, magnetic wire, copper tubing, wood, steel rod and access to 3D-printers, laser cutters and a machine shop. Prior to the project students are taught concepts of DC motor and brushless motor operation including magnetism, split ring commutators, brushes, electronic speed controllers and 3 phase generation. Students are given the opportunity to reverse engineer a number of manufactured motors. This allows them to see a number of different designs, appreciate quality manufacturing and to learn what has already been done in motor design. It is important to supply students with quality magnets either neodymium magnets or industrial size and strength magnets. Good quality magnets will more easily allow students to have success even if their rotor winding tolerances are not very good. It is valuable to maintain a few student motors from previous years. This seems to result in steady improvement in student designs from year-to-year. The students benefit from the larger sized three dimensional example to help them visualize their own projects. Evaluation is based on the creativity of design, quality of manufacturing and the maximum RPM attained by their motor. Students are given 6 weeks for the project.

The author has only been using this design project for about 3 years, but what is truly inspiring is how many of the students will try to improve on manufactured motor design. Their quality of production may not be quite as good as a store bought motor but they will often push themselves to try out new and different ideas than what they have seen in any other motor. The variety, originality and quality of student designs is impressive. It becomes obvious why employers want to hire young engineers - they have endless energy, think differently and don't accept the status-quo.

Fig 6: A few DC motor designs.

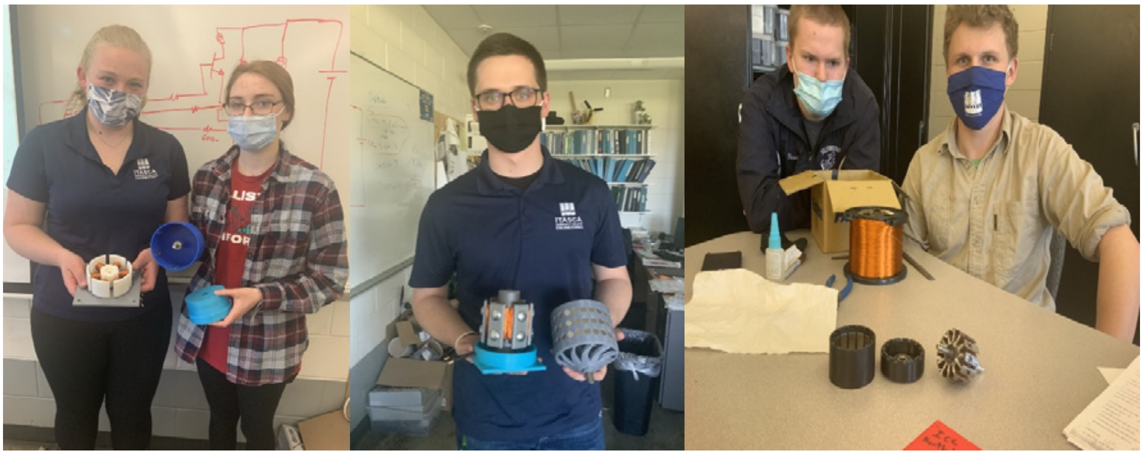

Fig 7: A few different brushless motors.

ADDITIONAL THOUGHTS ON DESIGN BASED LEARNING

Design-based projects provide an enhanced opportunity for critical thinking, application of technical concepts, and practical experience. So, it is wise to consider the balance of the project framework. For example, too many constraints may limit how far the student can explore the boundaries. Consequently, students lose the educational benefits of discovering for themselves what the natural limits are. Similarly, if no parameters are imposed, students may lack direction and project scope. This can significantly impact motivation for the in-experienced student. Furthermore, it is this author's belief, that in the first two years of an engineering education it is important to give students as much personal hands on experience as possible. In the case of a young electrical engineer this time is critical in developing the experience, comfort, conceptual understandings and electrical instincts that will be their foundation for all the electrical concepts that follow. Consequently, with the exception of the battery project, the projects presented here are limited to 1-2 students in a group. This will more guarantee each student has full involvement in the project. In regards to developing the skills of working in a larger group, there is plenty of time to provide these opportunities in the third and fourth years of their education. The emphasize in the first two years needs to be foundational concepts, hands on experience, opportunities to act on their ideas and inspiration in their chosen field of study; best accomplished in the small group environment.

One of the significant outcomes noted in using the design-based projects in electrical engineering classes is the improved ability of students to troubleshoot electrical circuits. The circuits that students are building are complex enough that invariably they will make a wiring error or one of the components will fail. Either way, at some point, usually in Circuits 1, they will have to troubleshoot the problem. Around this time, a short lesson on the fundamentals of troubleshooting is taught. It is a step by step summary of how to narrow down and isolate the problem. It is part Art, part Science to efficiently troubleshoot a circuit. Letting the student struggle to find the problem is beneficial for a while but at some point it is more effective for the instructor to work with the student to demonstrate proper use of test equipment to troubleshoot the problem. One good one-on-one training session is usually all it takes. Then the next time there is a problem, students have the confidence, knowledge and experience to figure it out on their own. The process has been very effective at developing one of a young engineer's most valuable skills, the ability to troubleshoot a problem!
Design-based projects take time and balance. Allowing occasional in-class time for working on the project allows the instructor to evaluate the process. Students also want to show their progress and occasionally ask instructor input. This is a normal human characteristic and part of the student's motivational needs. It is important for instructors to provide this access. It also allows you to keep track if students are having any difficulties that you did not anticipate.

A common instructor concern is, "How do you grade projects with the potential for so much variety?" Some instructors would feel most comfortable with a matrix with an itemized list of desired attributes and the appropriate score attached to each level of attainment. For this author the process is arguably more subjective. At the start of the project students are informed that their grade will be based on quality of manufacturing, originality of design ideas, complexity of final circuit design and professionalism of group presentation. This author then relies upon experience to assign the appropriate grade with feedback to the student on positives and negatives of their total design experience. One thing to keep in mind is that no two groups will be the same. One group may have a fairly simple design but spend a large amount of time and energy creating a very finished project with a high level of manufacturing. Another group may spend their time and creativity solving a much more complex electrical challenge but then not have as a high a quality of manufacturing in their finished project. Both groups benefitted and grew from the experience and in this author's opinion have the potential of still getting high marks. Also keep in mind that with this style of teaching there is often much more learning that occurs than what may be seen in the final project. Be sure to have students share their failures and struggles in their final presentation to the class. As much learning happens through one's failed ideas as during one's successful ideas. Whatever grading scale you decide to impose, the most important thing is that you never let the fear of how you will grade the assignment prevent you from challenging your students with a design project. Your students will thank you for the opportunity!

CONCLUSION

Looking forward, the author intends to survey students to more accurately evaluate success of design based learning. Student feedback will also aid in improving these projects. In addition, sharing these ideas with other professionals should aid in even further improvement. Each of the projects presented here have gone through numerous iterations. Constructing a good design project for students takes time and often takes numerous modifications. Evaluating the success and sustainability of a design project from year-to-year raises several questions:

1) What is to be gained by keeping or slightly modifying the current project?
2) What is to be gained by establishing a rotation of projects?
3) What significant improvements could be gained by more timely observation of student progress as well as student feedback on the difficulties they're facing?

Sheppard's characterization of what engineers do is especially relevant to design based learning: engineers "scope, generate, evaluate, and realize ideas" [6]. This focuses in on how engineers think and embraces the heart of the design process by highlighting the creation, assessment, selection, and the making or bringing to life of ideas[8]. The design- based learning approach provides an opportunity for metacognitive growth and naturally shifts the focus from teacher to student. This provides a catalyst for intrinsic motivation and genuine engineering skill development.

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A PLEA FOR CONNECTING DISCUSSION AND QUESTIONS TO THE COURSE MATERIAL

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Conference Key Areas: *Social aspects and communication in online/blended learning*
Keywords: *question and answer, social learning, educational technology*

ABSTRACT

Virtual learning environments offer a plethora of possibilities for discussion and Q&A (questions and answers). These discussions and questions are however most often placed in a "silo" separated from the actual course material. As a result, the discussion and questions are both from the perspective of the students and the teacher seen as separate entities. Connecting the discussion and Q&A to the actual course material (handbook, slides, solutions of exercises) opens up interesting opportunities: students can immediately see a discussion that digs deeper on the course material, or can see a clarification provided by the teacher or a peer student. But does the connection between discussion and Q&A and the course material also come at a cost? What platforms offer such connections?

This paper presents an analysis of the pros and cons of connecting discussion and Q&A to course material in interactive courseware platforms to create online learning communities. This analysis is based on desk-research and on case studies in three engineering courses where the Q&A around the model solution of the exam or the discussion on course material was placed on an interactive courseware platform in two different platforms, Perusall and Nextbook, allowing social annotation and discussion directly on the course material.

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1 INTRODUCTION, THEORETICAL UNDERPINNING AND CONTEXT

Social constructivism is a sociological theory in educational sciences that states that knowledge is constructed through interaction with others and that human development in general is socially situated [1]. This is supported by different researches that found that students' understanding of material is higher when it has been subject of discussion with others. While active discussion is related to better understanding according to social constructivism and has also shown to be related to higher academic achievement [2], a high proportion of the students does not access or post to online discussion platforms [2]. Any measure that results in a higher participation of students to the online discussion is therefore promising. The specific idea explored in this paper is to connect the discussion directly to the courseware, i.e. to augment the course material with a discussion functionality. Such courseware is often referred to as **interactive courseware:** course material augmented with interactive elements that allow users to interact with the course material (e.g. highlighting, commenting, editing, liking) or with other users in the context of social learning (e.g. discussing, asking questions). **Online learning communities**, a more general perspective than interactive courseware, refer to virtual learning platforms where social learning communities can be built and therefore provide an environment where learners and teachers can build knowledge interactively or collaboratively. Moreover, online learning communities can stimulate help-seeking and help-providing behavior of students.

Discussion is one of the most widely used aspects in online learning communities. Newer educational technology provides new social learning features such as online annotation and joint reading. Miller et al. [3] provide a nice overview of studies showing that social annotation increases student learning across many different education settings. Moreover, they add evidence themselves on the increased academic achievement in a course supported by the social annotation platform Perusall.

A particular opportunity of online learning communities and interactive courseware is that they accommodate for **asynchronous social learning**: online discussion fora for instance allow users to post questions, engage in a discussion, or reply to questions at any time and from any place. This asynchronicity has proven to be a particular supportive feature in the fully online or blended modus of teaching and learning that higher education institutions were forced in due to covid-19 in 2020 and 2021.

This paper focuses on three exploratory cases of the introduction of interactive courseware to help connect discussion and Q&A to course material. The cases were executed at KU Leuven in Flanders, Belgium. KU Leuven is a highly ranked research-intensive university both regarding research and education. The three courses discussed in this paper are a first-year bachelor course in engineering mechanics (Applied Mechanics, part 1), a second-year bachelor course in engineering mechanics (Applied Mechanics, part 3 regarding matrix- and vector methods for three dimensional kinematics and statics), and a master after master course in artificial intelligence (Uncertainty in Artificial Intelligence). Applied Mechanics, part 1 is a course with around 700 engineering and engineering architecture students, with a low success rate (around 40%). Applied Mechanics, part 3 is a course with a small number of students, this year 12 students with a medium success rate (60%). Uncertainty in Artificial Intelligence is a medium-size course (250 students) with high success rate (85%).

In this paper we will discuss the platforms used and the implementation of the social interaction in three courses (Section 2), present our findings from the three cases together with three recommendations (Section 3), and a conclusion (Section 4).

2 PLATFORMS AND IMPLEMENTATION

In the context of the Erasmus+ project Co-created Interactive Courseware (CiC), we explore the new interactive courseware platform Nextbook (www.nextbook.be) and develop pedagogical use cases, teachers guides, and learning analytics to support the use of interactive courseware on Nextbook and in general. In this paper we present our first experiences of using two platforms for interactive courseware to support asynchronous discussion directly connected to the courseware.

Beside the new platform Nextbook, a main actor in the CiC project, we used the longer existing and already established Perusall platform (https://perusall.com/). Below we shortly discuss the platforms and show how the platforms were used in our case studies.

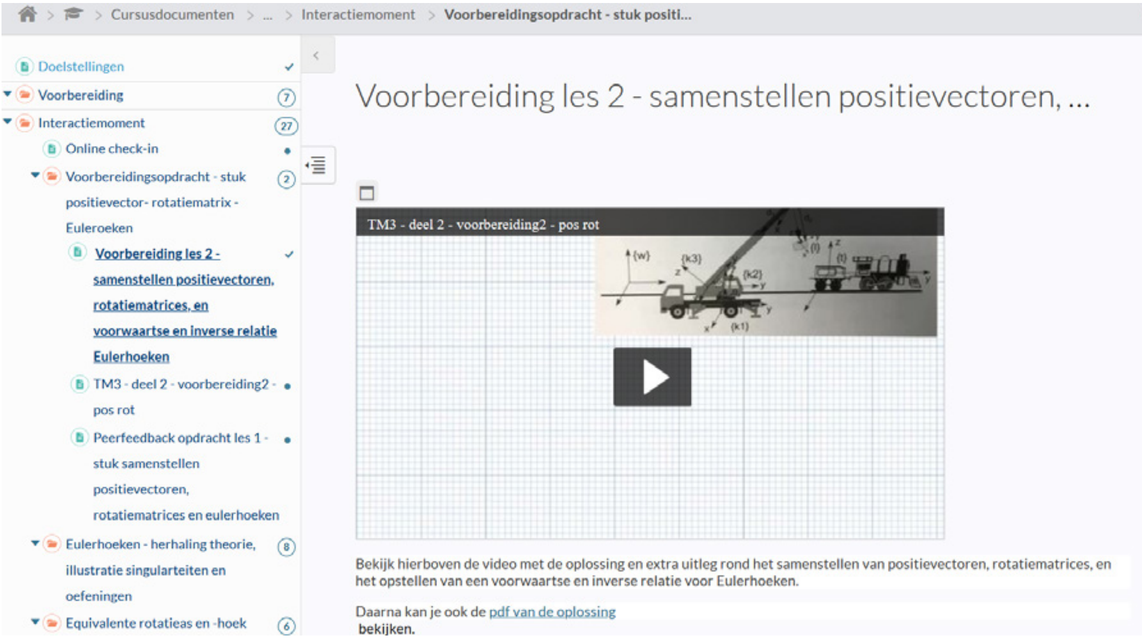

Figure 1: Example of Learning Pathway offered in Toledo, a blackboard-based Virtual Learning Environment, for Applied mechanics, part 3.

2.1.1 Perusall

Perusall (https://perusall.com/) is a free, online platform for "social reading" of textbooks. Teachers create an online course on Perusall and can populate the library of that course with their material (books from the Perusall catalog, web pages, own textbooks or documents, video or podcasts). Next, teachers create assignments on

the material in the library, with optional deadlines, grading, and anonymization. In the assignments, students can asynchronously ask or answer questions, comment, or discuss on the material connected to the assignment. To this end they select a particular text, formula, or picture and start a chat. Other students can see the question or comment, upvote it, or respond to it. Perusall offers Learning Tools Interoperability (LTI) integration, allowing it to integrate easily with most Virtual Learning Environments.
Perusall has been the subject of different scientific studies, which indicated that use of Perusall in flipped teaching is linked to higher academic achievement [3], increases social interactions during the course and peer-to-peer interactions in particular [4], and that automated scoring of interactions offered by Perusall is perceived positively by students and is similar to teacher scores [5].

2.1.2 Blended and flipped course with Perusall

Perusall was introduced in the course Applied Mechanics, part 3 in the second semester of academic year 2020-2021, when the university was forced to offer fully online education due to the covid-19 pandemic. The course uses a flipped teaching format where each four-hour long teaching slot is preceded by a flipped teaching task. The course was constructed using learning pathways in Toledo, the blackboard-based Virtual Learning Environment of the university (Figure 1).

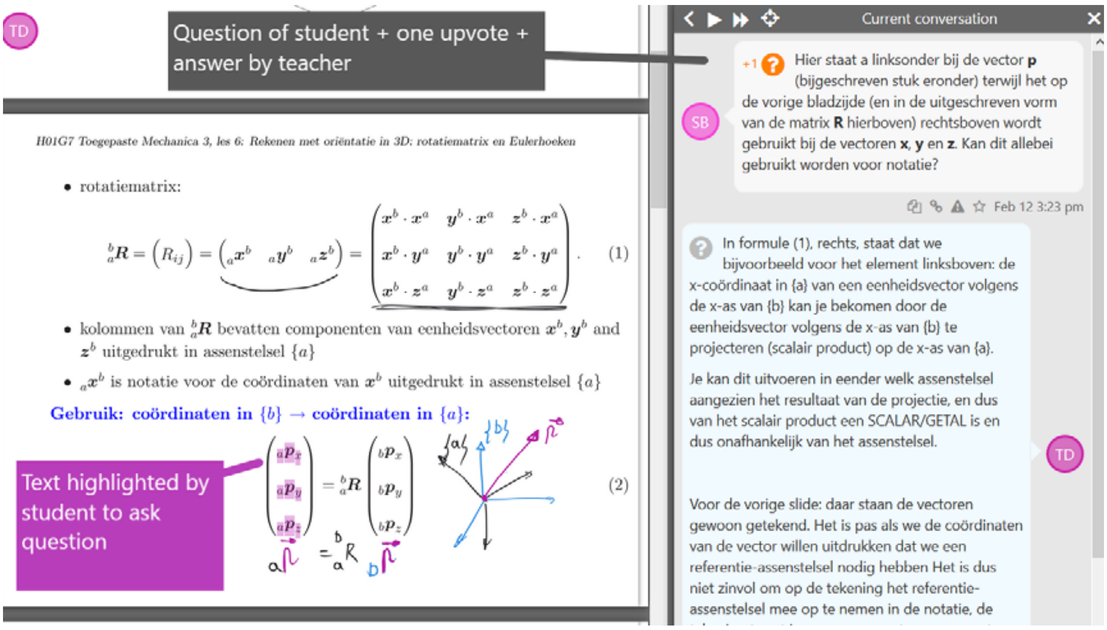

Figure 2: Perusall at work as a platform to ask questions during a blended and flipped course.

The flipped teaching task consisted of two or three short theoretical videos, reading of the textbook sections connected to these videos, and the solving of an exercise. Students could ask questions or start a discussion while preparing as the material was, besides being available on the Virtual Learning Environment, also made available in Perusall (Figure 2). The four-hour long teaching slot was started with an online “check-in” session in Microsoft Teams, where the teacher explained the “big picture" and the goals of the interactive session and then proceeded with answering the questions that students asked in Perusall or that they asked during the check-in. The remaining time of the four-hour teaching slot consisted of four slots with each 45 minutes independent work of the students, where they follow the learning pathway and in the meanwhile can ask discussion in Perusall, and around 10 minute-long interactive video calls in Microsoft Teams where questions were answered and progress was discussed.

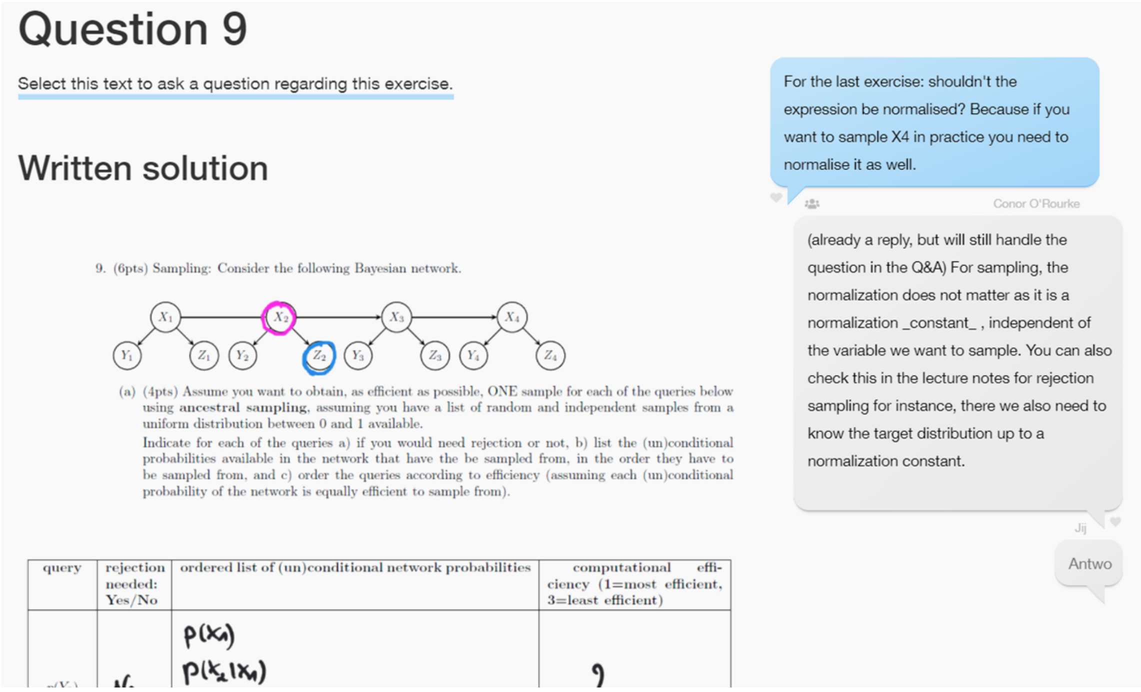

Figure 3: Nextbook at work to ask questions on the model solution of the exam to prepare for the Q&A session after the exam.

2.1.3 Nextbook

Nextbook (http://nextbook.be) is a free, online platform for "social reading" of textbooks, which envisions social construction (co-creation) in the future. Teachers can upload their textbook, augmented with video, 3D models, quizzes, etc. This augmented textbook immediately serves as a basis for social learning. Nextbook offers flexible reading on any platform as the book is transformed using web technology offering automatic scaling, free choice of font and text size, dark mode, etc. It also has functionality for reading out loud, a nice supplement on top of a dyslexia-friendly font for students with reading disabilities or challenges. Students can use highlights to mark important parts and even generate automatic summaries from these highlights. They can also add personal notes for later reference. From the social interaction point of view, they can select part of the text, image, formulate, … and start a discussion from this or ask a question. Questions or comments can be responded to in a chat-like manner and liked (up-voted).

2.1.4 Q&A after exam with Nextbook

In the courses of Applied Mechanics, part 1 and Uncertainty in Artificial Intelligence a Q&A opportunity is offered to student as part of the feedback after the exam of the course. To this end, for both courses the model solution for the exam was uploaded on Nextbook such that students could directly ask questions on this model solution. In the case of Uncertainty in Artificial Intelligence this was the preparation for an online live Q&A session where the teachers would more elaborately respond to the questions of students. Figure 3 shows a view of one of the exam questions and a question of a student, and the response of a teacher.

3 FINDINGS

We discuss the findings below using four categories: use and social learning, seeing discussion while learning, integration with the virtual learning environment, and overview for the teacher. For each category we present a recommendation.

3.1 Use and social learning

From the **teacher-perspective** both Perusall and Nextbook are rather user-friendly tools. Perusall relies on assignments, which makes it more time-consuming to configure. Nextbook on the other hand only requires the uploading of the course material and is then ready to go. From the **student-perspective** Nextbook appears to be more up to date than Perusall and Nextbook seems more intuitive to immediately start a chat. Neither platform triggered questions of students on how to use them.

Actual adoption of the platform for asking questions and initiating discussion was very disappointing in all three cases. For Applied Mechanics, part 3 (Perusall) students asked few questions anyway: both in the Perusall platform and in the live online video calls. If questions were asked, no other students interacted with the question (answering of upvoting). For Applied Mechanics, part 1 (Nextbook) only a minority of the students even entered the Nextbook platform, possibly because they could already see the model solution during the on-campus exam feedback and in a pdf in the Virtual Learning Environment. Therefore, the only reason to open the model solution was to ask any remaining questions. Moreover, as was also the case in the other course, students were already using the discussion forum from the Virtual Learning Environment as a discussion tool to which they were accustomed in the meanwhile. For Uncertainty in Artificial Intelligence (Nextbook), more students entered the Nextbook platform as this was the only way to see the model solution. From these students however, again a minority took the opportunity to ask a question, and these questions were not interacted with by the other students (upvoting, responding).

From our three cases we can only learn that social interaction connected to course material is no free lunch: it does not happen spontaneously especially if it is not offered throughout the entire course.

Our recommendation is that the pedagogical approach should focus on integrating the interactive courseware from the beginning of the course and stimulating the discussion in the platform.

3.2 Seeing discussion while learning

A potential advantage of the interactive courseware is that students can immediately see the discussion or other students' questions and (teacher) responses while studying the material. We were not able to harvest this potential advantage in our cases as in two courses the material was just the model solution of the exam, and for the other case the material was duplicated on the Virtual Learning Environment in the learning pathway. This choice was made in order to keep the learning material (and hereby also students) in the learning pathway (Figure 1) as much as possible. Therefore, students were only directed to Perusall in case of questions. We observed that students that do not have questions do not enter Perusall to browse for other students' questions and possible (teacher) replies.

Our recommendation is that the learning material should be natively offered in the interactive courseware platform, rather than being a duplicate from the material already offered on the Virtual Learning Environment. Otherwise, students will lack the social dimension while studying the material.

3.3 Integration with the virtual learning environment

Both Perusall and Nextbook are easy to integrate with the Virtual Learning Environment over LTI-integration, which allows the student to navigate from the Virtual Learning Environment to the Perusall and Nextbook environment using a simple link without requiring a new login (after the registration and login was done once). This click-through however causes students, both in the case of Perusall and Nextbook, to leave the Virtual Learning Environment and enter the social learning environment. This is seamless, but still an additional click and a potential point to ""lose"" the student.

Our recommendation is that the pedagogical approach and the interactive courseware platforms should be better integrated with the Virtual Learning Environments. Rather than redirecting students entirely the external platforms, the interactive elements should be part of the other learning elements in the Virtual Learning Environment, allowing teachers to compose learning pathways that blend together different types of didactical elements (interactive courseware, quiz, assignment, peer feedback, etc.).

3.4 Overview for teacher

A particular advantage of both Perusall and Nextbook is the "overview" of the discussion that is directly connected to the course material. This is a clear advantage over traditional discussion fora where this overview is typically lost. The overview comes in particularly handy when preparing for a Q&A session in the context of flipped-teaching or exam feedback. Moreover, when improving the course material for the next semester or academic year, it is easier to browse through the material and immediately see the intensively discussed parts, which for instance potentially require clarification or elaboration.

Our recommendation is to use interactive courseware platforms to increase the surveyability and structure of students' questions and discussions, supporting preparation of interactive Q&A sessions and discussions, and future improvements of course materials.

4 CONCLUSION

Interactive courseware has a large potential considering the theory of social-constructivisms and the available research evidence presenting a link between higher social engagement and academic achievement. The cases in this paper however show that despite that potential, the gains of interactive courseware platforms do not come easily. To realize its potential the interactive courseware must be well-integrated with the main Virtual Learning Environment and the learning material should not be duplicated to prevent students from missing out the social dimension of the discussion and questions and answers. The free lunch that comes along with the interactive courseware is the increased surveyability and structure of students' questions and discussions supporting teachers in preparing their (flipped) teaching interactions and improving their teaching materials.

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A GUIDE TO IMPLEMENTING ONLINE SIMULATIONS USING HTML, JAVASCRIPT AND SVG

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Conference Key Areas: *Open and online education, Engineering skills*
Keywords: *Online interactive simulation*

ABSTRACT

Online simulations created using HTML, JavaScript and SVG images can be accessed by any end user with a web browser, making them widely accessible and compatible with computers running Microsoft, macOS or Linux-based operating systems. This paper outlines the methods and tools used by the authors to create interactive online educational simulations using these core web technologies.

Three example simulations are referred to throughout the paper: A 'bare-bones' example which is used to highlight the key components of these type of simulations; a second example serves as template for more complex simulations; finally, an implementation of an oscilloscope, an electrical device typically used by electrical engineering undergraduates throughout their degree programmes, is used as a practical working example, which has proven popular with a global community of students and educators.

The paper is intended as a resource to assist educators developing simulations using similar techniques. The authors share their experiences in developing the simulations and provide links to relevant videos, resources, and tools.

1 INTRODUCTION

Online simulations can help students learn new skills by providing them with an opportunity to practice using equipment at a convenient time and location [1]. They can also allow students gain an understanding of the operation of equipment safely and without being concerned with damaging it or being exposed to the potential social anxiety of being observed using equipment incorrectly by peers and mentors.

The interactive online simulation of an oscilloscope available at [2] (see Fig. 1) is ranked at the top of Google's search engine for the term "Online Oscilloscope" and similar terms. It has received positive comments and feedback through its companion YouTube video tutorial and is accessed approximately 3,500 times per week (March 2020).

This simulation was developed using the core web technologies of HTML, CSS and JavaScript, which are widely used and are supported across a global community of developers. There are many introductory tutorials available which can assist inexperienced developers make progress relatively quickly. The authors recommend [3] as a learning resource for inexperienced newcomers, which provides a straightforward method of learning-by-doing in an interactive manner.

One of the benefits of using HTML, CSS and JavaScript is that users only require a modern browser to run the simulation, making it globally accessible without the need for end users to install any additional software. Any simulation developed using these core web technologies can be deployed on computers running Microsoft, macOS or Linux-based operating systems which overcomes issues associated with students having different OS preferences.

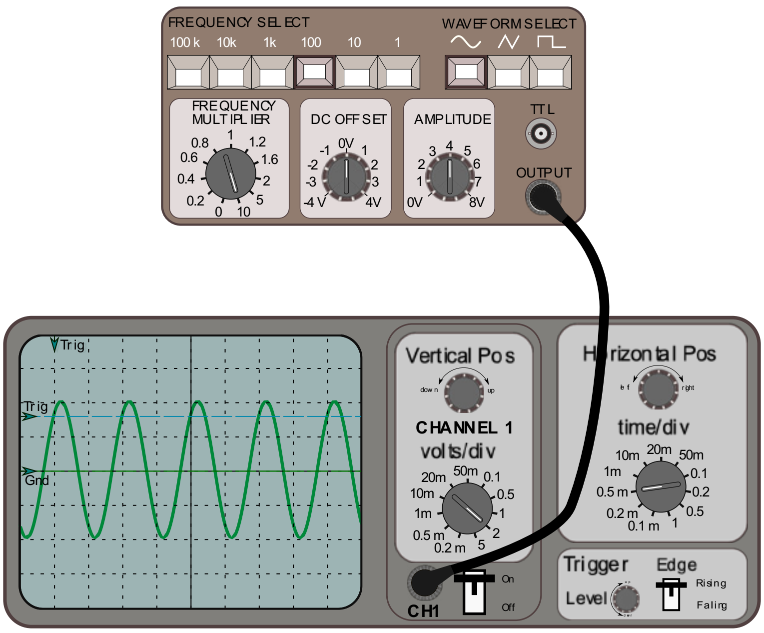

Fig. 1. Online Oscilloscope and Signal Generator interface from [2]

Another important feature of the simulation is that it makes use of SVG images. SVG images are scalable, which means that end users can "zoom-in" the simulation images without loss of image resolution or quality. This is particularly important for simulations that contain fine detail and contrasts with traditional web image formats such as JPEG and GIF, which are not scalable (see Fig. 2). SVG images can also be interactive and can be created to allow users change properties of the image by clicking on or dragging elements, for example. Another aspect of SVG images is that they are text-based (as shown in the 'bare bones' example below), so they can be edited using any non-proprietary text editor. The text-based aspect is also of potential benefit to those with some programming experience since image elements could be created conveniently through code.

It's worth noting that browser support for SVG images is relatively recent and that browsers pre-dating 2018 may not fully support these types of images. SVG images also tend to render more slowly in a browser than JPEG and GIF, an experience that can be noticeable to an end user, particularly for large files.

During the design and implementation phases of the simulation Notepad++ (a text editor) and Inkscape (an SVG editor) were used by the authors, both of which are free and open-source software applications. The remainder of this document provides three examples which provide insight into the creation of online simulation tools.

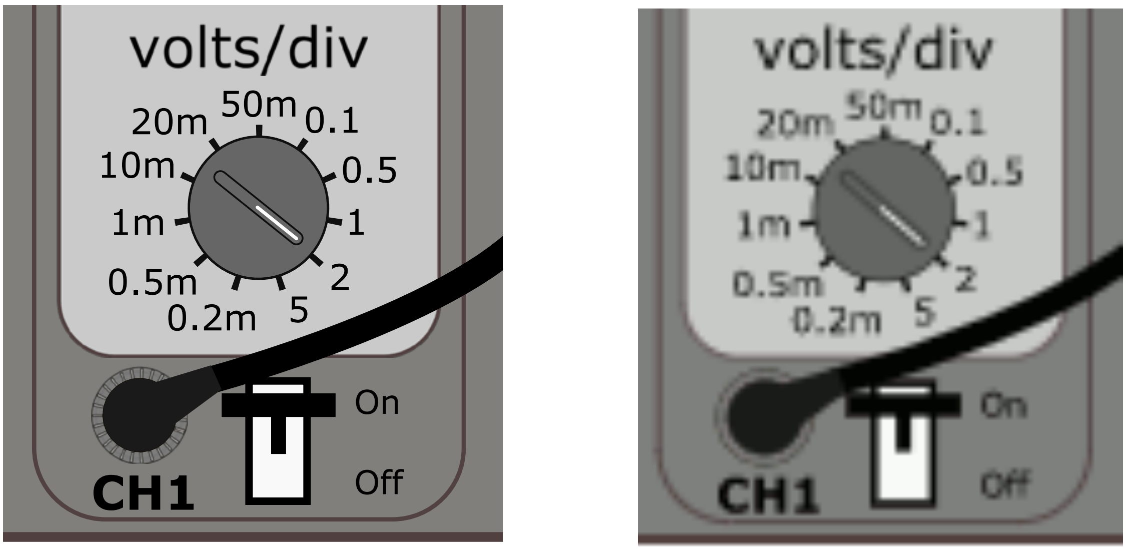

Fig. 2. Effect of 'zooming-in' in on a scalable SVG image (left) compared with a GIF image (right)

2 A 'BARE-BONES' EXAMPLE

Interactive simulations react to end user actions such as mouse clicking and dragging events. The 'bare-bones' example code shown below creates a web page containing an SVG image of a red square, if the end user clicks on the square it will turn blue (see [4] for an online demonstration). The purpose of this example is to introduce the reader to the key components of more complex examples referred to in the remainder of this document.

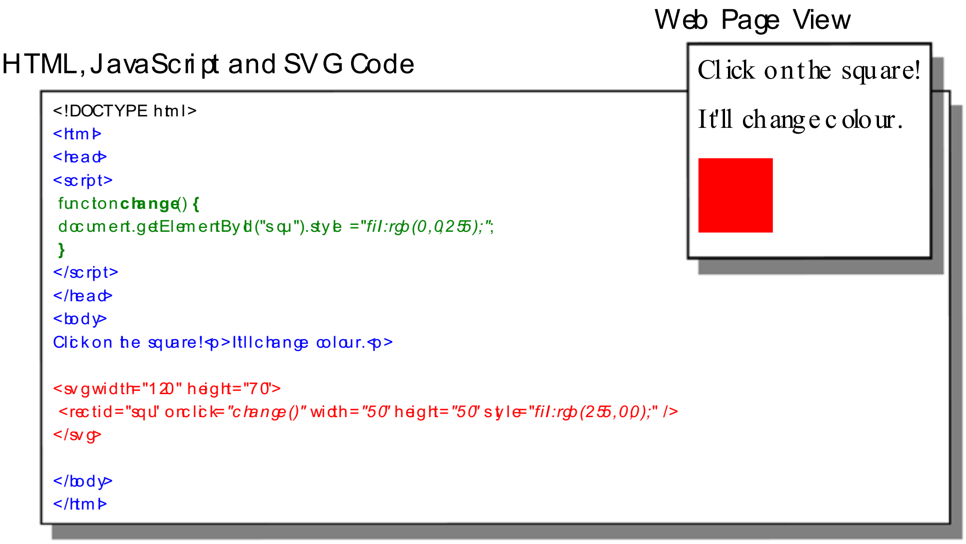

Fig. 3. 'Bare-bones' code with rendered web page output shown on the top right

An interested reader can copy this code into a text editor and save the file as an HTML file, as shown in the video demonstration available at [4], in order to explore its operation further. Changing the width and height attributes of the SVG image may be useful exercise to begin with. Note that a full explanation of the code is outside the scope of this document, the intention here is to provide a brief summary that may serve to pique the reader's interest and encourage further exploration.

Referring to the code above, both the JavaScript (green text) and SVG (red text) is contained within the HTML (blue text). JavaScript is used to add functionality to the example, in other words it provides the means to react to the end user's actions. SVG is used to create the image elements. In this example a red square element is created by inclusion of the following line, which is referred to as a rect SVG **element**:

<rect id=*"squ"* onclick=*"change()"* width=*"50"* height=*"50"* style="fill:rgb(255,0,0);" />

The rect SVG **element** is used to create a rectangle **element** and this example **element** has five **attributes** associated with it: id, onclick, width, height and style. The style **attribute** has a value *"fill:rgb(255,0,0);"* which fills in the square element with the colour described using the RGB colour model. The acronym RGB represents Red, Green, Blue. In this example, the fill colour is 255 parts red, 0 parts green and 0 parts blue.

The id **attribute** has a value *"squ"*. This value should be unique within the simulation code and is chosen by the developer (the author of the code). By setting the onclick **attribute** to the value *"change()"* the JavaScript function change() is executed when the end user clicks on the square. The JavaScript function change() updates the style **attribute** of the SVG element with the id **attribute** *"squ"* to "fill:rgb(0,0,255);", making the fill colour 0 parts red, 0 parts green and 255 parts blue. If the onclick **attribute** is removed then the image will no longer be interactive.

3 A SECOND EXAMPLE

While an SVG image can be created using any text editor, in practice images are generally created using SVG editors, which provide a user-friendly means to drag and drop elements onto a drawing. Figure 4, below, shows the SVG image from a second example which is available online at [4]. In this example the end user can select one of two shapes to be displayed in the left panel. The end user can also rotate and scale the shape selected using a dial and slider. A video available at [4] demonstrates how this second example was created which includes the steps requires to create the SVG image using Inkscape and the process of coding in JavaScript.

The purpose of this example is to provide the reader with a template to explore the additional functionality available to a prospective developer. The full code can be viewed by accessing [4] and viewing the source of the web page (use the search engine of your choice to discover how to do this within your chosen web browser). The code follows a similar layout to the 'bare-bones' example provided but the SVG image is over 350 lines and there are about 100 lines of JavaScript, making it impractical to present here.

The key steps involved in creating the simulation are:

1. Design the user interface using an SVG editor (e.g. Inkscape)
2. Copy the SVG text into the HTML file (see 'bare-bones' example)
3. Write JavaScript code to implement user functionality
4. Test using a variety of browsers and platforms (see section 5 for more detail)

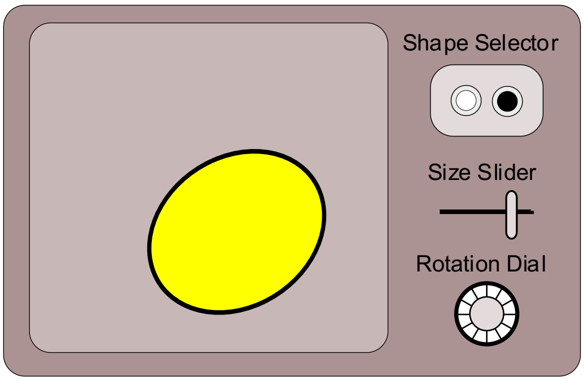

Fig. 4. User interface for a second example simulation

Inkscape has many drawing features and can take considerable time to master, however there are a few features that the authors relied on heavily during the development of the online oscilloscope. An overview of these features is provided in the video demonstration available at [4].

Being able to take full advantage of JavaScript requires programming experience, however with the wide availability of online examples the overhead in developing applications can be considerably reduced. When developing simulations it is important to be aware of the types of user actions and events that can trigger a JavaScript response. The key events utilised in the online oscilloscope simulation were:

- onclick – when a user clicks (presses and releases a mouse button) on an element
- onmouseover – when a users pointer is positioned over an element
- onmousemove – when a user moves their pointer over an element
- onmouseout – when a user moves their pointer away from an element
- onmousedown – when a user presses the mouse button down
- onmouseup – when a user releases the mouse button

4 ONLINE OSCILLOSCOPE DESIGN CONSIDERATIONS

There are a great deal of resources on designing user interfaces to achieve an optimal user experience [5]. The principals and best practices described in these resources should, of course, be borne in mind when developing any simulation. This section, however, places a focus on the design considerations specifically relating to the online oscilloscope with the intention of assisting developers who intend to design similar simulations.

During design phase of the online oscilloscope a priority was to present an interface that was quasi-realistic while at the same time being readily interpretable in an online 2-D context. One example where the design was adjusted to accommodate ease of interpretability can been seen in the case of the presentation of the 'Trigger' and Channel 'Switches' (see Figures 1 and 2). In an earlier version these switches where presented as buttons, similar to the 'Frequency Select' buttons shown on the waveform generator. These buttons would be more typical of the style used in modern oscilloscopes but the switches used in the final version indicate their state (on or off) more clearly in a flat 2-D context. Furthermore, the number of channels was restricted to one, and the options on the both the volts/div and time/div dials are less than would be found on modern devices. These steps were taken in favour of providing a more user-friendly interface.

Particular attention is required when considering elements of the interface that end users will interact with and how they will interact with them. For example, a decision was taken for users to rotate dials by clicking on the left side of the dial to rotate it in an anti-clockwise direction. To highlight this feature the left side of the dial is highlighted in red when the user hovers their mouse over the dial. Similarly, the right side of the dial is highlighted in green to indicate to the user that clicking will result in an action. A consequence of this decision is that additional image elements are required to highlight each side of the dial.

5 ADDITIONAL NOTES

In this section the authors wish to share some other experiences which may benefit developers create novel simulation tools.

The simulation should be tested on a variety of web browsers as browers can interpret/execute HTML, JavaScript and SVG in slightly different ways. It should also be noted that additional JavaScript code is required to make the simulations touchscreen compatible. The authors found [6] to be a useful resource to deal with issues relating to touchscreen devices.

It can be useful to convert SVG text elements to SVG path elements to prevent the text displayed on simulations being selectable. The authors converted all text elements to paths for the oscilloscope simulation as they found that users frequently and inadvertently selected text elements while interacting with the simulation prior to taking this step.

When using Inkscape to design the SVG user interface, developers should avoid editing the SVG mark up using a text editor as these modifications can be overwritten by the Inkscape editor if it is used again at a later stage. In particular, the authors recommend that JavaScript functions associated with SVG elements be only specified using the Object Properties feature, as shown in video demonstrations available at [4].

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COST EFFECTIVE ON-LINE MASTER THESIS FAIR

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Conference Key Areas: *Digital tools, Changes beyond Covid -19*
Keywords: *Virtual fair, Professional network, Master thesis, Corona, Industry relations*

ABSTRACT

Under corona restrictions it was expected to be extra hard to find an opportunity to do a master thesis in cooperation with a company as is the praxis in the investigated context. To mitigate this, a special master thesis fair was held in the area of Electric power engineering as most normally arranged fairs and other opportunities for the students to meet companies had been cancelled.

For economic and practical reasons was Zoom and the function on break-out room used. A two-hour event was held with 15 companies, consisting of a mix of local, national, and international companies. The companies were given a great freedom to act within their respective break-out room. Around three quarters of the second-year students, in a two-year program, attended as well as a few from the first year. Initially the students, especially the international, focused on the big and international companies, like Ericsson, ABB and Volvo Cars, but then they were also looking for opportunities at smaller local companies. This created some waiting times, both for the students and some of the small and less known companies.

Both the students and most of the companies were satisfied and it was clear that all wanted the arrangement to be repeated, some even if there would be no pandemic. The fair fulfilled its purpose but also gave insights on how future fairs, with limited economical resources, could be arranged, The recommendations are presented in form of a list at the end.

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1 INTRODUCTION

In year 2020, suddenly everything was different due to the Corona pandemic. Physical meetings in large gatherings were not allowed, but life had to continue anyway somehow. Most teaching at Chalmers were converted into distant teaching to prevent Corona spread. Cooperation with industry was also limited and turned into distant guest lectures or virtual study visits with very small possibilities to allow students and industry representatives to meet individually or in small groups.

In [1]–[5] it is stated that there are many benefits of cooperation between industry and academia in engineering education. Apart from the benefits in technical areas [1], it may also increase the sense of identity as future engineer [2] for the students as well as an improved self-efficacy for their future professional development both in lifelong learning and professional success [3]. In [4] was the idea presented that students' development of multidisciplinary skills may benefit through such cooperation. Also, companies may favour cooperation since working together on a thesis is a way to test a potential employee and to get questions answered that are not important enough to be funded internally. It might also create a connection to the university to get new ideas or knowledge, often more theoretical [3], [5]. In [4] digital tools are seen as a good way to increase cooperation since it gives a access to world class expertise at a low cost.

Improving their professional network is extra important for students that are close to graduation. Different types of fairs are well suited for expanding professional networks [6]. Normally, there are several career fairs arranged at Chalmers with different focuses, among others one in Electric power engineering, but not in 2020.

The transition into distant teaching required a great work effort for most of the teachers and therefore fairs needed to be arranged with minimal resources. Physical fairs will probably also play an important role also in the future but on-line fairs will be needed as a complement to increase accessibility, e.g. geographical [7] which is highly relevant for Swedish conditions. However, in [8] is it argued that virtual fairs, will become the preferred option in the future due to the possibilities for visibility and branding, costs and it is easier to evaluate due to access to metadata of the fair. However, there are several aspects that need to be considered when organising a fair with high student satisfaction. The identified success factors are apart from the organisation itself also exhibitor performance and pre-event services [9].

Doing a master thesis in cooperation with a company is one of the first ways for a student to utilize their professional network. It is a popular way for the students to both expand their professional network but also to get the first job [10]. It is for many students their first real occasion where they could put their newly gained theoretical knowledge to some practical use. It also give some experience on how it is to work as an engineer. At the investigated educational programme around 80 % of the students each year make their master project in close cooperation with industry.

The purpose of this study is to investigate if it is suitable to organize a master thesis fair in Zoom and to establish recommendation for future master thesis fairs under similar circumstance or to utilize the identified benefits. The target groups of this paper are teachers and administrators that need to create opportunities for students and their professional networking and are considering using a digital tool but have limited resources.

2 THE FAIR

The fair was organised on the 30th of September 2020 and had a clear focus on master thesis cooperation within the area of Electric power engineering. The date was approximalty three and a half months before the students are expected to start their thesis work. The fair was 2 hours long and organised by Chalmers. Only students from the master's program in Electric power engineering were invited as a way to limit the number of participating students since it was the number of students that was predicted to be the bottleneck in the flow during the fair.

The master's program in Electric power engineering at Chalmers is an international two-year program and currently has approximatly 50 students per year, where around 20 have a bachelor's degree from Chalmers.

Approximately 35 second year students and 5 first year students participated in the fair. International, national and local companies were invited to attend and 15 signed up, for example ABB, Volvo and Ericssson but also more local ones like Gothenburg Energy. The participating companies represented the categories; power utilities, design of electric drive systems, power components manufacturers, and consultancy firms.

To keep the cost low was Zoom used. The organiser arranged a meeting and then assigned each company a so-called breakout-room. This meant that the organiser had to direct each participant personally to the breakout-room of their choice. The number of participants in each breakout-room was limited to 10 persons.

3 EVALUATION METHOD

Two questionnaires were sent out, one to the students and one to the companies. The questionnaire for students started with question on how many companies they attended while the first question in the company questionnaire was regarding number of students that visited them. The last three questions were the same;

- How valuable were these visits for you?
- How well do think it was arranged?
- Do you think we should arrange this kind of fair next year?

The answers were all multiple choice and the options can be seen in Figure 1 to Figure 5. In addition, there were opportunities to send free text answers via mail to the organiser. Only 3 companies used this possibility. Observations were also done by the organiser.

As a follow up were the cooperation rate during the pandemic investigated and compared to the rate before. This was done by an investigation of whatever thesis works that were initiated were done in cooperation with a company or not. The students of the non-company related thesis works were approach individually for some follow up questions.

IV. OUTCOME

Approximately 60 % of the participating students answered the questionnaire and the number of companies each student meet can be seen in Figure 1.

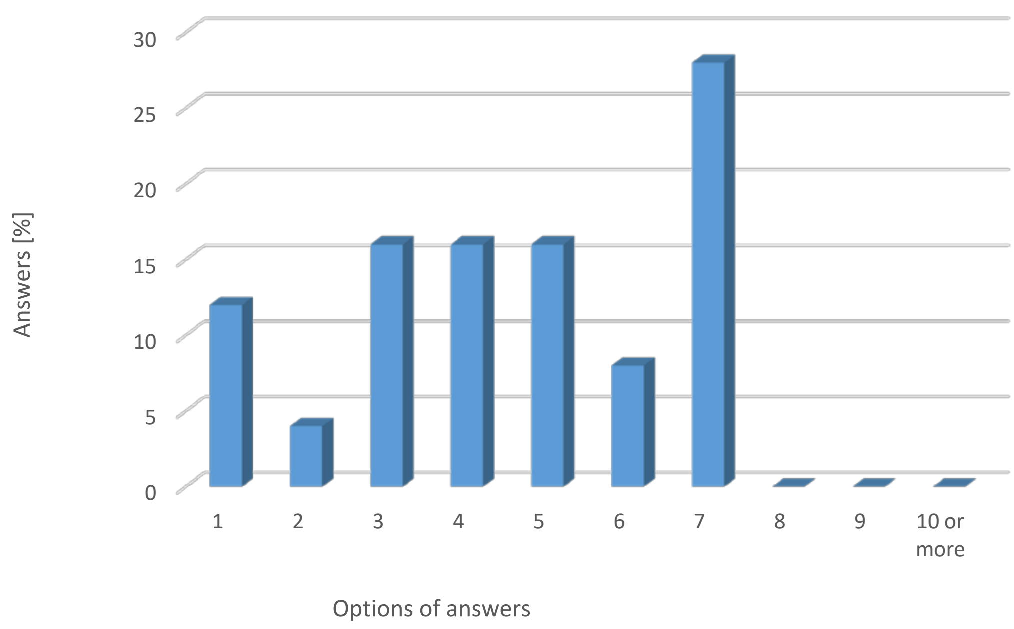

Figure 1. Number of companies each student meet during the two-hour fair.

In Figure 1, it can be seen that most students visited more than one company which indicates that the students were not focused on one meeting only.

Just above 85 % of the companies answered the questionnaire. Figure 2 shows the number of students that meet each company.

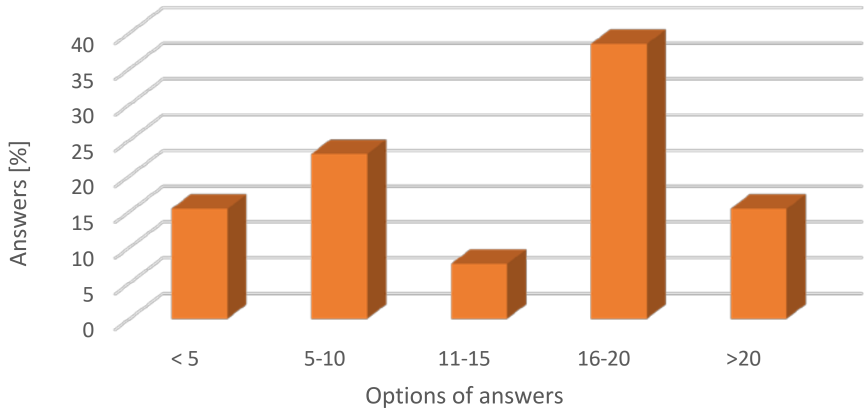

Figure 2. Number students that visited each company during the two-hour fair.

Some companies were more popular than others. It was mainly the large international companies while companies with less known brands where not that interesting in the beginning. One company did not get any visitor the first hour and then left the meeting. However, some students asked for the company after they had left.

In Figure 3 is the considered value of the fair shown.

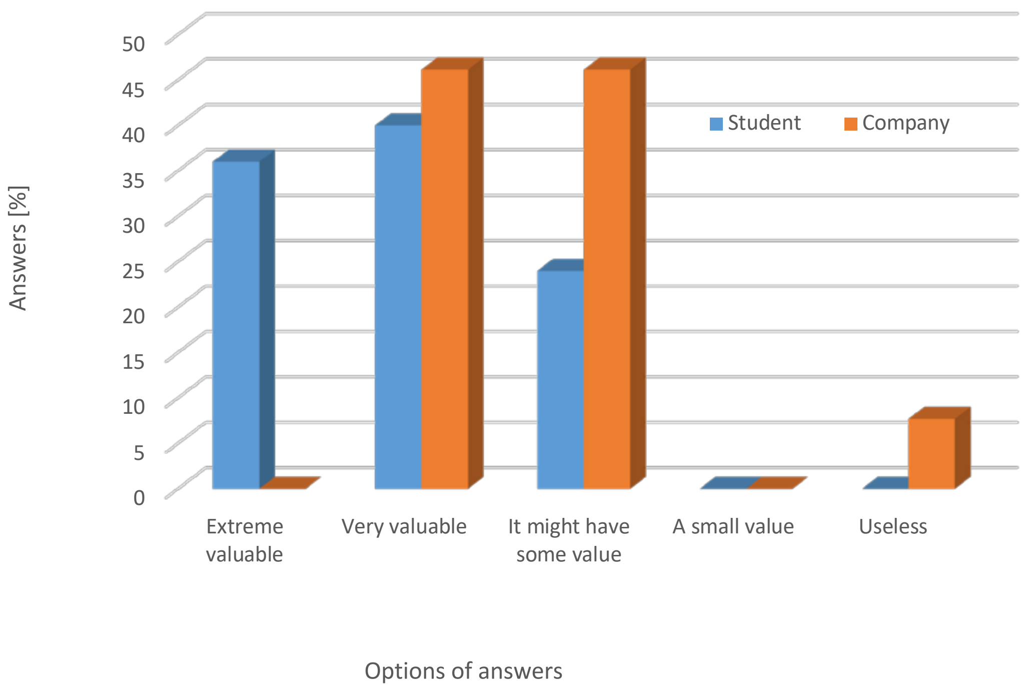

Figure 3 shows how valuable the students and the companies though the fair was.

Figure 3 shows how valuable the fair was considered to be by the students and the companies. The students thought the fair were more valuable than the companies did. The one answer ‘useless’ is likely explained by the fact that one company left before they had received any students in their room.

The third question was on how well the fair was organised and the answers of the students and companies can be seen in Figure 4.

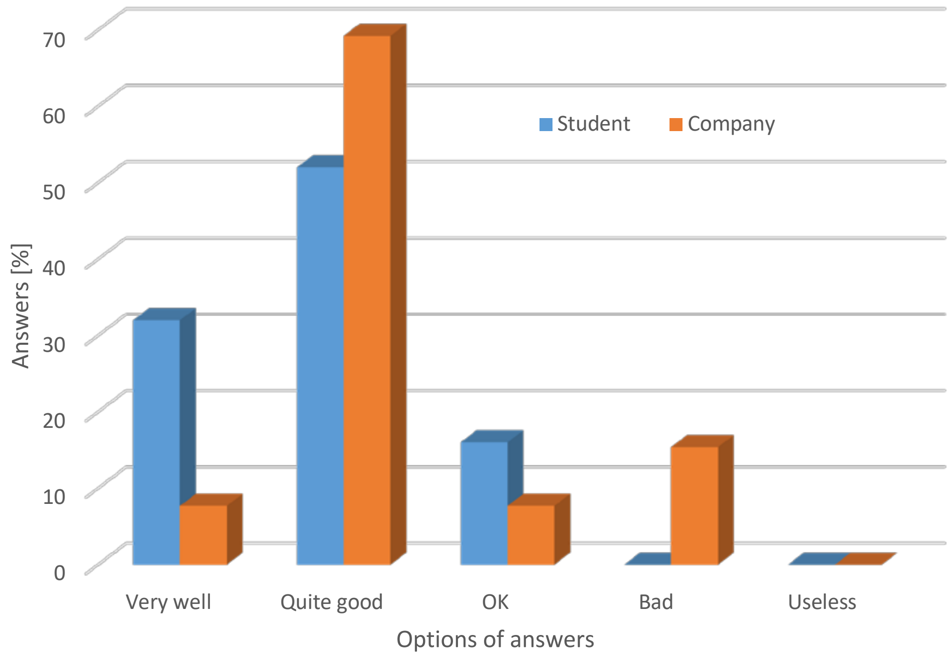

Figure 4. How well the students and the companies though it was organized.

The answers on organisation were more spread than the answers of the other questions. The situation for the organiser directing students was occasionally chaotic but after adapting a more direct approach for directing of the students, it went much smoother. The last question was whether the students and the companies wanted the fair to return next year and answers can be seen in Figure 5.

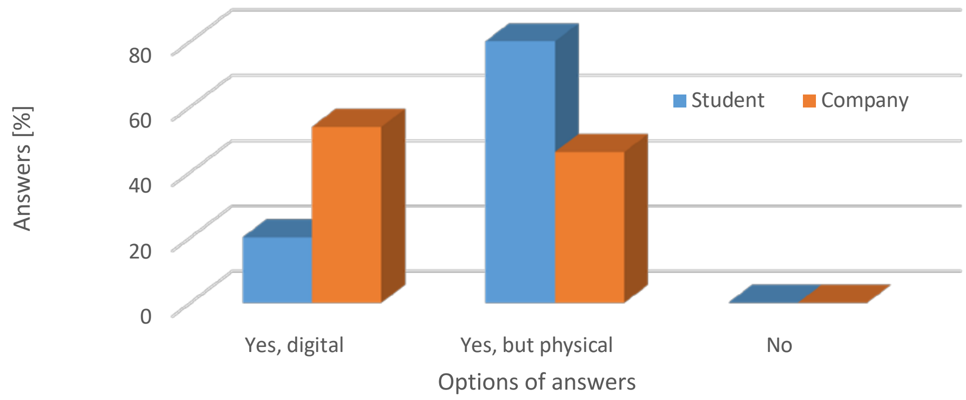

Figure 5. Answers on if the students and company representatives would like the event to return and it that case how.

All agreed that the fair should be repeated but how was more dispersed, as the students preferred a physical one while the companies were more eager to see another digital one.

Also 2021 around 80 % started their thesis work in cooperation with a company. However, most of the other students, that didn´t cooperate with a company, said that they tried to find a company but had a too specific project idea to find a suitable partner. Only one state that he could not find any possibility to cooperate with a company.

4 DISCUSSION

In general, the students were more positive to the fair than the companies. This may be explained by the fact that discussiing master thesis seems to be more urgent for an individual student than a company. The fair was probably extra valuable for the international students as their professional network in Sweden might be more limited than for the students with a domestic background.

The organisation seemed to be the weak link of the fair. The facts that the organiser had to personally direct all students to the different breakout rooms which created some frustration. However after the fair, an option for the students to join break-out rooms themselves was added to Zoom. Some companies had problems handling the constant dropping in and out of students, because they wanted more control the flow of the information which was probably due to changed the power balance in the meetings.

No student visited more than 7 companies probably because there was not time to meet all. Longer time would have been better for the less known companies since many students were not interested until they had ensured that they had meet the large ones.

A single zoom meeting with breakout-rooms had its clear advantages since the organiser was in the main room could both control the flow of the students and guide students to companies they might know less well. However, for a more general fair it would be harder since no long discussions were possible, the students needed to be well prepared and organiser well aware of both the situation of the students and the companies if it should work.

Companies were more positive to a digital conference also next year than the students. The reasons behind this could be less time required for participation and less travel cost [7], [8]. Despite the facts the students are a part of the younger generation, they were more positive to meet face to face. This is an interesting view and worth looking into deeper but it could a consequence of all the other aspects related well-being of students during the COVID-19 pandemic as discussed in [11]. Therefore, the such a reevaluation should be done without the threat of an pandemic before conclusive statements are done.

5 CONCLUSIONS

It is possible to organise a master thesis fair at zoom, at least in 2020, if the number of participants is limited to around 50. It is expected to be appropriate as a complement to a physical event even without corona restrictions. The on-line approach seemed to be especially appealing to the companies.

6 RECOMMENDATIONS

The following recommendations for arranging master thesis fairs can be made based on this work:

- On-line fairs are suitable for fair on topics with high level of specialisation.
- Keep the guiding resource in the meeting but if it is a highly specified fair the guide must be well familiar with the field.
- Make a test run with the company representatives.
- Advise the companies on which structure to use, so it fits the arrangement.
- Pre-event information about the different companies is needed to guide the students more, at least towards the less known companies.
- The event must be long enough so that there are opportunities for the students to visit all the companies they want to visit.
- Insert a break in the fair to allow students to communicate with each other to spread the word about less known companies or cool ideas.

7 ACKNOWLEDGEMENT

The authors would like to acknowledge all the students and the company representatives that contributed into making this fair such a success.

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SHAPING A NEW FUTURE? ENGINEERING STUDENTS' PERCEPTION ABOUT INTERDISCIPLINARY SUSTAINABILITY COURSES

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Conference Key Areas: *Sustainability and ethics, Attractiveness and future engineering skills*
Keywords: *Sustainability education for engineering students, Interdisciplinary sustainability courses*

ABSTRACT

The main purpose of this paper is to investigate the relevance and efficiency of interdisciplinary sustainability courses. These sustainability courses are designed for engineering students at Master level requiring the use of technical and sustainability skills and competences in the framework of project based learning.

We applied a mixed quantitative and qualitative methodology. First, we carried out a short quantitative survey (n=79) to investigate students' perception about the significance of sustainability courses, the developed skills and competences or the relevance of applied teaching and learning approach. After, we conducted a qualitative study with a group discussion about diverse questions for a deeper comprehension of students' view.

Our findings show a positive consideration of interdisciplinary approach viewed as particularly useful and relevant for addressing sustainable issues. Furthermore, sustainability courses develop numerous transversal skills and competences required for future sustainability achievements. In addition, by enhancing students' sustainability knowledge and awareness they were considered as impactful for students' future actions in their personal and professional life.

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1 INTRODUCTION

There is a growing interest of sustainable education for engineering students due to a collective awareness of the importance of sustainable development for our future that we can observe in the requirements of the accreditation processes of the CTI (Commission des Titres d'Ingénieur – French engineering degree accreditation body) in France. When we decided to develop a new sustainability education module for our first year Master level engineering students (from Physics engineering and Electronics engineering), we were highly motivated to work on diverse sustainability issues closely related to our technical domains but rarely discussed before with our students.

These sustainability courses (2 ECTS), applying two different pedagogical approaches, were spread over two semesters. At the beginning, we applied a traditional lecture based teaching approach consisting 20% of the courses (6 hours of lectures) presenting different sustainable development topics (e. g.: 'Global citizenship and individual impact on sustainability development', 'Quantitative evaluation and comparison of mobility devices', etc.). We defined the principal learning objective of these traditional lectures as the rising of students' sustainability knowledge, awareness and curiosity.

Subsequently, we applied a Project Based Learning (PBL) teaching and learning approach for the 80% of these courses. Students were asked to work in group of ten and set up their team. It was very unusual for them as they are used to work in small teams (composed only of two or three students) and often have no choice to select their team members. They had the opportunity to choose their subjects from a predefined list or propose their own subject according to their interest.[2] As a specific instruction, students had to follow a scientific approach and avoid any ideological approach. During their working sessions, they had the possibility to work with students from other disciplines and benefit from the coaching of professors. The project output consisted in the organization of a round table and the creation of a maximum 10 minutes long video including exclusively certified data. The assessment of the project work took place in a framework of a peer-evaluation.

2 LITERATURE REVIEW

Despite the overall recognition of the value and significance of interdisciplinarity in sustainability education, the implementation of interdisciplinary courses remains an important challenge for educators. According to a recent study of Van den Beemt et al. [1], the training of socially aware engineers and improvement of disciplinary programs are between the most emerging motivations of interdisciplinary engineering education. However, several barriers (like the lack of support, the complexity and diversity of interdisciplinary courses or the existing disciplinary

[2] For giving some example, the following subjects were chosen : 'Benefits and impacts of the digital world', ' Oil free mobility', 'Water management in agriculture', 'Issues & strategies for metals and rare earths'.

barriers in numerous institutions) could hinder the implementation of interdisciplinarity. Concerning the teaching approach, the students' participation in the group composition, applied pedagogy, assessment procedure and characteristics were identified as the most challenging issues of interdisciplinarity engineering education. Regarding the practice of PBL for engineering students sustainable development education, Guerra [2] provided empirical evidences and confirmed the relevance of the PBL for integrating sustainability education into engineering curricula by developing professional competences and expertise.

As to sustainability competences development, Quelhas et al. [3] identified the following eight key sustainability competences: systemic thinking, integrated problem-solving, interdisciplinary work, critical thinking, normative competence, competence of self-knowledge, strategic competence and contextualization and vision of the future (anticipatory thinking). In line with the results of Guerra [2], they confirmed by a comprehensive literature review that the practice of active learning (like PBL or case-based collaborative learning) is the most relevant pedagogical approach for development of sustainability competences.

Following the recommendations of Borrego and Cutler [4], the clear definition of the learning outcomes constructively adjusted to the curriculum is primordial for the good implementation of interdisciplinary sustainability education practice in engineering. They identified the following expected students' learning outcomes: contribution to the technical area, broad perspective, teamwork, and interdisciplinary communication skills.

3 METHODOLOGY

In this study, we use a mixed methodology, combining quantitative and qualitative approaches. The main advantage of this mixed approach is not only the opportunity to make the triangulation of our data but also the possibility to have a better explanation of what is behind the numbers of quantitative survey with the help of the findings from the qualitative study [5].

We have completed an online quantitative study with 79 fully completed questionnaire. Our questionnaire included closed questions with one exception of a multiple choice question about the competences. For the answers, we used a five points Likert scale (from 1='Not important at all / Strongly disagree' until 5='Very important / Strongly agree'). We asked students' perception on the three following thematic areas: sustainability courses' relevance, competences development and applied pedagogy.

For the qualitative study, we have designed the discussion guide in order to give us a broader insight about the motivations and experiences of the students. In the first section, we asked four open questions about the relevance of sustainability courses in engineering curricula, competences development and the possible impact of sustainability courses on students' future life. In the second section, we included five open question about students' perception concerning the relevance of applied pedagogy and their suggestions of improvements. The group discussion was recorded and partially transcribed for facilitating our data analysis.

We analyzed our quantitative and qualitative data in three steps. In the first step, we analyzed the results of our quantitative survey by descriptive statistics. In the second step, we studied the textual data of our qualitative survey by a method of thematic analysis. In the last step, we combined the findings from our quantitative and qualitative studies.

4 RESULTS

4.1 Relevance of sustainability courses

Our results indicate an unexpected finding: 71% of the engineering students considered that their sustainability awareness and knowledge, before this course, was from very poor to average. Consequently, a clear majority of surveyed students (86%) think that theses sustainability courses are really relevant in their engineering curriculum as seen in Figure 1.

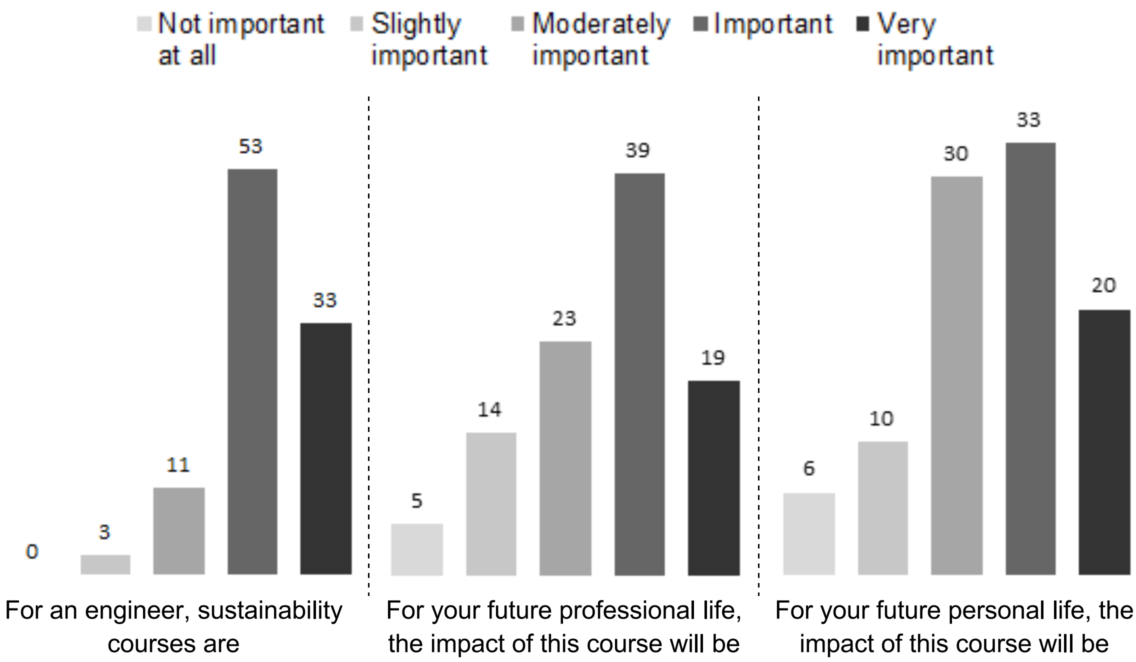

Fig. 1.: The perceived relevance and impact of sustainability courses on students' future professional and personal life (vertical axis in %)

Also, they clearly stated that sustainable issues are important or highly important for their future professional (58%) and personal life (53%). It is quite surprising that students consider sustainability development even more important in their professional future than in their personal life. During the group discussion, they also expressed that they would like to have more technical courses related to sustainability issues so as to convert their sustainable consciousness into practices and actions "…*Our individual engagement is not sufficient …we need to get* *technical expertise ….in recycling method… [or] to be able to make correct choices [in our professional life]*". Many aspects they mentioned correspond indeed to product life cycle and sustainable innovation issues. Students have pointed out that their engineering training mainly focuses on how to use or create new technologies and does not really take into consideration in it the impacts of these technologies on sustainable development.

4.2 Competences development

Surprisingly, the high majority of students (75%) mentioned teamwork as the most developed competence during their interdisciplinary sustainability courses (see Figure 2). During the discussion, they explained that it was the first time during their studies that they had a project work in a team of ten instead of the usual small teams of 2 to 3 students. It was an interesting experience to learn how to distribute tasks in an efficient way, handle them with close deadlines, to manage well progress meetings and for some of them to experience leadership. Students namely mentioned the ripple effect of the motivation of the group.

The sustainability courses obviously developed their critical and reflective thinking for a more sustainable innovation. 65% of the students surveyed consider that they developed competencies in considering the environmental and social impact of their decisions.

It is interesting that nearly half of the surveyed students (49%) mentioned the development of their future thinking ability. From this result it is clear that students appreciate the inclusion of future perspectives into sustainability courses.

Although the interdisciplinary approach was present both in lectures and in the project work, only 29% of students consider that they have improved skills in this domain. One possible explanation comes from a student's statement: *'.... the required level of scientific knowledge so as to cope with case studies was not very high…'*. Which may mean that the students consider that they would improve their interdisciplinary approach only if they increase at the same time their scientific knowledge in each discipline involved in the interdisciplinary context.

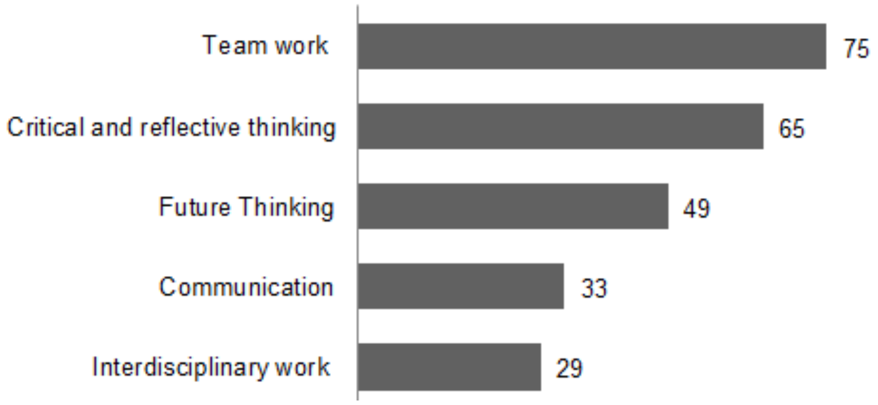

Fig.2. The perceived competences development of interdisciplinary sustainability courses. (% of students that mention the competence)

4.3 Applied pedagogy

The interdisciplinary sustainability courses includes lectures (20%) as well as project work (80%). The lectures are focusing on the global environmental impact of human living and the comparative energy cost of mobility both with quantitative analysis. The application of this mixed approach between a traditional lectures based on project based learning was considered by students as well balanced.

Students namely considered that the project based learning approach suited very well to sustainable issues. Furthermore, they pointed out that the size of the groups was well adapted to their team work even if it was not always easy to keep team members up to date to complete all the required tasks in time.

They highly appreciated having a huge autonomy and freedom in their projects and considered it as very profitable for developing their creativity.

During the discussion, students explained that their teamwork was particularly motivating due to the fact that they had the possibility to choose the thematic of their projects and to constitute their project team according to their interests (with students who wanted to work together or with students who were particularly interested by the same project thematic).

Students appreciated and realized the efficiency of collective learning from their own group but also from other groups. They mentioned that they learned much more in a short period of time than they would have alone.

Quantitative results are provided in Figure 3.

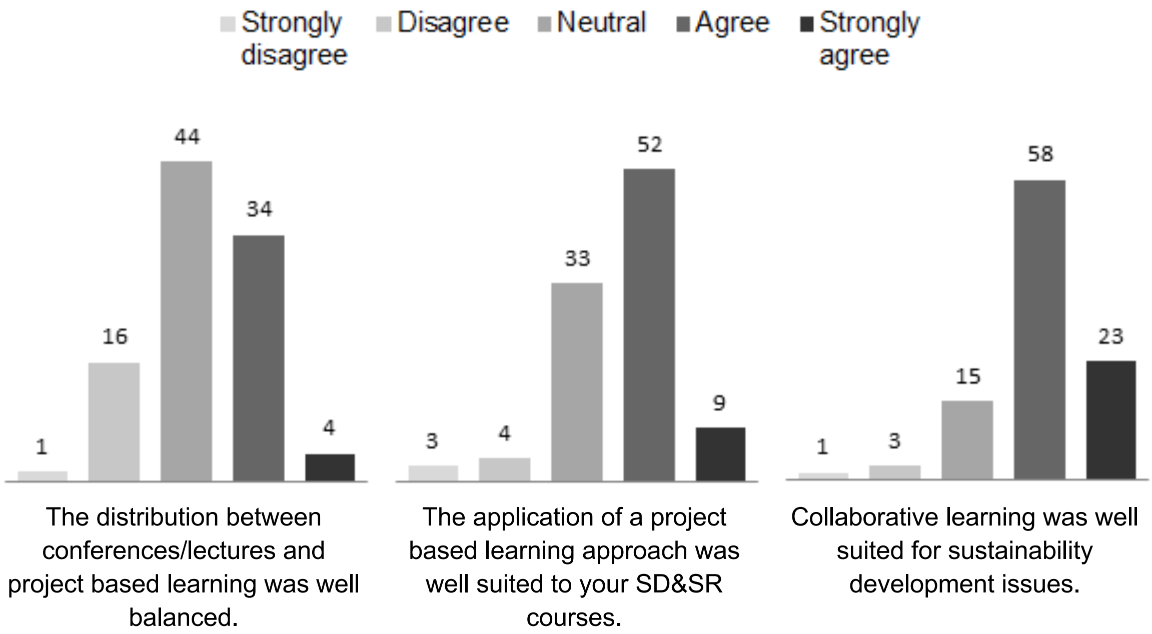

Fig. 3 : Students evaluation of the applied pedagogical approach

Nevertheless, they would have appreciated debates on each subjects. Debates on each subject that were initially planned via round tables, could finally not take place due to sanitary restrictions related to the COVID-19 pandemic.

5 CONCLUSION

Our findings enabled us to draw three main conclusions. First, the relevance of t the project based learning approach practice for sustainability courses. It is particularly effective for raising the sustainability knowledge and awareness of the students as well as for developing their sustainability competences like critical and reflective thinking, teamwork or future thinking. The experience of working in a large team was strongly appreciated by the students. This collective learning offered them a huge autonomy and flexibility and it was perceived as a more motivating and engaging way to learn (comparing to their traditional lectures). The introduction of interdisciplinary courses was viewed valuable for understanding the interconnection between disciplines and for the comprehension of complex and open-ended sustainable development issues requiring expertise from different disciplines.

Secondly, and this is maybe the main result of our study, there is a growing demand of engineering students to include in their technical engineering courses a specific part dedicated to sustainability development issues. The students would like to acquire the needed sustainability skills and competences to tackle sustainability issues in their future professional life (in a similar way that they traditionally acquire technical knowledge and competences in engineering) in order to have an active contribution in achieving the sustainable development goals necessary for a better future.

Finally, the introduction of interdisciplinary sustainability courses is a challenging task that requires a relevant training of educators. The collaboration with other disciplines is not trivial for technical teachers who has prior experiences only in their own discipline. And in addition to this, it is not trivial either to acquire the expertise required in SD that will enable them to incorporate in their scientific courses the appropriate technical aspects related to sustainable issues.

As a future perspective, based on our findings, we would like to enhance the effectiveness of these sustainability courses by several major improvements like the further development of a specific collaborative learning practice between disciplines or the development of additional key sustainability competences.

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INTERACTIVE ONLINE LEARNING MODULES FOR ENGINEERING STUDENTS BASED ON JITT AND PI

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ABSTRACT

At German universities of applied sciences, the composition of first-year engineering students is very heterogeneous (some have completed vocational training, schooling dates back many years). At our university, the first semester Physics course lays the technical and methodological foundations for engineering studies. It should have been converted to activating teaching in summer 2020.

Important goals associated with this change should also be incorporated online: Arousing curiosity, experiencing a positive error culture, and providing confirmation. Considering local circumstances, we decided on the following implementation based on JiTT and PI: Each week was dedicated to one topic. For each, students received a reading assignment, associated learning objectives, and a test including a mandatory open question. Subsequently, students worked on learning modules containing videos (explanations, experiments), interactive questions, tasks, PhET simulations etc. In a weekly recitation, tasks and remaining questions were discussed.

The biggest advantage for students was the constant availability of content. This mitigated bandwidth problems, supported exam preparations, and allowed balancing family, work, corona and study life. Advantages for instructors included a more structured presentation, the possibility to introduce additional materials, and the (necessary) individual contact to students through feedback on the open questions.

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Problems included a high workload for instructors, the need for more instructors to be well-versed with the content, and heightened challenges for shifting from traditional to activating teaching.

Taking into account all constraints, this implementation of online teaching is the best option for students. In the future, the learning modules can support students with different personal needs.

1 INTRODUCTION

At our university, the first semester Physics course lays technical and methodological foundations for engineering studies. The course was redesigned and should have been converted to activating teaching methods in the summer semester of 2020 (15-week teaching period).

The new physics I course has 5 credits and on average 5 teaching units of 45 min per week (90 min lecture every week, biweekly 90 min exercise class and 90 min tutorial, and three 180 min lab courses (two during Corona)). Lectures should have been transformed to Just-in-Time Teaching (JiTT) and peer instruction (PI).

Due to the Coronavirus and the problems involved, the concept was adapted. Our mission was to meet the goals we had relating to the new teaching concepts, offering the best possible online teaching under the given circumstances as well as to consider all restraining social, legal, organizational and technical conditions. The course was held with the adapted concept for three consecutive semesters (summer 2020, winter 2020/2021, summer 2021).

The remaining paper is structured as follows. In section 2 some background on the constraints, the teaching methods and the evaluation is given. This is followed by a description of the adapted concept and its implementation in section 3. In section 4 the experience of students based on the evaluation and instructors is presented. The paper concludes with a discussion of the concept, key findings, and an outlook.

2 BACKGROUND

2.1 German Higher Education System, Local and Legal Situation

The German Higher Education System consists of universities and universities of applied sciences. More people are allowed to study in the latter ones since not only "Abitur" (high school degree) but also work experience, a good vocational degree and others qualify for a study programme. Therefore, the composition of first-year engineering students is very heterogeneous. Some of the students have already completed vocational training, some are having little knowledge of physics and maths since schooling dates back many years, some have children, some difficulties with the German language, and some came directly from high school and therefore are having difficulties to work / learn self-dependent, to organize themselves and to study continuously. A lot of students have to work while studying since they are too old for financial support from the government.

Social bonding has been very difficult for first semester students since 2020. Our university is in a smaller town and a lot of students live in larger cities within a radius of approximately 50 km. For the online semesters a lot of students stayed in their home towns much further away. Student organizations to help and welcome students were basically non-existent.

The summer semester of 2020 lasted from April to July 2020. It was held online only and no teaching in the university was allowed. The winter semester 2020/21 lasted for 15 weeks and for a few weeks at least some teaching in presence was possible. The summer semester 2021 was again online only.

ILIAS, Stud.IP and BigBlueButton were used for online teaching. The use of software was very constrained due to data protection laws and their interpretation by the university as well as the demands from students. A lot of software tools were not allowed, including ZOOM. Therefore, the software BigBlueButton (BBB) had to be used but ran very unstable. Students and lecturers suffered from severe problems with internet connections. Hence, the university ordered that no one should turn on their videos and students should not speak but rather ask questions via chat. Stud.IP and the learning management system ILIAS were implemented a long time ago.

Further constraints exist due to insurance. At home students are not insured through the university and instructors might have to take the full responsibility in case of injury for instance while performing a physics experiment.

2.2 Activating and Online Teaching

Blended Learning: Peer Instruction and Just-in-Time Teaching

Peer Instruction replaces part of the frontal teaching by small-group discussions on conceptual questions and helps to counter declining participation in classes. In many cases students understand explanations by other students i.e., their peers, better than the recitation by the instructor. Students demonstrate a better conceptual learning, especially when students have less background knowledge [1].

With Just-in-Time Teaching [2] students are encouraged to prepare for class in order to make optimal use of the in-class time. Preparation can consist of reading assignments, videos and many more. Students should use learning strategies which fit to their personal preferences, background and previous knowledge. Subsequently, they should ask remaining questions or write down their most important learning outcomes. Teachers can identify learning difficulties and address them during class.

Flipped Instruction and Online Learning

Flipped instruction uses the in-class time for active learning and interactions with students. The respective content is reviewed beforehand. Instructors serve as consultants. In-class time may consist of answering questions, peer instruction, mini lectures and many more [3].

Online learning is very different to being taught in class. A key ingredient is communication with and between students as well as a continuous (online) presence and commitment by the instructor [4]. Due to the rapid shift to online due to Covid-19 transition should not be complicated further by technology [5]. Existing learning management systems with which the students are familiar should be adapted instead of introducing new tools.

2.3 Data Collection

The data used for this paper is based on written and oral anonymous feedback from the students. In the middle of the semesters, questionnaires with the following open questions were given to the students (translated from German).

- What I like about the Physics I module
- What I do not like
- I have the following suggestions for improvement
- What else I wanted to say

Students were also encouraged to continuously give feedback during the semester and once more after the exams were written and graded.

3 ONLINE / HYBRID TEACHING CONCEPT AND IMPLEMENTATION

3.1 Priorities and Main Objectives

In the summer semester 2020 the Physics I course should have been shifted from traditional teaching to Just-in-Time teaching and Peer Instruction. It was adapted to the online situation, keeping the most important goals from the original concept. So we put an emphasize on activation of students, letting them think through the content, arousing curiosity, letting them experience a positive error culture, and providing confirmation.

We also set priorities for the shift to online teaching. Transition should be as easy as possible by reducing the technical and organizational hurdles. Students should connect and communicate with each other. Also, we wanted to be present and approachable for them even though much of the teaching was online and asynchronous. Students should be flexible in when they worked through the content due to the unknown general conditions (jobs, closed kindergartens, bad internet connections, infection, relatives in need). Last but not least, a clear structure of the content should help them to understand and follow the module.

Considering those priorities and the local and legal circumstances mentioned above, we decided on the following implementation.

3.2 Implementation

Each week was dedicated to one topic (e.g., “Kinematics of Translation”, “Kinematics of Rotation”, “Dynamics of Liquids and Gasses”). For each topic, students received a reading assignment, associated learning objectives, and a test (quiz) including a mandatory open question (Fig. 1). In this question students were asked to phrase out the problems they still had with the topic or, when no problems came up, to state their two greatest learning outcomes. They were encouraged to name examples they

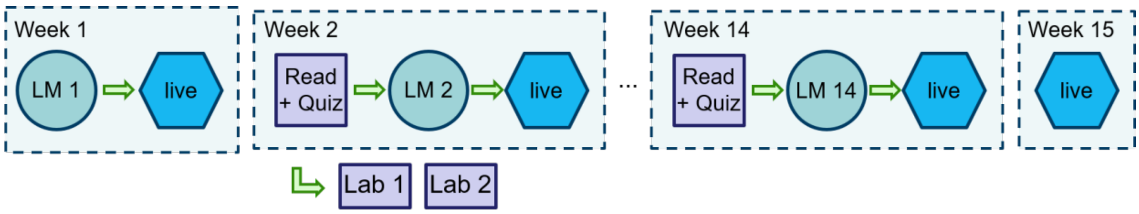

Fig. 1. Flow chart of the schedule for the semester. Read+Quiz - reading assignment and test, LM - learning module, live - live session (online or in person), Lab - lab course.

knew from their daily lives, previous careers, or hobbies. Every student received an individual answer to their questions and statements.

Subsequently, students worked on learning modules in ILIAS. Time for working through the modules was reserved in their weekly schedule but students were free to study them at any other time up to the respective live session. The learning modules contained videos that either explained special aspects in more detail, like topics that were difficult to understand, or the derivation of formulae, experiments, or additional information. Every module started with a welcome video where the lecturer could be seen and gave motivation for the topic as well as an overview. All other videos were either self-recorded or taken from the internet, mainly science channels and other universities. Over time we implemented our own YouTube channel to mitigate bandwidths problems. Students can choose the video quality on YouTube.

The modules contained interactive study control and comprehension questions meaning that students got feedback when giving incomplete, wrong or correct answers. PhET interactive simulations (https://phet.colorado.edu/) with specific tasks and questions to investigate were included as well as tasks to calculate and interpret physical problems. Hints were given for tasks in form of drop-down menus. In this way students could work on the tasks and get help, when needed.

In the learning modules we laid an emphasis on a good and clear structure, on easy handling for the students, on the optical appearance of the content and that the lecturer also brought in her personality. We wanted to show the students that we care for them and are interested in their thinking, ideas and knowledge.

Once a week a lecturer and students met either online in a video conference for 90 min or, when allowed, in person. There, some of the open questions were discussed when the problem affected more students and / or could not be answered in writing (e.g., feedback to open question). Calculation tasks were discussed together. Experiments were shown when possible. In addition, chat was available on Stud.IP the whole time where students could ask questions and receive answers from the lecturers or other students.

During the semester we tried to promote group development since we found this relevant not only for deeper understanding but also extremely important for motivation, perseverance and psychological well-being of the students. We asked them to upload short videos about themselves in the beginning of the semester and we encouraged students to work through the learning modules in small groups of two or three people and discuss the topics multiple times during the semester.

4 EXPERIENCE WITH THE NEW CONCEPT AND FEEDBACK

4.1 Students

Advantages

The biggest advantage for students was the constant availability of the multimedia and interactive content with semi-individual feedback and thought-provoking impulses. This mitigated bandwidth problems, supported exam preparation, and allowed balancing family, work, corona and study life. Especially bandwidth problems, problems with our BigBlueButton servers and closed kindergartens and schools made it hard for students to participate in synchronous meetings.

Students with a big gap between their school knowledge and the standard requirements on prior knowledge for studying highly benefited. They valued, that they could go through the modules at their own speed.

Students liked and were motivated by the individual answers they got on their open questions in the quizzes. They said, that their interest was aroused for physics more than they could have thought.

Here are some quotes from the evaluation (translated from German):

- “By working on my own on the lecture at ILIAS, I have the opportunity to combine it with work better and at my own pace.”
- “The possibility of being able to look through the online units again later.”
- “That all questions, no matter how stupid, are answered; that everything is clearly presented.”
- “Physics is more fun than I expected!”

Difficulties and Problems

Because a lecturer is generally not restricted to a 90 min lecture slot, the learning modules easily get too laborious for students. Some had the feeling they were left alone with the content and requested traditional lectures. Not only the online teaching was new, but also the idea of activating teaching as well as really understanding the content and not only learning “recipes”. It was difficult for students to imagine an exam that tested understanding, even though we continuously confirmed / repeated that we would ask questions that tested understanding.

Connecting students has shown to be very difficult. We attempted to motivate them by uploading welcome videos of themselves as mentioned above, to use the chat and / or the forum in Stud.IP, and to meet in small groups online in BigBlueButton rooms that we created and go through the learning modules in those small groups.

We asked them to turn on their videos in online meetings, but we were very much limited by the capacity of BigBlueButton. Only few students turned on their videos at least in the beginning. Even participating in the online sessions with a microphone was rare. The most convincing explanations were

- the request by the university to turn off videos and microphones in BBB meetings,
- the shortage on equipment and no motivation to buy it,
- data protection considerations that weighted higher for some students than a good learning environment,
- demotivation due to the general situation (lockdowns, little social and public life, insecurity, all exams are "free trials", so bad marks are deleted)
- distraction.

Here are some quotes from the evaluation (translated from German):

- “Too much to read. The videos are not optimized and cause problems if the internet reception is poor.”
- “That you cannot continue in the online units if you have not answered a question or answered it incorrectly.”
- “It is more difficult to acquire the knowledge yourself with the reading assignment than if it is explained by someone.”

Solutions

We reacted to the feedback in the following ways.

- Lots of videos
  It is much easier for students to follow important ideas in explanations or mathematical derivations, if they are explained and shown to them rather than when they are in writing.
- Videos on YouTube with subtitles
  Students had huge bandwidth problems and therefore wished the videos to be uploaded on YouTube. The text to the videos was uploaded in ILIAS so that in a printed pdf file the content was accessible. A huge advantage is, that the learning modules are now even better accessible for handicapped persons.
- Clear distinction between necessary and additional content
  The workload was too high for the students. Therefore, we checked if the content presented was really necessary or only helpful and additional. Helpful and additional content was put in drop-down menus.
- Hints for the tasks
  The tasks were quite similar to those from the last years. Nevertheless, due to the open esteeming communication with the students they brought up problems that had probably always been there. One was that if they did not have an ansatz for a task, they could not do anything on their own. Therefore, they wished for hints for that case. We implemented staged hints on the ansatz and the path of the solution for almost every task.

This way we could not only defuse this burdensome situation for the students but in the end got very positive feedback (translated from German):

“Thank you very much for your effort and the aforementioned euphoria for physics. That made the start of my studies and especially the Corona situation much easier. Incidentally, my interest in physics has definitely been awakened.”

4.2 Instructors

Advantages

Especially for a lecturer in her / his first year the learning modules offer a more structured presentation and the security that students are aware of this structure. Learning modules offer the possibility to introduce a lot of additional material. This is not possible during a lecture. Students can pick the topics they want and get more informed about their areas of interest. The lecturer had more time to think about the points she / he wanted to make in the course. This was quite good in our case, since the author held a Physics I course in general for the first time, for the first time used JiTT and PI, and for the first time online.

The (necessary) individual contact to students through feedback on the open questions not only motivates students but connects the lecturer more with the students. We are convinced that teaching can be better and better organizational solutions can be found (especially during the Coronavirus pandemic where everything changes quite often) when the lecturer is aware of the character and background of the students in her / his course.

We learned much more ourselves. Due to the individual contact / the one-to-one communication channel students were very motivated to share their knowledge and interesting and funny examples with us e.g., a marble music instrument (dynamics of rotation), science slammers, an ice cream safe (thermodynamics, linear expansion), pressure in fire hydrant systems, or a leaning tower not too far away from our university. Additionally, the fit to other modules could be improved since students reported overlaps and gaps.

The restrictions due to the Coronavirus pandemic also hit our lecturers (quarantine or quarantine of children, own infection, bandwidth problems at home). Therefore, asynchronous teaching helped us to secure the teaching and prevented course cancelations.

Difficulties and Problems

Creating the learning modules came with a very high workload for instructors, even though a student helped to implement the modules into ILIAS. Too much content was put in the learning modules at first. This was because there is no direct feedback on how long students worked within the learning modules.

For the weekly meetings the instructors had to be well-versed with the content. Usually only one person has to have such a deep knowledge which is the one giving the lectures and answering the open questions in the quizzes. Exercise classes usually can also be held by new employees shortly after finishing their study programme. In typical traditional exercise classes "only" tasks will be discussed with the students. In our setup, students may ask any question and require deeper explanations as well as spontaneous answers in the weekly meetings. This was very difficult for our new colleagues that just completed or were in the final stages of their master programmes. Also, a good communication between the colleagues involved was necessary so that problems could be addressed immediately.

Online teaching and especially teaching with learning modules and a weekly meeting heightened the challenges for shifting from traditional to activating teaching. Of course, we encountered all problems that generally come with a shift from traditional to activating teaching with JiTT and PI in a first semester studying programme. Students are used to exact recipes and listen-only lectures. They want to know correct answers immediately, want to do what the teacher says (vs. learn from the reading assignments and have an influence on the content of the weekly sessions through their feedback), and are very frightened of the exams.

Solutions

The content, students' questions and the process of the live sessions should be discussed beforehand with all participating lecturers. Hence, all instructors are well-prepared and informed. Also, with the now more stable internet access and video conference software and the existing learning modules, more synchronous online sessions can be provided in addition. However, these synchronous online sessions are only a stopgap solution. If possible, an attempt should be made to hold them in presence. Our experience is that face-to-face sessions have a positive effect on group dynamics, learning motivation, attention and understanding.

5 DISCUSSION AND OUTLOOK

5.1 Summary and Key Findings

In this paper we presented a transition from traditional to activating, online teaching for an introductory physics course. We discussed the local circumstances and constraints. A detailed description of the implementation with weekly learning modules followed.

We realised that these weekly learning modules require a much stricter planning compared to offline teaching (strictly distinguish between necessary, additional and "just" interesting content). First semester students hardly know anyone and have no learning groups which makes the transition into online study life very hard. Hence, it was important to give individual feedback to the quizzes in order to open a communication channel to the students. Discussing the problems set by the instructors in the weekly sessions helped mitigating the reduced contact between students. Students could be kept motivated to stay on track, for instance by showing experiments in the weekly sessions.

5.2 Conclusion and Outlook

Taking into account all local and legal constraints, this implementation of online teaching might be the best option for our students. In the future, the learning modules can be used to support students with different personal needs in addition to the lectures. This is especially helpful for motivated students with bigger problems (little knowledge, only rarely familiar with the German language), for students that start late into the semester (up to 6 weeks late out of 15 weeks), and for all students for the exam preparation.

The effort to create the learning modules was very high for the lecturers but we hope, that it was and is worth it. Students will profit from the online modules in the upcoming years for the reasons mentioned above. Since we always searched for additional content to motivate the students, we ourselves probably learned much more, than we would have with a "simple" online lecture.

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Examuntu: A Secure and Portable Linux-Distribution for Summative E-Assessments at Universities

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ABSTRACT

As electronic assessments emerged into the academic landscape, specialized software solutions were developed along with them. Nowadays, many e-assessment systems that provide secure environments for digital examinations are available. However, they often lack portability or possess a complex software architecture that is laborious to maintain. In order to address these issues, we developed the *Examuntu* operating system. It provides a robust and secure e-assessment environment, being both lightweight and easily deployable in a wide range of computer pools, while allowing a flexible adaptation to multiple types of e-assessments and their respective software application requirements.

With this paper, our contribution is twofold. First, we present the design of our novel e-assessment environment for computer pools. This includes the basic system architecture as well as individual aspects, such as web traffic filtering, browser security, and configuration management. Second, we report on our use of Examuntu in conjunction with a Moodle LMS during math lectures. Our setup features various question types and an optimized computer algebra system, allowing to parameterize exercises and generate differentiated feedback. We confirm that applied security measures did not negatively impact students by comparing their performance within digital to pen-and-paper examinations. Qualitative evaluations of three different e-assessment types show how students, assessment developers, and exam supervisors benefit from proposed Examuntu environment.

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1 INTRODUCTION

Electronic assessments (e-assessments) have become an integral part of academic teaching. Digital summative assessments introduce new challenges and entail many aspects that need to be considered beforehand [1]. Especially the security precautions that need to be taken by the software environment were found to be a major challenge. Current solutions often lack portability, hence are bound to specific computer labs with their respective hardware. Due to their technical design, extensive work is required in order to deploy them in additional labs. If solutions allow customization, they commonly possess complex system architectures, hereby further limiting ease of portability. Many of these e-assessment environments moreover involve manual configuration overhead for each conducted examination.

Within this work, we present *Examuntu*, a security oriented and portable Linux-distribution we developed to support academic e-assessments in Section 3. It addresses shortcomings of current solutions by combining out-of-the-box security measures with an easily customizable software stack into a lightweight and self-contained exam environment. Centralized roll-out via campus network allows easy portability between computer labs and ensures that every examinee receives an identical software environment. We subsequently report on our use of Examuntu at the Hamburg University of Applied Sciences (HAW Hamburg) in Section 4. Both our teaching-learning scenario and the used software stack are outlined. The performance of the proposed exam environment is assessed by qualitative evaluations, covering three different types of digital assessments we conducted. Besides our primary contributions, an overview of related work is given in Section 2 and a concluding outlook is made in Section 5.

2 RELATED WORK

Among all examined related work, the environment proposed by Ritter et al. [2] is most similar to our contribution. It uses a network booted Linux system to employ basic security measures and web filtering. User applications are further encapsulated in a virtual machine (VM) that is additionally started within the Linux system. A similar architecture is used by the Alpen-Adria-Universität Klagenfurt [3], though only providing one fixed Windows VM, in which a Safe Exam Browser[1] (SEB) instance is run. Replacing the minimalistic Linux system with a virtual desktop client, executed in a secured SEB context, is done by Schneider et al. [4]. Each virtual desktop then again runs another instance of the SEB, which is used to interact with a Moodle learning management system (LMS). All the above solutions encapsulate multiple operating systems (OSs). This results in complex software hierarchies and negatively impacts system performance. As these solutions are not designed to be lightweight and portable, they entail an extensive amount of work for deployment and configuration. Easy transfer between computer labs therefore is hard to achieve, hereby limiting the flexibility of examinations.

Besides OS-based environments, some approaches rely solely on software applications to secure assessments. Among these, the Safe Exam Browser is becoming increasingly popular with web-based e-assessments and often is used in conjunction with a Moodle LMS. At the same time, security concerns are risen, and exploitation methods are found, e.g., by Søgaard [5] as well as Küppers et al. [6]. They all conclude that the SEB is insufficient as a standalone measure for e-assessment security and becomes especially fragile with Bring Your Own Device (BYOD) scenarios or take-home exams. Using a kiosk browser like the SEB as part of a larger security concept, however, can be highly beneficial and should be considered when designing an e-assessment environment. Besides technical cheating countermeasures, Apampa, Wills, and Argles [7] further stress the importance of strong user authentication for e-assessments.

Apart from all the technical details, various additional aspects need to be considered when

[1] Safe Exam Browser project website: `https://safeexambrowser.org/` (Retrieved 19.04.2021)

designing and conducting e-assessments. An encompassing overview is given by Vogt and Schneider [1]. This includes among others: didactic properties, technical requirements, and available e-assessment environments. Sauer, Froitzheim, and Hoffmann [8] moreover depict the whole lifecycle of an electronic examination, ranging from initial conceptual work up to archiving of test results. Even though these publications go far beyond the context of this paper, we still recommend taking them into account when developing a comprehensive concept for electronic assessments and designing a respective environment.

3 SOFTWARE ENVIRONMENT FOR E-ASSESSMENTS

At most universities, a large variety of computer labs exist. These include general-purpose workspaces as well as specialized department or topic specific labs, offering from just a few up to more than 100 workstations. Being able to provide a unified e-assessment environment across all labs benefits examinees and examiners alike. As students are familiar with the uniform environment, they experience less technical difficulties and stress during exams. University staff, on the other hand, is able to develop new and re-use existing digital exams independent of the available PC pools and exam supervision is simplified by using a standardized system.

None of the currently available e-assessment environments suits our need for lightweight portability across diverse computer labs. We therefore developed Examuntu, a novel Linux-based operating system that is specifically designed for e-assessments. Its primary objectives are:

a) **Security**, to prevent PC-based cheating and simplify exam supervision
b) **Portability**, so that the system can effortlessly be deployed in varying computer labs
c) **Customizability**, allowing adaption to multiple types of e-assessments, each coming with different types of exercises and a distinct set of software applications
d) **Fairness**, by providing equal conditions for all examinees

3.1 System Architecture

The Ubuntu[2] Linux distribution in conjunction with a lightweight LXQT desktop environment[3] is used as a base system for Examuntu. This allows our environment to perform well, even in labs with older resource-restricted PCs, benefiting the aspired portability. Most OS functions are restricted and a solid web filtering solution is integrated. These components form the core system, which then can be extended according to individual software requirements of specific examinations. A self-contained OS image is semi-automatically generated for every type of assessment. With our scenario, as discussed in Section 4, a lockdown web browser (i.e., kiosk browser) is integrated to allow controlled access to a Moodle LMS[4], which provides the assignments. This yields our system architecture, as depicted in Figure 1.

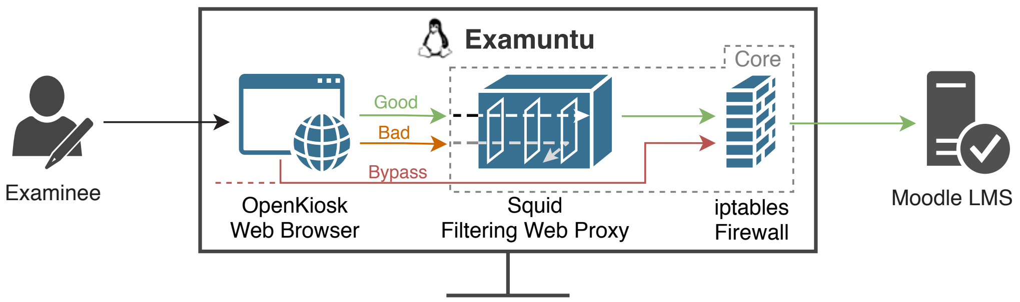

Figure 1: Interaction of the examinee with a Moodle LMS through Examuntu

[2]Ubuntu Linux distribution website: `https://ubuntu.com/` (Retrieved 25.04.2021)
[3]LXQT desktop environment website: `https://lxqt-project.org/` (Retrieved 25.04.2021)
[4]Moodle learning management system website: `https://moodle.org/` (Retrieved 25.04.2021)

During examinations, the OS is centrally deployed via network boot (PXE) as a live system without any persistence (see Section 3.2). This solution not only offers lightweight portability, but also benefits the aspired fairness by reliably providing a clean and identical environment for every examinee. Key aspects, performed adjustments, and technical details of the proposed Examuntu e-assessment environment are discussed within the following sections.

3.1.1 Base System

Several measures were applied to harden the operating system itself. Live systems typically allow the local user to gain system administrator privileges. This permission was revoked and all superfluous software packets, such as the calculator, were removed. Many features of the desktop environment were restricted or completely disabled. This includes the removal of start menu entries, disabling of system settings utilities and tools, removal of virtual desktops, and unmapping of hotkeys, such as `ALT + F4`. Access to internal and external storage media, such as hard disks or USB drives, was prevented by revoking device access and mount permission from the local user. These security measures ensure that the examinee can neither exploit the local operating system nor use external storage devices to exchange data. Additionally, since some PC pools offer multiple displays per workstation, the operating system forces a fixed display configuration at boot, hereby preventing the usage of these additional screens.

3.1.2 Web Filtering

Blocking or selective filtering of outgoing internet traffic is a necessity for an e-assessment environment. Fine-grained traffic control is achieved by using a Squid web proxy[5]. With it, advanced access control lists (ACLs) are used to whitelist websites and services based on their URL, the current time, and various other attributes. This enables assessment developers to selectively allow access to specific websites, network shares, and other network resources, while unwanted web-based tools, such as calculators or messaging services, are blocked. Integrating web filtering directly into our environment not only benefits security, but also further fosters portability by making external and computer lab specific filtering solutions superfluous.

The possibility of forcefully bypassing the filtering proxy, e.g., by modifying the browser network settings or by gaining access to another application, was eliminated through the use of an `iptables` firewall. It was configured to only accept outgoing traffic that originates from the Squid filtering proxy. Hence, all unfiltered traffic, originating directly from the local user and therefore not passing through the proxy, is dropped, as illustrated in Figure 1.

3.1.3 Browser Security Measures

Since controlled access to a Moodle LMS is required by most current e-assessments at the HAW Hamburg, we extended the Examuntu core system with a secured web browser. OpenKiosk[6], a Mozilla Firefox derivative featuring lockdown capabilities (i.e., kiosk mode), was used instead of the commonly found Safe Exam Browser, since the latter only offers support for Microsoft Windows and macOS. Because application access control and network filtering are implemented by the Examuntu core system, the sole purpose of the lockdown browser is to keep the examinee focused on the assessment. The browser was therefore configured to automatically start in full screen mode and prevent application switching. Features such as address and bookmark bars or developer tools were disabled and the browser settings were locked. This yields an uncluttered user interface, leaving the maximum amount of screen space available for displaying the actual assessments. To allow quick recovery from the unlikely case of system failure, a reset button that initiates a clean browser session was integrated.

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[5]Squid web proxy project website: `http://www.squid-cache.org/` (Retrieved 25.04.2021)
[6]OpenKiosk project website: `https://openkiosk.mozdevgroup.com/` (Retrieved 25.04.2021)

3.2 Configuration and Deployment

A key design concept of Examuntu is to provide a core system that can easily be customized and extended according to the requirements of different e-assessment types, such as browser-based exams or programming exams that require specialized development environments (IDEs). A semi-automated image creation process is used to build and maintain the different environments. All images share the same Examuntu core system, but differ in the provided software packets. Generated self-contained OS images are stored centrally and get rolled out via network boot (PXE). This allows their use in varying computer labs while only entailing a minimal initial configuration effort, hereby relieving system administrators and simplifying lab reservations. For assessments of the same type, no additional configuration is necessary once deployed. Installation of software updates is accomplished by updating the single central OS image instead of all lab computers individually.

During boot, the OS image is loaded into the RAM of the respective computer, leaving all local disks untouched at all times. As a result, the OS is non-persistent, hereby protecting the lab PCs from modification while also reliably providing an identical and reproducible environment to every examinee. All transferred files are compressed to speed up the system boot process and reduce network stress when starting multiple PCs concurrently. OS size is further reduced by purging caches and other optimizations during release. Once booted, no further traffic to the network file system (NFS) share is required, since the OS is fully loaded during system startup. This not only preserves network bandwidth during ongoing exams, but also enhances resilience against network outages.

4 USE AND EVALUATION

The developed e-assessment environment was successfully tested during multiple examinations at the HAW Hamburg. We start by describing our teaching-learning scenario, the configuration of our Moodle LMS, and our local Examuntu deployment. Subsequently, we evaluate and discuss our experiences and present insights gained from the conducted exams.

4.1 Teaching-learning Scenario and Moodle LMS Environment

Students have to be familiar with both the e-assessment environment in general and individual aspects of the question types, such as the mathematical input syntax. We ensure this by two measures. First, students are familiarized with Moodle by using the online learning environment viaMINT [9] during pre-courses. Second, subject-specific aspects and respective question types are learned with online exercises throughout the entire semester, hereby establishing a well-founded constructive alignment. At the time of examination, all students therefore are already familiar with both the environment and the used question types.

All our exercises and e-assessments were carried out using a Moodle LMS that we customized and extended to our specific needs. The system currently is capable of smoothly conducting exams that feature advanced question types with more than 200 participants. Assessing the equivalence of complex mathematical expressions is mandatory with most of our questions. Besides the default Moodle question types, the STACK[7] plugin was therefore used in conjunction with GoMaxima [10], an optimized Maxima[8] worker pool we developed. STACK features question randomization as well as parameterization and is able to generate individual feedback for every question variant. This not only provides resilience against cheating, but also allows developing exercises that assess higher competence levels. The integrated feedback tree is evaluated for every submitted answer and question variant. It allows both the fractional grading of student responses and the automatic detection of subsequent errors.

[7] STACK question type project website: `https://www.ed.ac.uk/maths/stack/` (Retrieved 26.04.2021)
[8] Maxima CAS project website: `https://maxima.sourceforge.io/` (Retrieved 26.04.2021)

Students are assisted by the platform in two ways when using these complex question types. First, a syntax reference table that contains all required symbols is displayed alongside every exercise. Second, a graphical live preview of the entered mathematical expression is rendered for every formula input field. This allows students to quickly verify that their entered response is correctly interpreted by the system and fosters double-checking of proposed solutions.

4.2 Deployment

The Examuntu environment was deployed and tested in three of our computer labs. Capacities ranged from 55 to 80 workstations each, spread across multiple rooms. Dynamically switching between labs was found to require only minimal effort due to the lightweight and portable design of Examuntu. Initial deployments were completed within less than four hours and the roll-out of updates only required about 15 minutes. Activating the Examuntu environment prior to an exam took less than a minute and can even be further automated. Parallel booting of all computers in a pool took no longer than two minutes.

Prior to all conducted e-assessments, a technical dry-run with a total of 28 computers was performed. Initial NFS performance problems during boot were solved by OS compression and configuration optimizations. Moreover, lab specific details, such as the availability of multiple screens and other peripherals that need to be taken into account, were observed and handled appropriately. For example, an inadequately configured permission that was still allowing access to a subset of storage devices was hereby found and fixed.

4.3 Conducted E-Assessments

We evaluated Examuntu within multiple examinations for students of various mathematics courses at our university. The following types of e-assessments were conducted:

(a) **Intermediate Test**: ungraded, fully digital, 60-75 minutes

(b) **Hybrid Exam**: graded, split into digital and pen-and-paper part, 120 minutes

(c) **Digital Exam**: graded, fully digital, 75-90 minutes

All assessments were carried out in computer labs with workstations spread across multiple rooms. Every room was supervised by a staff member in order to support students and to monitor the exam. Even though all computers were running the secured Examuntu environment, supervision by a staff member was still necessary in order to prevent analog cheating.

A Moodle course, containing only a single test activity, was created for each assessment. Every eligible student received a personalized one-time user account that only allows access to the respective test. Login information were handed out to the students by a staff member after a successful identity verification. Once logged in, examinees were taken directly to the associated assessment. Additional Moodle features, such as personal messaging, forums, or blogs, were disabled. A synchronous exam start was achieved by requiring a simple password to access the test. It was revealed, once every student was ready to begin. After examination, all accounts were frozen and results were exported.

Grading of student responses was automatically performed by Moodle and STACK, but was subsequently reviewed by a lecturer before a final grade was assigned. All results were exported as PDF documents and the Moodle course was hidden and backed up. Generated exports were then handed out to the examiners for archiving. Students could inspect their individual test results by using the accounts that are associated with the respective exam.

4.4 Evaluation

All conducted e-assessments worked very well and revealed neither major problems nor severe technical difficulties. Students immediately were familiar with the exam environment due to the constructive alignment of our courses. In a qualitative survey, they reported that Examuntu was easy to use and applied security measures caused neither problems nor irritation. The digital workflow was described as simple, supporting and well streamlined. Two students experienced issues while inputting mathematical expressions. These syntax confusions, however, could be quickly resolved by the present university staff during the ongoing examination.

Exam supervisors also benefited from the digital security measures. They reported, that the environment relieved them from digital cheating prevention tasks like monitoring open browser tabs or checking running applications. Even large computer labs could therefore easily be supervised by a single staff member, since solely analog cheating had to be prevented.

The performance of 32 students within digital and pen-and-paper parts for two of our hybrid exams is compared in Figure 2. An examinee that performs significantly different in one of both parts would be represented by a point in either the upper left or lower right corner of a diagram. Results show no such case for both e-assessments. Instead, most students scored slightly better within the digital part. The performance of individual students throughout the semester was also found to be consistent across the different examination types. We therefore assume that Examuntu, despite all applied security measures and restrictions, did not systematically reduce student performance. However, due to our small sample size, differences between student cohorts, and the unclear comparability of exercises, we consider this assumption only a rough indication rather than a confirmation of our hypothesis. In order to reliably confirm it, further systematical evaluations are required.

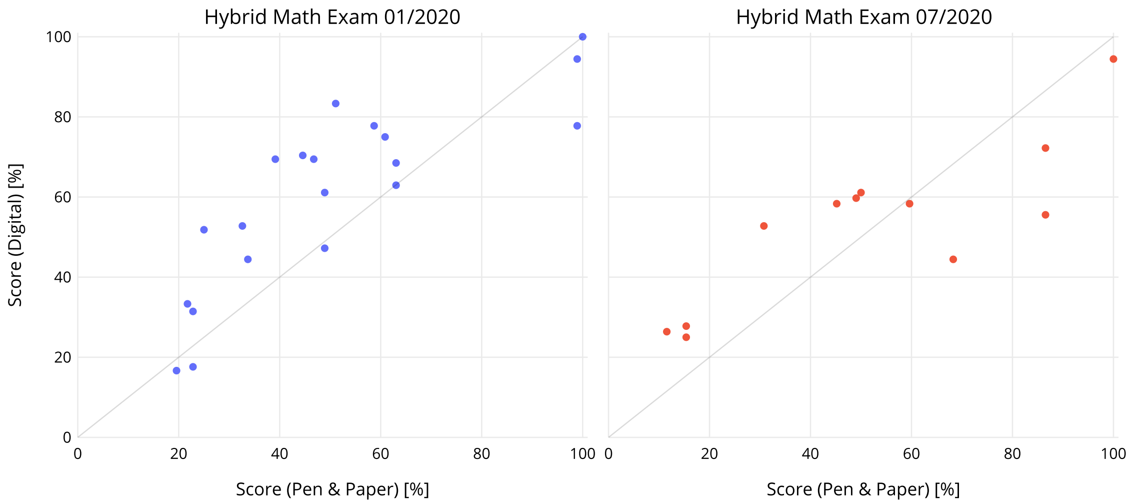

Figure 2: Student performance in digital vs. pen-and-paper parts of two hybrid exams

5 CONCLUSION AND OUTLOOK

With this work we contributed Examuntu, a lightweight, secure, and portable e-assessment environment. We outlined its successful use within multiple examinations. Our qualitative evaluations confirmed, that both examinees and examiner benefit from the novel environment. Applied security measures were furthermore found to have no systematical negative impact on student performance, when compared to other forms of examinations.

Future work includes the integration of different software applications, such as programming environments or MATLAB, as well as improving the configuration management and provisioning process. Dynamically extending lab capacities by using portable laptop computers, running the Examuntu environment, furthermore is part of our agenda.

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FRAUD DETECTION USING WATERMARKS IN EXAMINATION ANSWERS

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Conference Key Areas: Online assessments

Keywords: remote examination, watermarking, fraud detection

ABSTRACT

Most examinations at TU Berlin had to be conducted online due to the COVID-19 outbreak and lockdowns during the winter term 2020/21. Although most exams were designed to be open-book or non-collaborative take-home exams, it enabled students to commit fraud by collaborating. Therefore, we implemented a method in the Moodle LMS to detect copied answers by adding individual watermarks while the students type their answers. If a student were to copy their answer out of the textbox and share it with their classmates (e.g. via an instant messaging service) who then paste the answer into their own textboxes, the system would be able to recognize the watermarks and who copied from whom. The text watermarks are invisible (by using non-printing Unicode characters) and will not get lost while copying. The system is able to reliably detect fraud if students use the described approach. Even though the students were made aware of a fraud detection system, a very small percentage of cheaters were still able to be exposed by it. There is a possibility that many others cheated through other means (e.g. by sharing screenshots) that are hard or impossible to be detected. The collaborations that were detected took place only in exams that consisted of no or a very small number of random questions. Accordingly, building a large question bank is one of the most effective ways to stop students from easily collaborating during an exam.

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1 INTRODUCTION

All students should take an examination under the same conditions that allow their results to be comparable. Usually, the teaching staff ensures that by supervising the students and checking whether they collaborate or use forbidden reference materials. As a consequence of the COVID-19 outbreak and lockdowns, most examinations at Technische Universität Berlin had to to be conducted online from remote during the winter term 2020/2021. The assumption is that more students than before now try to cheat as they feel confident enough that their attempted fraud cannot be detected. Since there are numerous ways to cheat and to access disallowed resources, one important measure was to design the exams to be open-book or take-home exams and allowing the students to use all resources that are not communication tools. Before they can start their exam attempt, our students had to log in to our Moodle learning management system (LMS) with a two-factor authentication method and they had to make an affidavit to work on their exam autonomously, that they do not receive help from any third party and that they do not provide any help to others. We were not allowed to use proctoring solutions because of privacy and missing legislative basis. We also did not force use of the Safe Exam Browser (SEB) as this software is not available for Linux and the security means are bypassed easily (e.g. students can use a second device).

We assumed that the students who collaborate share their answers via instant messaging services. Hence, we concentrated on trying to unveil some of these collaborations and implemented a method in Moodle quizzes that inserts invisible individual watermarks into the questions and student's answers using text and image watermarking, allowing to detect copied answers and to identify who shared their answers. These watermarks are preserved even when an answer is copied and pasted multiple times through messengers. Since we made the students aware of a fraud detection system, we hoped to prevent fraud on a psychological level.

2 BACKGROUND

2.1 Digital Watermarking

Watermarks are classified as visible and invisible. Visible watermarks usually consist of a noticeable text or a logo and invisible watermarks are not or hardly perceptible to the human eye. Digital watermarking may be used for ownership assertion, fingerprints, copy control, or fraud detection by embedding information somewhere in a way that it can later be extracted or detected [1]. There are multiple possible ways to embed watermarks in videos, images, audio files, and documents like PDF files, but they can also be put in plain texts. Traditional approaches display the text as an image and include the watermark in that image, or they modify sentences while keeping their meaning (e.g. by passivating clauses or substituting words with synonyms) [2]. Watermarks can be embedded in images by slightly modifying the luminance of some pixels in a way that it is detectable by machines but hardly perceptible to a human [3].

2.2 Unicode

Unicode is a standard that describes the digital encoding and representation of letters and other characters. Each character is assigned a *code point* (a numerical value) and Unicode may define up to 1,114,112 *code points* (in the hexadecimal range of U+0 to U+10FFFF) with the aim to represent the characters of most of the world's languages. The most important Unicode encoding formats are *UTF-8* and *UTF-16*. The code points are encoded as up to four *code units* each consisting of a bit sequence of 8 bits (UTF-8) or up to two *code units* each consisting of 16 bits (UTF-16). [4]

2.3 Digital Text Watermarking

The Unicode standard does not intentionally provide a possibility to hide arbitrary data in a plain text. However, the various features and the large amount of 143,589 characters that are currently defined in Unicode allow to implement a digital watermarking for plain texts.

Homoglyphs are one option to be used as watermarks. These are characters or glyphs that appear very similar or identical, e.g. Latin letter 'j' (Unicode code point U+006a) and Cyrillic letter 'j' (U+0458) are visually identical in many fonts. The Unicode standard publishes a list of these visually confusable Characters. Homoglyphs can be used to encode the bit sequence of watermarking data. Whenever a confusable letter is found in a text, it represents one part of the bit sequence (by leaving the original symbol or replacing it with a homoglyph) [5]. Usually, this method is only able to encode one bit per symbol since there are not so many confusable characters. Accordingly, the text must have a specific minimum length that there is a chance to embed the whole watermark data.

Unicode also defines several space characters of different widths (from hair space to quad space), which allows embedding more than just one bit of the watermark bits per space. A drawback is that the different space widths might catch the reader's eye and thus be too distracting in plain texts [6].

There are also special non-printing characters in Unicode, such as zero-width joiner, non-joiner [7] and tag characters. They provide a way to hide the watermark data in a text, and they allow embedding two or more bits per code point. Additionally, the non-printing characters can be put together to form the whole watermark. They also can be repeated throughout the text as often as needed. Hence, the watermark could also be embedded in very short texts. However, this method may heavily increase the text size (in bytes), while homoglyph approaches might not or only slightly influence the text size.

The Unicode tag characters (U+E0000 to U+E007F) are used to insert information separate from the ordinary text. They are utilized in *emoji flag sequences* as a modifier to display national flags. Initially, these code points were supposed to provide a language tagging feature for texts, which has been deprecated since.

3 IMPLEMENTATION

When watermarks should be embedded in examination questions and answers, the main issues are:

- *Capacity*: How much information/data (in bits) can be inserted in an answer? Exam answers might be very short (only one digit/character).
- *Transparency*: How do you embed the information in a way that it is hardly perceptible to the human eye and cannot be noticed when writing, copying, and editing the exam answer? First of all, the watermarking must not disturb or distract the students during writing their own answers.
- *Reliability*: How can you reliably determine that someone copied/pasted an answer and from whom? How do you prevent false accusation when someone maliciously or accidentally modifies the watermark?
- *Robustness*: The watermarks should not get lost when an answer is copied and pasted multiple times and when they are shared via instant messaging services or collaboration tools.

We wanted to implement two completely different approaches of watermarking an examination: (1) Text watermarking using non-printing Unicode characters and (2) watermarking the exam's website background.

We assumed that the students who collaborate during the remote exam primarily stay in touch with their classmates (during the COVID-19 outbreak and lockdowns) via instant messaging services or via real-time collaboration tools like Google Docs. They might copy their answers out of their textboxes or they might take screenshots and share that. The purpose of the watermarking is to identify both the person who shared their answers and the person who copied/pasted the answer. However, watermarking the website background only helps in the rare case when someone posts the screenshots on a public website or publicly available chat rooms.

The watermarking is implemented as a Moodle plugin and core modifications[1]. When a student starts a new quiz (exam) attempt, a 64 bit random unsigned integer will be generated, which serves as a unique identifier of the student and the quiz attempt. We agreed with our data protection officers to delete these identifiers 30 days after the exam took place. Since we only consider the watermarks within one exam, even a much smaller integer could prove to be sufficient (our largest exam has about 1,300 participants). However, we wanted to reduce the risk of false accusation in case someone accidentally modifies their watermark and that watermark now matches someone else's identifier by a coincidence. This is why we chose that the watermark has to consist of at least 32 bit of this identifier.

When the student views an exam page, the watermark is embedded on the client side using JavaScript. When a teacher views an exam attempt, the student's watermark will not be embedded to avoid that the teacher accidentally distributes the identifiers. In fact, our teachers cannot access tables or reports with the students' watermarks.

The watermarking functionality has to be enabled by a teacher in the Moodle quiz settings. Just before starting an examination attempt, the students are made aware of this fraud detection system ("The exam is protected by security measures, which reveals your identity if you share answers or screenshots!").

3.1 Text Watermarking

We explored the different approaches of digital text watermarking regarding the main issues and implementation effort. The homoglyphs and whitespace approach is unsuitable for examinations because they offer too few data capacity and they are not applicable to short exam answers like numerical answers.

The Unicode tag characters were promising because contemporary Windows, Linux and Android systems do not display these characters at all, and the range U+E0000 to U+E007F would allow placing seven bits of the watermark data within one character. However, we identified that iOS 14.4 displays most of these characters as a question mark and only the range U+E0061 to U+E007A as a whitespace (all neighboring tag characters are displayed as one space as long as there is no other character in-between). The characters are invisible starting from Windows 7 (Windows XP displays them as empty boxes). The instant messengers WhatsApp, Discord and Matrix/Element as well as Google Docs preserve them. Telegram's desktop client removes the tag characters, while Telegram's Android and web client keeps them (at the time this report was made).

The four zero-width characters U+2060 to U+2063 (word joiner, function application, invisible times and invisible separator [4]) allow to embed two bits per characters. We also checked these characters under the mentioned operating systems and applications, and found that they preserve these characters and do not display them.

[1] The source code is available under: `https://github.com/innocampus/moodle-quizaccess_watermark`

A double click also highlights the adjacent tag and zero-width characters. In Linux and Windows, we observed that Firefox highlights the characters before and after the word, while Chrome only highlights the code points that are after the word that a user has double clicked on.

We decided to make use of both the tag characters and zero-width characters in order to ensure that at least one of them are preserved when copying and sharing answers. Due to the limitations imposed by iOS, we only use the range U+E0061 to U+E0071, which allows us to embed four bits per character. We modified the exam web page's text input fields to insert the zero-width characters at the beginning of the text and before each space. The tag characters are inserted after each space and at the end of the text. The text is modified only when the student leaves a textbox and at the moment when they highlight something.

Whenever the watermark is embedded using tag characters, we insert 16 tag characters at the same time, which allows to embed the whole 64 bit identifier. This watermark consumes 64 bytes in UTF-8 since each of these code points needs four code units. We also insert 16 of the zero-width characters. Since they embed just two bits, we can only take the first 32 bits (beginning with the most significant bit) of the identifier. This consumes 48 bytes in UTF-8 because each of the code points takes three code units. In total, each space (one byte) now requires 112 bytes additionally, which greatly increases the memory consumption of the text input fields. We consider this being acceptable.

We do not put the watermark in the middle of a word, which would break all spellcheckers and distract the students. In addition, the tag characters are displayed as one space in iOS, which would be distracting too within a word. However, the gap between two words is still a little wider than normally in iOS. We observed that we can safely insert the watermarks into the input fields of Moodle's short answer, numerical, calculated, and cloze question types.

Despite the characters being invisible, the students may still notice them when they hit their arrow or backspace/delete keys. These keys skip or remove one character after another, but the user does not immediately see anything happening because there are so many of these invisible characters. It seems as the cursor cannot move forward and, obviously, this would be too confusing. Hence, we implemented a logic on the exam website that adjusts the cursor accordingly and makes it behaving as expected.

When a student submits their answers, we remove the watermarks (using regular expressions) on the server side as Moodle would evaluate the answers wrong. The raw answers (including the watermarks) are saved in a separate database table.

Finally, we implemented the watermark detection and reporting functionality. All foreign identifiers that are found in the answers, i.e., all identifiers that do not belong to the student, are reported and the system tries to find and name the answer's actual author. The system searches for the author only within the same exam.

3.2 Website Background Watermarking

We modified the exam's website background by inserting an SVG background image that appears identical to the usual background. The watermark is embedded by modifying the luminance of certain pixels at a fixed position and there are 64 pixels that encode the whole student's unique identifier. A modified (slightly brighter) pixel denotes bit 1 and an unmodified pixel bit 0 (Figure 1). We also insert one slightly darker pixel that indicates the beginning of the watermark. It is located left to the first pixel that refers to the identifier's most significant bit. The SVG image has a size of 90x90 pixels and it is repeated (horizontally and vertically) to cover the whole exam's questions and answers background area.

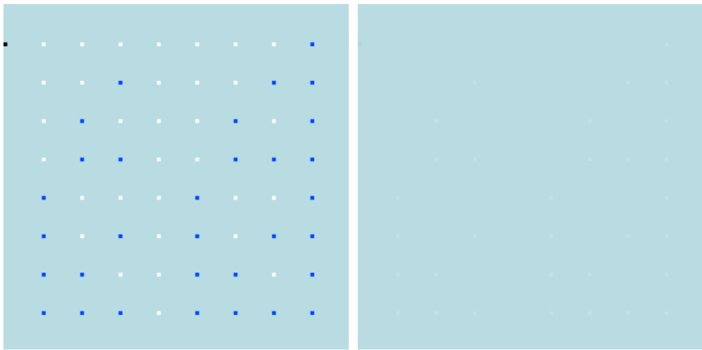

Figure 1: Stretched example of an SVG background tile with the embedded identifier *0x0123456789abcdef*. The left image consists of highlighted pixels for better visuals (blue=1, white=0, black=beginning).

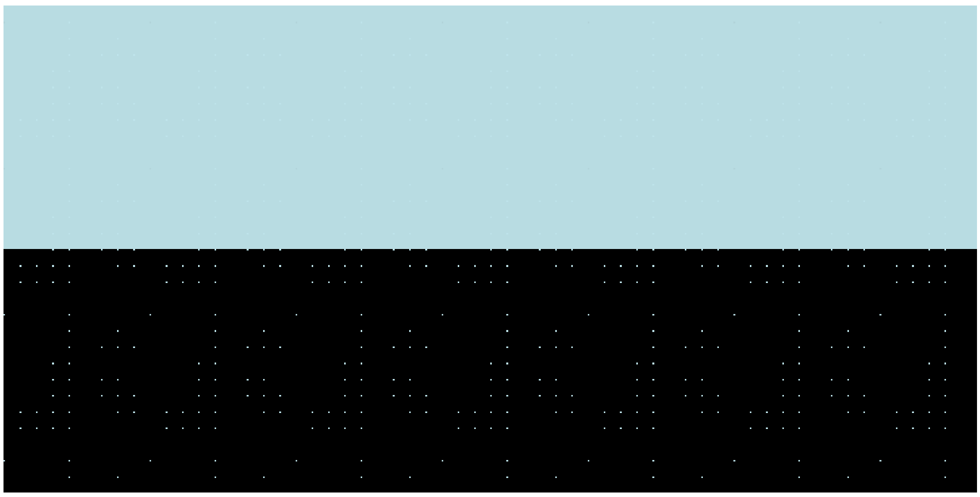

Figure 2: Image watermarking with the embedded identifier *0x101217303637f3f0*, partially filled.

This image watermarking method is very simple, but it is sufficient in this case because we only want to deal with screenshots. Since screenshots are perfect copies usually, we do not have to consider printing errors, and therefore error correction algorithms are not necessary.

When we need to extract a watermark from a screenshot, we do that manually with the help of a graphics editor by filling the background with an inverse color (as seen in Figure 2) and identifying all pixels that differ. That way, we are able to determine the student's identifier and to look up this identifier in the database.

4 RESULTS

The watermarking feature was enabled in 58 exams, distributed nearly equally across all faculties. This number is much smaller than the actual number of examinations because we finished the Moodle plugin after our winter term's examination session already started and we advised teachers to enable the watermarking feature only in mock exams for the moment. After one week we were confident enough that this feature can be enabled safely in real exams too, but left the final decision up to each teacher. We only counted exams that consisted of questions with answer fields where it was possible to embed a watermark. 24 exams with 1945 participants were omitted because they only consisted of single/multiple choice, drag & drop or essay questions.

	No. of exams	No. of participants	Collaborations
All exams and mock exams	90	10995	7
All exams	58	6119	6
Exams with detected collaborations	3	612	6

Table 1: Number of exams having the watermarking feature enabled (and having questions that allow watermark embedding) together with their number of participants and detected collaborations.

Within these 58 exams, six participants in three exams were detected by the system having copied and pasted an answer from someone else (Table 1). That means, we know of twelve students in total (0.2 % out of 6119 participants) who collaborated without permission (one sharing their answer and the other one copying/pasting the answer in their own text fields). As a consequence, we provided the teachers with the evidence and recommended that these students should not pass their exams. In addition, one pair of students was found having been collaborating during a mock exam, which was not forbidden. We noticed that the detected collaborations took place only in exams that consisted of no or a very small number of random questions/variants (only two or three random questions per topic and difficulty level).

As we are not aware of anyone who posted screenshots of their question/answers on a public website, we did not had a chance to uncover anyone with the help of the website background watermarking. Probably, the psychological level of making the students aware of a fraud detection system also matters a lot, but we are not able to substantiate this effect.

There is a possibility that many students could have cheated through other means (e.g. by sharing screenshots in private chats, removing our text watermark, meeting in the same room despite the COVID-19 lockdowns or hire a ghostwriter) that are hard or impossible to be detected. However, building a large question bank still seems to be an effective and reasonable way to stop students from easily collaborating with themselves during a remote exam. Even when they still try to work together, they need to spend more time on finding and comparing their questions and answers in the chat log.

5 SUMMARY

Our text watermarking system is able to reliably detect a certain way of cheating and it was able to unveil a few forbidden collaborations, although the students were made aware of it shortly before they started their exam. We cannot substantiate this psychological effect and whether students still cheated through other means that this system cannot detect. Since these collaborations occurred only in exams with few to no random questions, we suggest building a large question bank with at least four random questions/variants as a way to prevent students from easily collaborating. As we do not know of a student who published screenshots of their question and answers, our website background watermarking could not reveal fraud. We only embedded the watermarks in short answer, numerical, calculated, and cloze question types, but it could also be applied to more. Notably, essay questions and other multiline answer fields could be covered in future work.

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PERCEPTIONS OF MULTIMODAL ONLINE INSTRUCTION DURING NATIONAL LOCKDOWN: EXPLORING THE BLENDED CONTINUUM

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Keywords: *Online instruction, face-to-face instruction, COVID-19 pandemic, engineering mathematics, perceptions*

ABSTRACT

In the context of a global pandemic, education at most universities in South Africa is undergoing rapid adaptation and transition to online, blended learning. Tertiary educators are expected to adapt to flexible schedules, changing pedagogical practices, and learning and work environments shaped by technology. The COVID-19 pandemic has made it increasingly important for institutions to migrate their traditional face-to-face (F2F) instruction methodology to fully online teaching and learning. Educators and institutions have urgently had to adapt to a ‘new normal’ that responds to the demands of the global crisis. A new approach is perhaps essential to address the learning needs and challenges of currently enrolled first-year students, who are obliged to study in varying environments yet still need to progress equally toward attaining a high-quality qualification.

This case study determines educators’ and students’ perceptions of multimodal online instruction and learning and the experience of first-year engineering students transitioning from F2F to online multimodal teaching and learning. The study, in this way, explored the efficacy of transition to online multimodal teaching and learning across the F2F-online continuum. The first-year University of Technology (UoT) engineering students were exposed to both face-to-face and online multimodal teaching and learning environments. The data collected were analysed both qualitatively and quantitatively. The findings indicate that the students performed better when exposed to multimodal online instruction than when exposed only to face-to-face classroom instruction. The study also found that the students and lecturers positively perceived online multimodal teaching and learning.

INTRODUCTION AND RATIONALE

The current pandemic caused by the novel coronavirus disease of 2019 (COVID-19) makes it increasingly important for educational institutions to adapt their instructional methodologies to address the challenges experienced by educators and students. Numerous studies show that many educators do not effectively use the technological resources at their disposal (Karimzadeh, et al., 2017; George et al., 2012; Appana, 2008). There also seems to be a prevailing assumption that face-to-face instruction can be directly translated into an online format (Mdlongwa, 2012; Churton, 2008). The main focus of this paper is to explore the various modes of instruction to which students were exposed pre-and post-national lockdown due to the COVID-19 pandemic. This study used the blending with purpose model based on the blended learning conceptualising framework of Picciano (2009). It spans the continuum of instruction from face-to-face (F2F) in the classroom to entirely online and provides both the foundation for the study and a lens through which its findings are viewed.

The mere presence of a device does not denote a habit of study digitally, and educators need greater clarity on the functionalities of devices and how different profiles of students utilise them. Nevertheless, there is a legitimate concern that as the millennial generation enters university in more significant numbers, there will be a need to accommodate technology-savvy students taught by technology-literate educators (Picciano, 2009).

LITERATURE REVIEW

Online instruction, in general, has many benefits over face-to-face instruction, which include increased access, improved quality of learning, better preparation of students for a knowledge-based society, and the opportunity for 'lifelong' learning (Appana, 2008). Nevertheless, despite the ever-increasing popularity of online instruction, there are limitations to its ability to replicate features of a traditional F2F classroom environment, such as social interaction, prompt feedback, engaging activities, instructional flexibility, adaptation to individual needs and immediacy (Larreamendy-Joems & Leinhart, 2006). Frymier's (1993) research concluded that students who began a course with low to moderate motivation to study had increased motivation to study after interacting closely with an effective instructor, while students with a high level of motivation were unaffected by a high level of immediacy.

The term multimodal instruction means different things to different people. In the broadest sense, multimodal instruction encompasses a "wide variety of technology/media integrated with conventional, face-to-face classroom activities" (Picciano, 2007). Multimodality refers to communicative situations that rely upon combinations of different 'forms of communication to be effective. "Multimodal" itself denotes a mixture or combination of modalities. The mix can be a course comprising both F2F and online components. In this study, multimodal instruction is contrasted with the traditional talk-and-chalk classroom instruction and the combination of different modes of instruction and learning, enabling new affordances of learning and choices. The concept and application of multimodal learning will be explored in this paper based on the Blending with Purpose model illustrated in Figure 1.

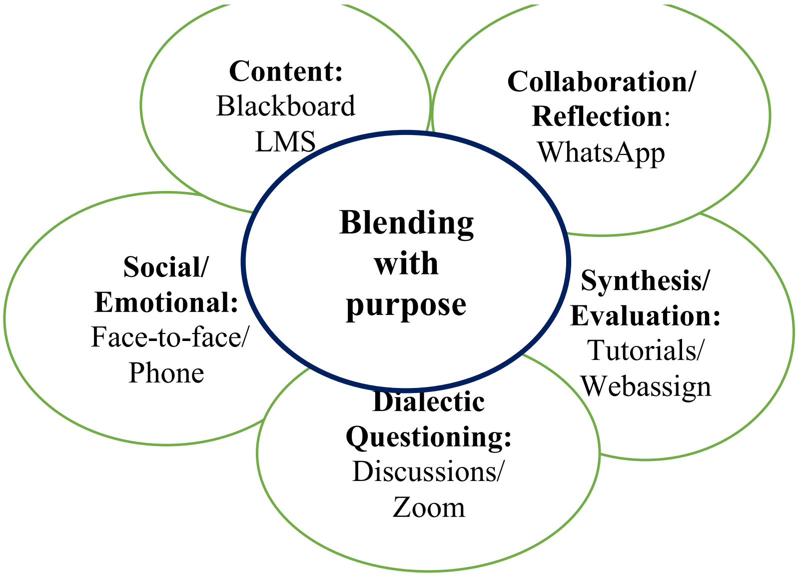

Figure 1: Adapted Blending with Purpose model

The Blending with Purpose model depicts the various modes of instruction, including conference platforms, social media, a learning management system, WebAssign and phone. This model posits that instruction is not always about learning content or skill but can also be about supporting students socially and emotionally. Social and emotional development is an important part of anyone's education, especially for students in their first year of study. They may frequently need someone to speak with, whether to help them understand a complex concept or provide advice on career and professional opportunities.

METHODOLOGY

This case study used a mixed-methods approach to collect data from marine engineering science students and lecturers. Questionnaires comprising questions answerable according to a 5-point Likert scale and six structured questions were used to collect data from a purposive sample of 10 lecturers and 36 students, probing the perceived usefulness and ease of use of technology, technophobia, and the availability of and access to multimodal online teaching and learning.

Figure 2 illustrates the transition in the continuum from face-to-face to online instruction experienced by the educator and students, based on the blended learning conceptualisation framework of Picciano (2007).

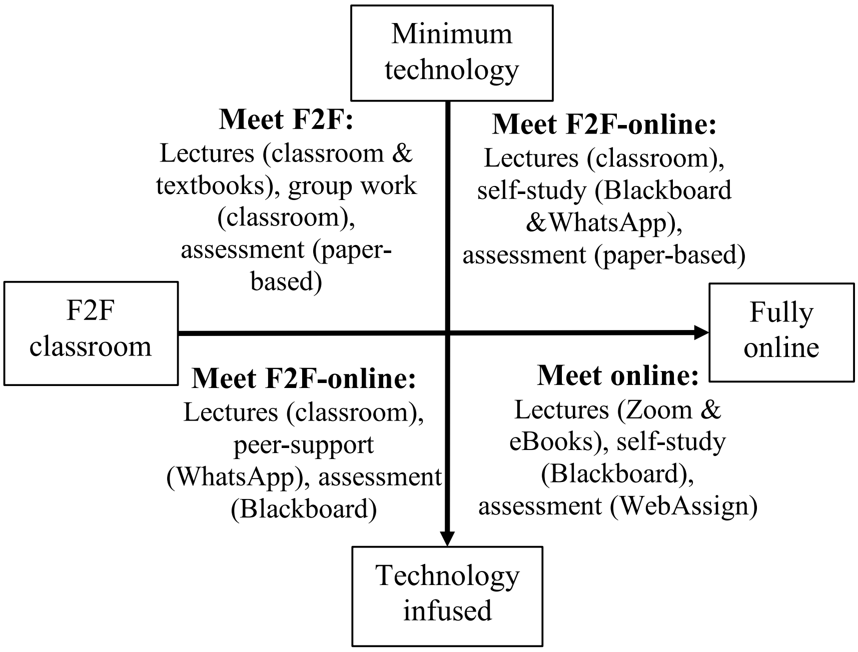

Figure 2: Adapted blended learning conceptualisation framework (Picciano, 2007)

The educator and students used the Blackboard Learning Management System (LMS) for instruction and learning, utilising various functionalities such as text, video and audio. Students submitted six assignments. The teaching and learning for the first three assignments took place primarily in a F2F environment (left quadrants in Figure 2), and the teaching and learning for the last assignments took place in a predominantly online environment (right quadrants of Figure 2). All the assignments were standardised to be of a similar degree of difficulty, covering the following topics: Matrices, Trigonometric functions, Exponential functions, Complex numbers, Vectors and Derivatives.

RESULTS AND DISCUSSION

Perceptions and accessibility of online multimodal instruction and learning

Gardner (1983) posits that "intelligence is not a singular entity but is made up of multiple entities in different proportions used by individuals to understand and to learn about the world." Gardner's work also addresses the concern that too much teaching and learning is linguistically-based (reading, writing, speaking) and that the other intelligence needs to be better utilised using a multimodal instruction approach. Figures 3 and 4 illustrate the students' and educators' perceptions of online multimodal instruction and learning, respectively.

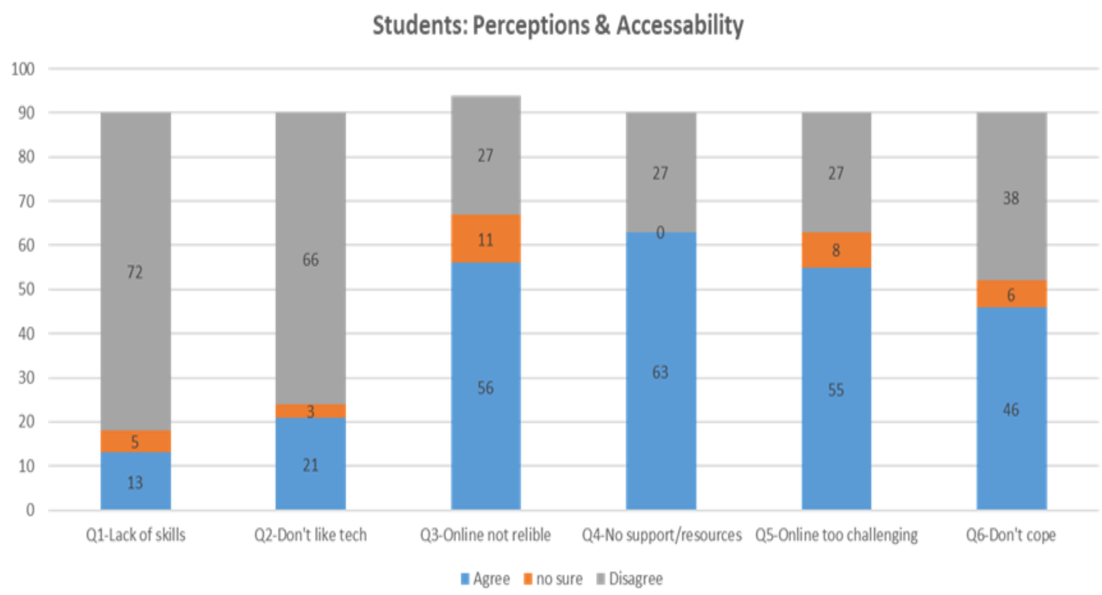

Figure 3: Students' perception of multimodal online learning

The students' responses, as set out in Figure 3, evince a generally positive perception of multimodal online learning. This observation is based on the responses to Questions 1 (skill deficit), 2 (interest) and 3 (reliability). The data bears out the notion that younger students are "digital natives" who use technology most comfortably (Prensky, 2001). However, it is noteworthy that most of the students indicated a preference for face-to-face lectures rather than online lectures (Question 5). This might be attributed, at least in part, to "cabin fever" and/ or "online learning fatigue" because of the prolonged national lockdown and students' need for social and emotional interaction. The students also indicated that the course content was too demanding for the multimodal online learning format alone, and many students found it challenging to manage "cope" with the workload (Questions 5 and 6).

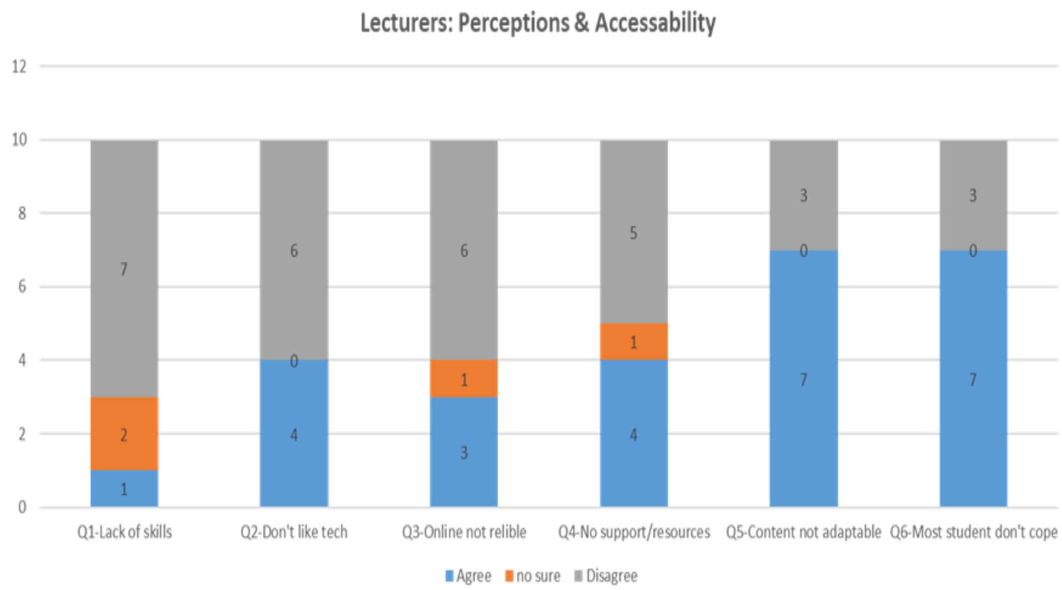

Figure 4: Lecturers' perception of multimodal online learning

Figure 4 indicates that the overall responses for Questions 1 (skills), 2 (interest) and 3 (reliability) on the part of the lecturers were positive towards online multimodal instruction and learning. The lecturers' responses also suggest that they have ready access to online multimodal instruction facilities and support (Question 4). However, most of the lecturers found that most of the course material was not online-friendly (Question 5), and students struggle to deal with it online (Question 6).

When the students and lecturers' responses are compared, it can be seen that they both express positive perceptions but feel that the course material is not always adaptable to the online format and that most students could not keep up with the workload and pace of online instruction. This observation could be attributed to the unpreparedness of content and lecturers and students' new online learning experience. While the students expressed reservations about the reliability and the accessibility of online instruction and learning, their educators felt otherwise.

Observations during instruction

The first part of the study involved observation of face-to-face instruction for five weeks. Students were seated at desks, with the lecturer conducting the lesson at the front of the classroom. The instruction methodology involved mainly question-and-answer and taking notes from the board. Occasionally students had group discussions with peers next to them. The assignment scripts and the assessment thereof were pen-and-paper based. The latter part of the study focused on online multimodal instruction. The lessons were conducted using the online conferencing platform, Zoom. Students were divided into breakout groups on the online platform to discuss specific problems with peers and share their responses in the main virtual room with all the participants. The lecturer and students used online multimedia Google Docs/ Forms, WhatsApp and email for asynchronous engagement outside of the online sessions, illustrated in Figures 5 and 6.

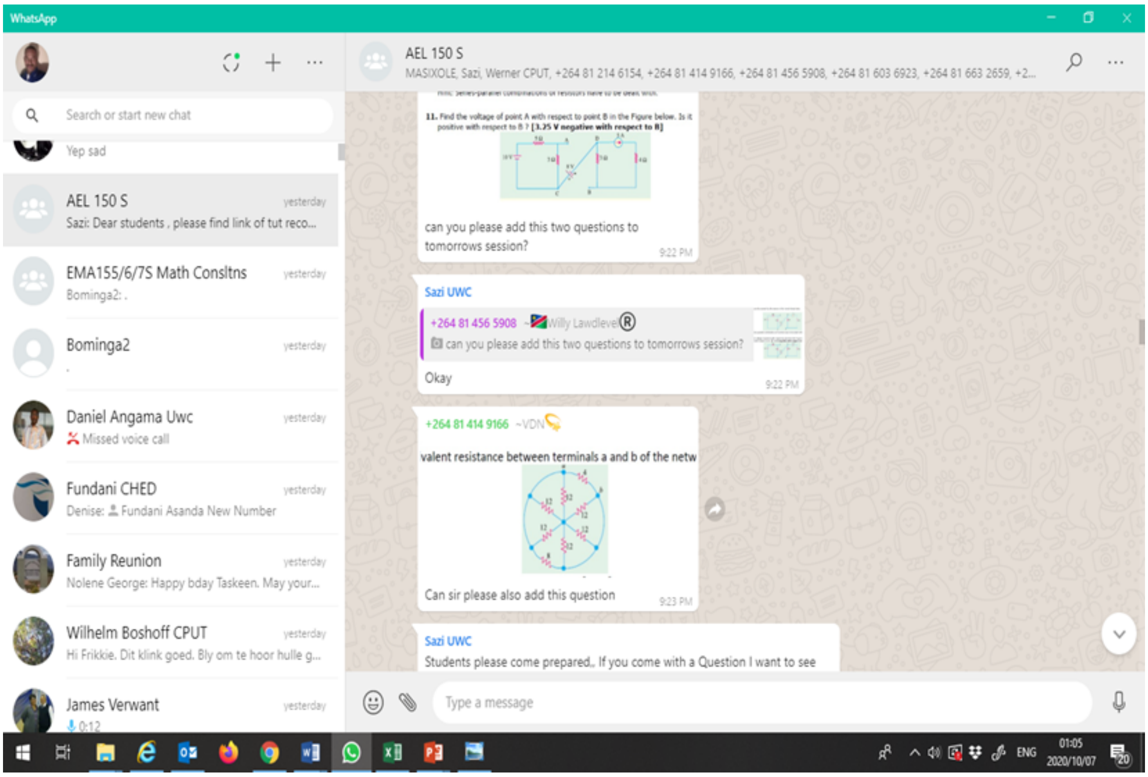

Figure 5: Engagement on WhatsApp

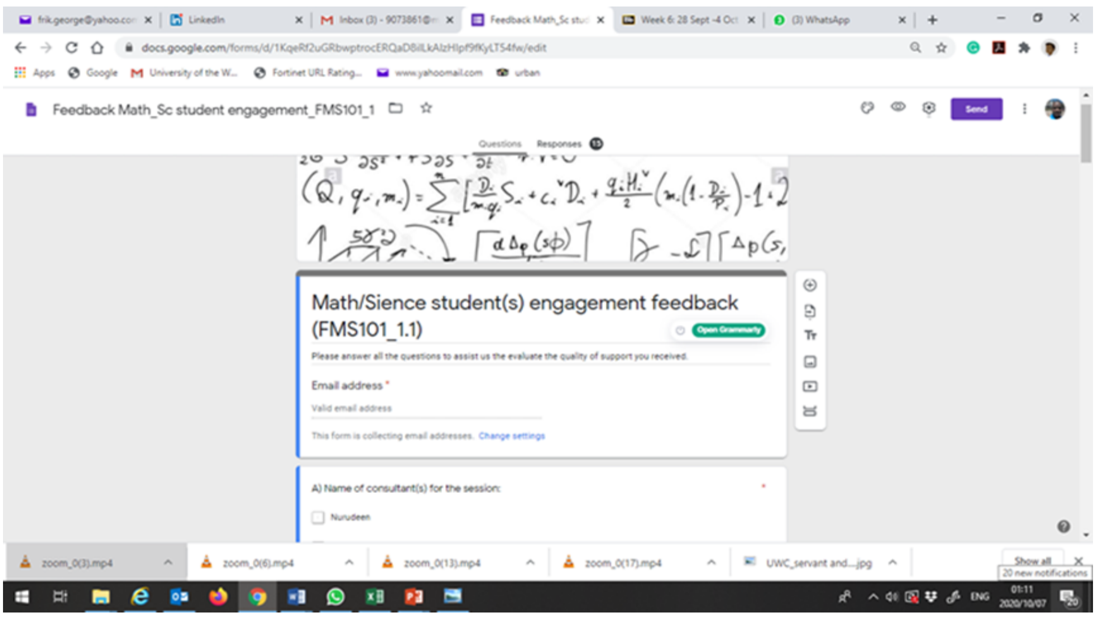

Figure 6: Google form for feedback

The students also used an e-textbook with the WebAssign online platform for self-study, submission of assignments and assessment. During both the face-to-face and online instruction, the educator used dialectic questioning to probe students' knowledge (Black & Wiliam, 2009). The educator also used the Dialogical Argumentation and Assessment for Learning Instructional Model (DAAFLIM) to stimulate discussion and constantly assess students' progress, thereby ensuring that they were responsive to the teaching and learning process (George et al., 2019). Students used a threaded electronic discussion board during online lessons to take part in the presentations and provide responses. Figure 7 represents a screenshot during an online lesson on vectors.

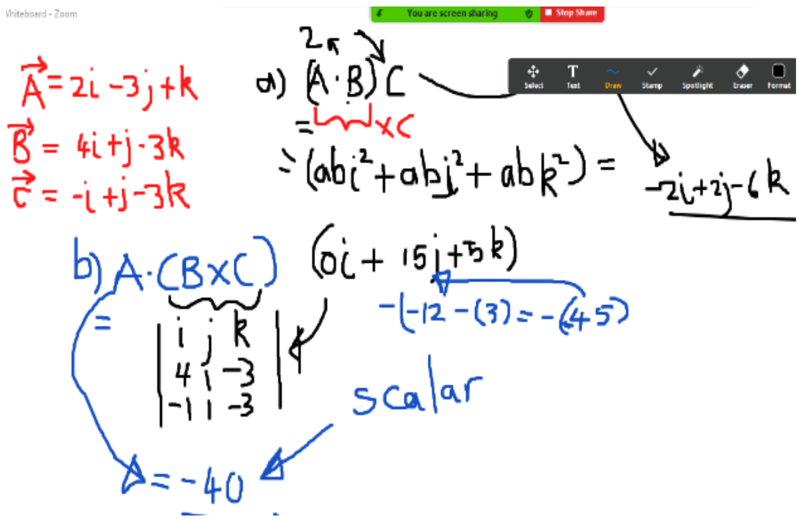

Figure 7: Screenshot of a Zoom presentation of a lecture on Vectors

During this lesson, the lecturer assessed the students' conception of the vector and scalar product. The problem was shared with the students before the online session to solve on their own. During the online session, the whiteboard was shared with the students who worked collaboratively to solve the problem. Students used different colour annotations and the microphone to contribute and explain their understanding/ solution of the problem. All the students can provide their responses in a chat-box, which the lecturer used to stimulate discussion. After the lesson, the students provided feedback via Google Jamboard; one of the responses was, "I loved the interaction of the other students, they made the session lively!"

Table 3: Comparing assignment scores in F2F and online environments

Statistics	F2F environment			Online environment		
	Ass. 1 Ave score (%)	**Ass. 2 Ave score (%)**	**Ass. 3 Ave score (%)**	**Ass.4 Ave score (%)**	**Ass. 5 Ave score (%)**	**Ass. 6 Ave score (%)**
Mean	36 (60%)	34 (57%) 35.7 (59%)	37 (62%)	35 (58%)	40 (67%) 39.3(66%)	43 (72%)
Difference			3.6 (6%)			

N = 36; Maximum score of assignments = 60

Table 3 compares the students' performance scores in assignments conducted during face-to-face and online multimodal environments. The mean scores of the different teaching and learning formats indicate that the students performed better in the online environment, with an average difference of 6%. Closer analysis reveals that the students' performance increased gradually over time for both environments, with the exception of Assignment 1. The gradual improvement of assignment scores in both environments can probably be attributed to the fact that students gradually acquire familiarity with a particular mode of instruction. However, the steady improvement appears to be greater during the online environment. Therefore, it is reasonably safe to conclude that the overall difference in performance during the F2F and online environments can be attributed to the innovative online multimodal teaching and learning approach.

IMPLICATIONS AND RECOMMENDATIONS

This paper compared the F2F and online multimodal teaching and learning environments in terms of students' performance. The data show that the online multimodal environment produced better results in learning compare to F2F learning. Therefore, it is suggested that some key elements employ various modes of online teaching explicitly and deliberately in the classroom. Online multimodal teaching is, of course, not limited to the engineering mathematics classroom and can profitably be introduced in other disciplines. This paper has not attempted to develop concrete strategies for teaching mathematics, instead, the paper should be read as an invitation to engineering educators who teach mathematics to consider the potential of the multimodal approach presented here and to more complex mathematical problems during online activities. The paper provides the basis for understanding the potential of online multimodal learning modes for teaching abstract and calculation-based subjects such as mathematics.

CONCLUSION

This study will prove of interest to researchers interested in supporting national STEM education reform efforts, particularly those interested in designing innovative instructional methodologies for implementation on both a small and a large scale. Moreover, the study provides a tangible example of how online multimodal teaching can help teachers evaluate their students' knowledge-in-use and ensure that it is coherent with learning objectives, both in the classroom and in a virtual setting. This approach has profound implications for how educators organise their instructional methodologies to support learning.

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PANDEMIC AND UNCHARTED NEW NORMAL: MOOCS, SERIOUS GAMES AND ONLINE LEARNING COMMUNITIES TO SUPPORT HYBRID CLASSROOMS

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ABSTRACT

The paper outlines the INSYSTED pedagogical framework and the participatory process based on actual university courses that led to it.

It will then discuss the relevance of the INSYSTED pedagogical framework to the European context. To this end, the paper takes stock of current developments by integrating insights from a variety of sources in terms of research and grey literature, complemented with the outcomes of targeted contacts with teachers. In many universities the pandemic led to hybrid delivery modes, with some students attending in the classroom and others participating at the same time remotely online, basically via videoconference; this resulted in an online extension of the physical classroom that blurs the boundaries between physical and online learning spaces.

Finally, the paper will elaborate some key points to give an account of available information, so that it feeds into instructions to operationalise the INSYSTED pedagogical framework. The aim is to maximise the relevance of this approach to the current pandemic and to the uncharted "new normal".

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1 INTRODUCTION

This paper explores the added value of using MOOCs, serious games and forum-based online learning communities in view of the developments boosted in higher education by COVID-19 pandemic. The aim is to make the most of the pedagogical framework developed by the EU-funded INSYSTED project (Giannatelli & Tomasini, 2020), whose distinctive features are instrumental in promoting student-centred approaches suited to foster soft and digital skills and internationalisation, with a special focus on industrial and management engineering education.

That is what happened in a nutshell: the vast majority of European universities closed their campuses in March 2020 and moved online in April and May due to the COVID-19 crisis: according to the European University Association (2020), 95% pivoted to distance learning throughout the institution. This sudden and unplanned shift to online learning has led faculty and non-academic staff to use new tools, even if already in 2013 almost all higher education institutions offered some kind of digitally enhanced learning (Gaebel et al., 2021).

HEIs and international organisations published online resources to manage teaching and learning during COVID-19[3]. The situation seemed to be exceptional but transitory, with a response to the unpredictable circumstances that could not always be aligned with the usual quality of pedagogy (Hodges et al., 2020); currently HEIs are experiencing adjustment and systematization to handle the prolonged pandemic with a view to post-COVID recovery.

2 DESIGN AND RATIONALE

This paper investigates the elements that are emerging as pivotal to operationalise the integration of MOOCs, serious games and forum-based online learning communities into curricular higher education in a blended learning setting: the aim is to reasonably maximise the relevance of the INSYSTED approach both to the current COVID-19 crisis and to the uncharted "new normal".

As the situation has not stabilised yet, the paper takes a pragmatic approach and surveys a variety of relevant sources in terms of research and grey literature such as reports and tutorials, complemented with the outcomes of targeted direct contacts and ad-hoc consulting to faculty during the pandemic. Special attention is devoted to literature regarding the European context produced after the pandemic outbreak.

By reviewing evidence and insights, the paper takes stock of current developments that have an impact on the integration of MOOCs, serious games and forum-based online learning communities in the wake of COVID-19. The pivotal elements

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[3] Examples include European University Association (EUA), *Resources for digital learning and teaching during the coronavirus pandemic*; Resources for online teaching from European universities https://empower.eadtu.eu/coronacrisis; Educause https://library.educause.edu/topics/information-technology-management-and-leadership/covid-19 , but also Commonwealth of Learning (COL), UNESCO, OCDE.

surveyed in the paper are expected to feed into the operationalisation of the INSYSTED pedagogical framework in the following project outputs.[4]

3 THE INSYSTED APPROACH

The INSYSTED approach was devised to be flexible so that it can be applied to a whole course, a course section or a single lesson; it aims to support the design from scratch and the (re)design of learning opportunities by blending face-to-face instruction with online activities underpinned by these pillars: MOOCs, serious games and forum-based online learning communities. The pillars can make students engage more actively, so that they foster their soft and digital skills and develop their ability to act in ways that resemble those of experts in the engineering field (authentic learning), hence increasing their preparedness for the challenges of a rapidly evolving labour market.

A distinctive feature of the INSYSTED approach is that it leverages the expertise of Alliance4Tech partner universities in defining relevant Intended Learning Outcomes (ILOs) that students are expected to achieve in order to direct the (re-)design of learning opportunities: ILOs are based on actual university courses and can refer not only to the knowledge and skills concerning course topics, but also to soft and digital skills that are somewhat implied.

The challenges emerged from the pandemic give value to the INSYSTED approach because:

- soft and digital skills were proven to be crucial to make the most of digitally-enabled courses that ensure teaching continuity; actually according to a questionnaire to institutional leadership for EUA DIGI-HE project (Gaebel et al., 2021), digital skills are not fully embedded in the compulsory offer of HEIs but need to be reckoned with in curricula and learning outcomes for a more systematic use of digital learning; considering students per se as digitally competent is misleading, as some of them have only limited experience in digital learning (Steffens et al., 2017; Aristovnik et al., 2020);
- the prolonged pandemic sparked universities' reflection on renewed models of internationalisation at home (Coimbra Group, 2020);
- MOOCs, serious games and forum-based online learning communities can offer sustainable ways to complement internationalisation as they are accessible independently of physical location.

In addition to that, students that are accustomed to learner-centred approaches seemed to cope better with the digital semester during the pandemic in Germany (German Centrum für Hochschulentwicklung - CHE, 2020); literature review suggests that student-centred learning approaches are promising at the cross-roads

[4] The INSYSTED project (http://www.alliance4tech.eu/insysted/) is expected to develop staff training events and a manual for faculty and non-academic staff to support longer term integration strategies of MOOCs, serious games and forum-based online learning communities in an international context.

between mathematics and engineering education and that the actual use of videos of online courses and simulations by engineering students is a direction for future research (Pepin et al., 2021). Recent research (Campos et al., 2020; Langer et al., 2021) explores the use of serious games in the areas of engineering, science, and management in on-campus, online and blended settings in Europe.

4 BLENDED AND HYBRID LEARNING

Operationally we can define "blended" a course that is designed so that some in-class time is substituted by equally meaningful online activities, with online components being not an addition to the full course load but a purposeful substitution of some in-class activities[5].

Blended learning can be operationalised with different levels of sophistication, but it is important to consider that its very context evolved during the pandemic: course delivery modes serving both on-campus and online students gained momentum, with some students attending in the classroom and others participating at the same time remotely online, basically via videoconference. These modes are generally referred to as hybrid learning; they catched on due to COVID-19, as they allow to reduce the number of people in the classroom as a sanitary precaution, and support participation of persons with a condition preventing them from on-campus attendance.

"Blended" and "hybrid" are complex and blurred concepts that were and sometimes are still used as synonyms: in the INSYSTED approach "hybrid" refers mainly to the modalities of accessing classes, with learners alternating between on-campus and online participation modes at the same time with various degrees of choice (Irvine, 2020; The Quality Assurance Agency for Higher Education, 2020; Beatty, 2019). In this new context "hybrid" indicates constituents distinctively at once, changing the notion of learning space (Cohen et al., 2020). Generally in French this concept is designated as *formation comodale* ("apprentissage hybride" means blended learning); in German as *Hybrid-Lehre* or *hybride Lehre*; at Politecnico di Milano it is referred to as *classe estesa*.

There are variations to how hybrid learning works, with options in-between, such as the instructor deciding that groups alternate on campus so that all students participate in person to some classes, or students choosing each week which modality suits them best. Terms such as blended synchronous, mixed-mode, dual-mode, multi-modal, multi-access, synchromodal, hybrid-flexible (HyFlex) / comodal, Here or There (HOT) share the notion of instruction which combines online and on-campus students at the same time.

By way of illustration, due to the pandemic the University of Edimburgh outlined some bare-bones prototypes for hybrid teaching (Bayne, 2020), Université Toulouse

[5] https://tlss.uottawa.ca/site/what-is-a-blended-course

III published hybrid learning scenarios (Université Toulouse III, 2020) and Universität Göttingen described some operational options to organise student attendance[6].

It is worth noting that students are experiencing a wide variety of disruptions, as some of them are not on campus anymore and are connecting from environments that might not be conducive to learning because of defective equipment and no high-quality internet connection; furthermore some international students have returned home, in countries sometimes in different timezones and/or with limited or blocked access to foreign internet tools.

Due to the above-mentioned context, this paper outlines the implications for classes that accommodate students participating in diverse modalities, especially on-campus and online at the same time (hybrid synchnous learning).

5 INSYSTED IN CONTEXT

Let's explore how the INSYSTED approach can be fine-tuned for hybrid synchnous learning by considering the emerging pivotal elements to take the synchronous / asynchronous dichotomy beneficially on board:

- equity in course participation;
- student engagement;
- balance between synchronous and asynchronous interaction.

5.1 Equity in course participation

As literature seems to argue, it is crucial to ensure that students have access to an equitable learning experience independently of the modality they are using to access it. That implies to cater for the needs of both students that are on campus and students that participate online synchronously. Actually it is worth considering that teaching on-campus and remote students at the same time requires preparation and organisation as it entails multitasking: instructors need not only to teach on-campus and online students at the same time, but also to operate technology and facilitate interaction between the two cohorts; typically a crucial issue is to manage the audio in the physical space so that those participating via video conferencing can hear properly. Some tools allow to create sub-meetings within a videoconference meeting for smaller groups of participants to collaborate and have discussions (breakout rooms). A study from Malmö university (Leijon & Lundgren, 2019) outlines some challenges in terms of teacher communication within the different spaces and physical interactions within the campus room.

The workload for teachers to prepare lessons might be considerably higher than for usual in-person formats (Seyfeli et al., 2020): more detailed planning is needed to design the possible interactions among the different cohorts of students and among students and materials. One way to mitigate the load on individual teachers is to employ one or more teaching assistants (Bower et al., 2015).

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[6] https://www.uni-goettingen.de/de/632946.html#collapse-info-2-01

As an emerging practice, hybrid synchronous education especially needs to be increased empirical investigation to complement the qualitative case studies (Raes et al., 2019). An Australian research on dual mode approach amongst students undertaking a statistics course in an Australian university, face-to face against online study (Soesmanto & Bonner, 2019), found no significant difference in academic performance, achieved through consistent course delivery and teaching strategies. Another study (Binnewies & Wang, 2019) reports the HyFlex course design used at two campuses of an Australian university, emphasizing the design factors and instructional practices successfully implemented to assure student equity and student engagement in the learning process.

Examples of strategies recommended in European universities to help students keep at pace include providing (e.g. on the LMS) a course schedule with associated tasks and deliverables expected from students (Wylie et al., 2020) and providing a weekly outline/summary with key points to remember and links to assigned readings and resources (École Polytechnique Fédérale de Lausanne, 2020a).

Considering all of that, to make the most of the INSYSTED approach also in a hybrid context, it is important to identify the ILOs and the Teaching Learning Activities to achieve them that can be (re)used across on-campus and off-campus participation modes, with a portion carried out asynchronously, such as question-and-answer sessions in class upon previous exposure to targeted MOOC content at home, mindmapping or diagram-labelling tasks or peer evaluation activities launched in class and to be completed asynchronously in the forum-based online learning community, exercises to apply knowledge through the serious game.

5.2 Student engagement

Student engagement is integral to the INSYSTED approach as it supports active learning pedagogies where learners participate in the instructional process beyond listening and taking notes. Nevertheless, promoting engagement in a hybrid setting deserves some scrutiny. Dietrich et al., 2020 present the lessons learned from the feedback from students and teachers who participated in the lockdown semester of two different groups of a 5-year program in Chemistry, Environment and Chemical Engineering at INSA Toulouse (France): considering international students, who were more isolated and less equipped than most other students; unlocking new technologies and quizzes during videoconferences to motivate learners, offering regular question/answer sessions to guide students or give and receive feedback and implementing support materials such as videos so that students can apply their knowledge before the final assessment. Similar suggestions also emerge from Raes literature review (Raes et al., 2019).

Providing opportunities for learners to give peer feedback is also an effective way of empowering and motivating students and, if properly designed, to reduce teacher workload (Wylie et al., 2020). Some research in collaborative group assessment seems to suggest that students are capable of judging peers' performance accurately when the mark is not counted towards the final grade, but tend to be overly generous when their mark is counted towards their final grade (Sridharan et al., 2019). Louvain learning lab offers some reflections about promoting active behaviours in students by expecting “visible productions” from them, that require to manipulate information (e.g. by taking notes on a video and writing a summary), to transform it (e.g. by synthesising a video, organising it in a chart /mindmap), to discuss/debate it (e.g. by highlighting the links / implications of a specific topic for professional life) (Docq, 2020). Louvain learning lab provides additional food for thought with the ICAP model (Chi & Wylie, 2014) which connects the engagement modes of students with their learning level, gradually going from surface learning to in-depth learning. This model enables instructors to fine-tune the design of teaching activities and to have a more global overview of cognitive engagement modes they can elicit in their students.

Other examples of strategies recommended in European universities to keep students engaged entail scheduling weekly live sessions for students to ask their questions (École Polytechnique Fédérale de Lausanne, 2020a) and setting milestones (such as regular submission of exercises, or mid-term take home tests) to give feedback on learning. Choosing questions that are complex enough so that answers are not already available online because they have multiple correct answers, which require some written explanation, or which use freshly available datasets reduces the risk of cheating in an unsupervised setting (École Polytechnique Fédérale de Lausanne, 2020b).

5.3 Balance between synchronous and asynchronous interaction

As the hybrid setting serves on-campus and online students, it is important to balance distance online collaboration in synchronous mode during classes, that implies a risk of cognitive overload, and in asynchronous mode, that is conducive to developing responsibility and autonomy by students. Some research in blended synchronous learning highlights the importance of designing for active learning and possible challenges related to heightened levels of cognitive load for teachers and students (Bower et al., 2015).

Examples of strategies include using asynchronous communication tools such as discussion forums to increase students’ engagement (McGee & Reis, 2012) and to scaffold knowledge construction activities through communication with and among students that is permanently available for consultation.

Zydney et al. (2019) suggest to build hybrid synchronous sessions upon asynchronous activities (e.g. readings or performing exercises) from a flipped classroom approach, which lends itself because of the duality of places and modes it implies (in class / at home; synchronous/asynchronous). A concrete example of synchronous session is reported by Heiss and Oxley (Heiss & Oxley, 2021) from a quantitative analysis course where teamwork activity on different portions of a multi-part question has been conducted assigning different roles to each team member to increase engagement.

However, a US-based research (Muñoz et al., 2021) claims that many students in flipped classes during the pandemic have difficulty with self-regulation and keeping up with course materials without a grade incentive; many low-stakes grade incentives interspersed throughout the course can ensure that students learn and benefit from engaging with course materials throughout the term.

Research (Bower et al., 2014; Bower et al., 2015) suggests that permitting backchannel communication during synchronous sessions, by using a live feed (e.g. videconference text chat) enables everyone to ask their questions and to see other students' questions, with multiple simultaneous non-interfering contributions; strategies to visually identify questions from the rest of the live feed can be used and students can be asked to answer their peers, hence potentially fostering peer interaction within and across attendance modes and reducing the instructor's burden.

The INSYSTED approach supports the combination of synchnonous activities with asynchronous activities through the forum-based online learning community; again, accurate planning is needed to reckon with the implications of synchnous activities with students participating both in person and online at the same time.

6 CONCLUSIONS AND TAKE-HOME MESSAGES

How will higher education move forward after the pandemic? It is far too early to come to a conclusion, but it is possible to identify some hints for further in-depth reflection. The exploration of the practices that are gaining momentum during the pandemic seems to suggest that the INSYSTED approach is beneficially adaptable to the new paradigms of course delivery.

Considering the sources surveyed in this paper, blended learning formats are here to stay and to be extended (Bergan et al., 2021; European Higher Education Area and Bologna Process, 2020), as long as they cater for more individualised and flexible learning opportunities complementing in-person teaching and international student mobility (Coimbra Group, 2020; Hudzik, 2020); other prospective elements include increased focus on the flipped classroom and on learning spaces (Farnell et al., 2021; Ackeren, 2020).

Equity in course participation, student engagement and balance between synchronous and asynchronous activities are pivotal in integrating the INSYSTED approach into a hybrid setting; nevertheless ad-hoc reflection and further investigation are needed to calibrate them according to each specific context: as context is key, no size fits nobody.

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COMPETENCE DEVELOPMENT THROUGH ONLINE SELF-ASSESSMENT

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ABSTRACT

Self-regulation and self-assessment are essential skills in the development of competences in engineering education in general, and more specifically, to educate future generations of industrial designers. We created an online *Competence Development Tool*, a competence chart, and implemented this tool in the blended-learning course *Exploratory Sketching*, an elective course for Industrial Design (ID) students at the Eindhoven University of Technology (TU/e). The purpose of the *Competence Development Tool* was to encourage students' sketching skills development by setting personal learning goals and regularly self-assessing the progress. An experiment was conducted in two phases with two students' cohorts. This experiment shows the importance of providing online feedback to make students' development insightful and to support self-directed learning in engineering education.

1 INTRODUCTION

The integration of technology in education has become a common practice in higher education to increase students' learning. Research on online and blended-alike methods has shown interesting insights on effectiveness in learning, in students' achievement, to activate students during lectures [1], to facilitate students' assessment [2], and to foster collaborative knowledge construction [3]. Likewise, self-assessment supported by online methods has been proved to be suitable to encourage students to take more responsibility for the learning process. There are, however, less evidences regarding students' course performance (2011) [4].

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In this study, we explore how an online *Competence Development Tool* (CDT) chart can influence students' attitudes to self-assess regularly own competencies to enhance learning and boost self-directed learning in engineers. We conducted a number of experiments with the use of the CDT with students. During the first experiment, the *Competence Development Tool* was tested with N=52 first year students to analyse behavioural patterns in competence development along 8 weeks. This experiment was repeated three times with subsequent cohorts in different quartiles. The number of students participating in the consecutive three studies consisted of N=46, N=50 and N=43 respectively. Results indicate a positive effect on reflection that support self-assessment. In addition, a study on the relation between attendance and grades indicated that students attending the lessons regularly influences study results. However, when reviewing the students' grades or course achievement no impact is observed. Moreover, the responsible teacher for the course was positive about the developments of students and used the tool to monitor progress and distribute personal feedback effectively over the student population.

2 THEORETICAL INSIGHTS

Research on digital education collects relevant findings about the integration of tools combined with online or blended methods in education. In these studies, it is described how the combination of, for instance, online platforms with peer assessment is used successfully to learn skills [2]. Other studies report about positive effects of flexibilization of education, specifically on the increased students' motivation, on in-depth understanding and critical thinking supported by technology-driven assessment [5]. The use of technology in classroom facilitates not only the transfer of responsibility but also encourages a critical attitude in students to assess own progress and process. Additional benefits of organizing assessment with the help of technology lies in that assessment can be carried out any time in any place while the teacher can still follow students' progress and performance and provide feedback.

Literature reports about interesting insights in learning with the use of self-assessment through online methods. These studies point out the importance of the shift in the teacher's role and indicate positive values in the transfer of responsibility from the teacher to the students towards learning and developing competencies [8]. Assessment for learning increases students' involvement and responsibility in own progress, so that the can re-orient and adjust learning and learning habits influencing the thinking process as well [6-7].Hattie and Timperley (2007) [8-9] describe the benefits of formative feedback as part of assessment for learning and reflect upon the importance of focusing on task, process and on the self as key elements in learning. 'Just-in-time' feedback becomes essential in this regard to continuously evaluate progress and encourage students' self-regulation. As a 'safe control' mechanism, it helps adjust learning habits potentially influencing course achievements [10], although the success of self-assessment lies in the quality of feedback provided to the student [11].

In learning students to assess own progress critically the notion of self-regulated learning is central [12]. Self-regulated learning implies a reflection on actions which includes metacognitive knowledge, regulation of cognition and motivation by understanding the knowledge and skills to be acquired with the purpose of adjusting study behavior, learning strategies, goals and activities [12]. In this process, the feedback from the teacher (environmental stimuli) is crucial to help students cope and adjust own learning strategies.

Following the rationale to educate new generations of engineers, the need to promote self-directed learning through encouraging students to critically assess themselves' competencies and learning progress becomes essential. We believe that online systems well supported by feedback can stimulate students' self-evaluation inferring in self-regulation.

3 RATIONALE FOR INNOVATION AND EXPERIMENTATION

Within the Industrial Design program students develop a broad set of competencies and learn how and when to combine them effectively. To successfully develop their competencies it is important that students are aware of all sub-competencies involved, understand when to apply them during the learning process and eventually within the creative process.

The rationale for self-assessment and reflection in this course has a two-fold goal: on the one hand, students are encouraged to critically think on their development by using the criteria on quality of sketching; on the other hand, they reflect upon achievements and adjust progress in a self-directed manner. Another important aspect of this rationale is the experimentation with blended and online forms of education. In addition, the purpose was to get an insight on whether the tools are sufficient to effectively supervise students' competency development.

Ultimately, the intention to run these pilots was to experiment with newly designed online feedback and competency development tools as suitable instruments to facilitate students' competencies development and progress.

3.1 Research questions

Research on benefits of quality of feedback also with the support of digital self-assessment platforms abound in the literature. However, it is less known to what extent the quality of feedback could motivate and engage students in order to self-assess their own sketching skills. For the purpose of this study, we focus on the following research questions:

1. To what extent does the online *Competence Development Tool* enhance learning and motivate students to self-assess progress of sketching skills development?
2. What are students' perceptions about the self-assessment online *Competence Development Tool as a* suitable method to enhance competence development?

The assumption for this study was that the self-assessment online *Competence Development Tool* chart would make students aware of the multi-faceted nature and the various aspects involved in developing a competent level of sketching skills. We also assumed that it would stimulate students to frequently reflect about progress and monitor own development so that students would carry out the necessary adjustments and improvements against achieving the ambitions on personal learning goals.

4 INSTRUCTIONAL DESIGN

Exploratory Sketching is a hands-on first year elective course at the department of Industrial Design. The course is taught every quarter and it is also open to students from the other engineering departments as well, for instance, Mechanical Engineering and Built Environment departments.

The learning outcomes of the *Exploratory Sketching* course aim at helping students develop sketching skills as a tool to explore, develop and communicate ideas and concepts. In the elective course *Exploratory Sketching* students develop their sketching skills compiling a number of sub-competencies such as fluency, accuracy, line quality, perspective and rendering techniques. The sub-competencies are first trained individually and later in a more integrated fashion. Furthermore, expert just-in-time feedback (by teachers) is also included in the course as a key in the successful training and development of the Industrial Design students' ability to critique and improve their own work.

The course consists of 5 ECTS (total 140 hours) and it is divided in 8 workshops of a total number of 16 hours, accompanied by 58 videos (13 hours) distributed along the 8 weeks-contact time course. In addition, this course relies on a strong self-study component which includes 111 hours. During the self-study component students complete weekly assignments wherein they apply insights and knowledge from the accompanying course content on Sketchdrive. The content is structured around a series of topics and themes aimed at building up the skill of sketching by training and integrating the individual sub-competencies in a controlled manner. These topics are *setting the mind, to draw is to see, linear products, cylindrical products, combined products, complex geometry, redesign and setting the scene.* With the last two topics students will start using the combination of all previously trained sub-competencies and acquired insights in the context of a creative design challenge. Furthermore, the self-study time opens up opportunities not only to work on assignments. It also enhances students to self-assess themselves by monitoring and evaluating own competences and reflect on achievements. In this course, Teacher Assistants (TAs) support the teacher with both logistic and content-wise activities.

4.1 E-leaning approach for the *Exploratory Sketching* course design

The design of the Exploratory Sketching course has evolved in several stages. Starting out with a traditional on-campus lectures and workshops format the hands-on course was initially supplemented by a teacher blog and individual student blogs on Wordpress. This blended-learning set-up included as well the use of flip-the-classroom as an educational approach so that students would spend time in preparing course content during the self-study time before attending the lectures and workshops. In this regard, students would have more time for deep questions, peer interaction and hands-on assignments during contact hours where the teachers can also provide direct and qualitative feedback.

Additionally, students were requested to maintain an online portfolio on the Sketchdrive platform to document their work and progress. This new format facilitated self-paced and collaborative learning, a-synchronous teacher feedback (Figure 1) as well as peer feedback on individual student work.

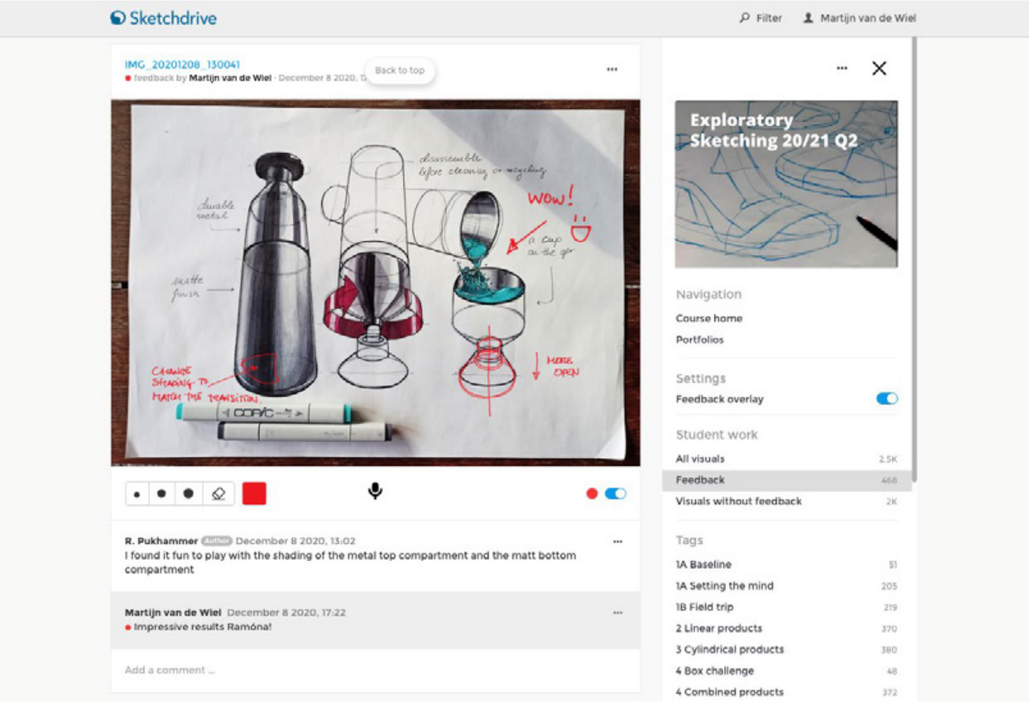


Figure 1. Example of teacher feedback on the Sketchdrive platform.

With the break-out of the COVID-19 pandemic worldwide and the Corona regulations at the TU/e university, teachers were involved in a rapid transformation process of education from on-campus to online and urgent remote type of education. The fact that the Exploratory Sketching course already had a blended-learning set-up allowed the teacher to swiftly transform the course into a fully online and remote format. Weekly workshops were now hosted remotely via a live video connection and used for group reflection, peer review, collective challenges and live feedback.
By providing this elective (partially) online students were no longer bound by time and location and they are free to set their own pace and work on the course's assignments from anywhere. Additionally, a series of optional workshops were offered online when extra guidance was needed. This format potentially created opportunities to scale up student enrollment for this popular elective, made hands-on education available online, opened enrollment to other departments and reduced the need (and cost) to reserve physical facilities. To support the teacher in giving weekly personalized feedback on the students' work online two additional Teacher Assistants became essential.

With the lack of face-to-face interaction and the need for just-in-time feedback, additional online tools were added to the online set-up of this course in addition to the already existing online material developed in the blended-learning version of the course, the digital portfolios, assignments and online resource materials.

4.2 *Competence Development Tool* (CDT) chart

An online *Competence Development Tool* (CDT) chart was integrated in the course with the purpose of stimulating self-assessment students' development of sketching skills. The CDT consisted of nine criteria, i.e. confidence, accuracy, line quality, perspective, rendering, exploring, communicating, personal style, and shading) relevant for students to acquire and develop in the course (See Figure 2). The tool also includes 5 levels of expertise being 1 – Novice, 2- Advanced beginner, 3 – Competent, 4- Professional, and 5 – Master, against which students can score themselves. The students are asked in week 1 to make an estimation of the level of development or ambition expected to reach by the end of the course. In the example, the orange line shows the scored expected ambition of the student in week 1. The blue shading indicates the weekly growth in sketching competences. In addition, the CDT allows for additional creation of criteria in case students would like to challenge themselves with regards to other abilities. The purpose is to stimulate students to regularly assess the progress by themselves as well to encourage the possibility to adjust the learning curve to optimize the sketching skills.

Students fill out this chart at the start and the end of the elective to keep a record, set personal goals and reflect on the progress they make in learning. However, an online competence development tool becomes essential to foster self-directed learning and to help all staff and students structure the learning path at the ID department but also at other TU/e departments. With this tool a lecturer can create an overview of the (sub-) competencies involved and can monitor and guide the individual ambitions for each student.

5 METHODOLOGY

5.1 Research set-up and approach

The research has been carried out in two phasis including two different cohorts and four different groups.

Phase 1 – Research on the suitability of the *Competence Development Tool* chart to enhance self-assessment by visualizing the individual weekly development. This experiment was conducted with the students' cohort 2019/2020.

Phase 2 – The *Competence Development Tool* chart was again tested to research the impact of this tool on students' course performance. This experiment was carried out with students' cohort 2020/2021 in three different quartiles of the year. Slight changes were made to better explain the criteria and the different levels on the chart to ensure an optimal use of the tool in setting personal goals and documenting progress. We also switched to a bi-weekly schedule for recording the progress on the charts to make the progress more visible.

5.1.1 Participants

Students attending the *Exploratory Sketching* course in quartile 4 in academic year 2019/2020 and in quartile 3 in academic year 2020/2021 (See Table 1 and 2) took part in the quantitative as well as in the qualitative research.

Table 1. Quantitative research: Overview cohorts, students' comments collected and interviews

Students' cohorts	N= students attending the course	N= students' comments
Quartile 4 2019/2020	N= 52 students	N= 15
Quartile 1 2020/2021	N= 46 students	N= 5
Quartile 2 2020/2021	N = 50 students	N= 8
Quartile 3 2020/2021	N = 43 students	N= 5

Table 2. Qualitative research: overview students' cohorts and number students' interviews

Students' cohorts	Individual interviews
Quartile 4 2019/2020	N=7
Quartile 3 2020/2021	N=5

5.2 Research method

5.2.1 Quantitative research

During phase 1 of this study, a quantitative research was conducted. It consisted of the registration and analysis of the students' progress of the weekly competencies' development. The registration of parameters allowed for a weekly quantitative visualization of the level of achievement (See Figure 3 average of all students) against the ambitions that students stated at the beginning of the course. In addition, we also compared students' course performance in two quartiles, by analyzing the students' grades (Figures 4 and 5). The rationale was to understand whether there is a relation between attendance and students' grades. Finally, students' satisfaction was collected through the formal course evaluation filled in by the students as part of the quality assurance system of the department.

5.2.2 Qualitative research

Moreover, a qualitative study was carried out with limited number of students attending the *Exploratory Sketching* course. Comments from students from both cohorts quartile 4 in academic year 2019/2020 and students of quartile 1, 2 and 3 in academic year 2020/2021 were collected. In addition, in-depth interviews took place with a limited number of students to understand better the added values of the CDT chart.

5 RESULTS

In this section we present the results of the two research questions we formulated for this study.

RQ1 - To what extent does the online *Competence Development Tool* enhance learning and motivate students to self-assess progress of sketching skills development?

We collected the average of students' progress represented in the graph below (See Figure 3). In this graph the horizontal lines show the average of the students' ambitions regarding the nine sketching skills in different colors. The diagonal lines indicate the average in growth in sketching skills development of the students participating in this study. The scale is based on a 10,000 (low) to 40,000 (high) values, and it is based on students' weekly self-evaluation. The values are collected every week to gain an overview on progress. As appreciated in the graph the lines including the skills steadily grow per week along the 10-week course. Despite the constant growth none of the skills achieve the average ambitions of the students of cohort 2019/2020. This result reveals that there is growth in competencies' development in all skills being Confidence and Perspective the most developed ones while Custom and Personal Style are the less developed ones. Reasons for that is that Confidence "*grows as you practice you get reinforcement and you become better in your competences…",* says a student. Custom and Personal Style are less developed as *Personal Style is a skill you acquire along years and not only at once, and Custom is difficult to translate products in your personalized ones,* according to some students.

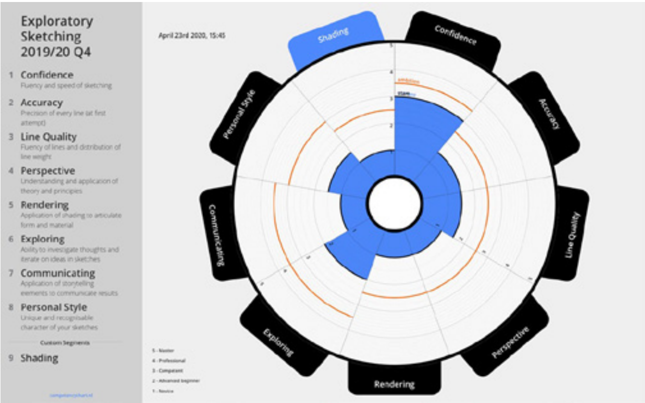


Figure 2. Competence Development Tool chart

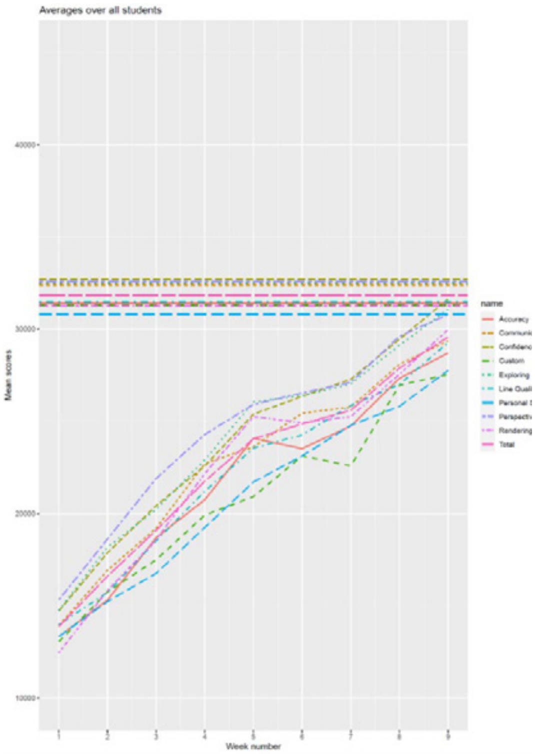
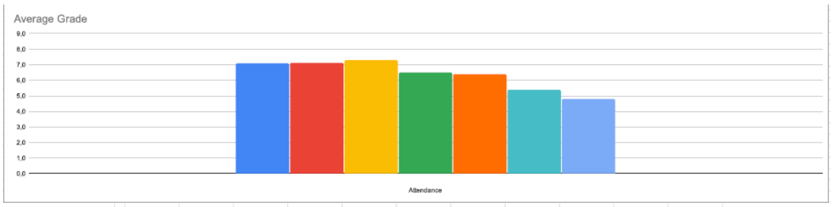


Figure 3. Average students' growth in sketching competencies progress

In addition, we collected students' comments from two cohorts on the CDT. Comments are positive about the added value of the CDT "*Thanks to the competence chart, I was able to see my improvement and therefore gain more motivation to improve"; "After knowing the different competencies, I worked on them all very hard and I managed to hit most of my initial goals"; "I liked the competence chart as a means of visualizing your ambitions for different sketching skills. The chart also reminded me that you do not have to focus on every skill in every sketch. I developed most skills about as much as I would have liked during this course"; "By keeping my progress in the competence chart, I was able to see which competencies I had to improve in (perspective) and in which I was already quite good (e.g. communicating)'.* Also, taking a look to the percentage of the ambitions reached, we can confirm that most of the students providing these comments reached between 60% to 100% their ambitions.

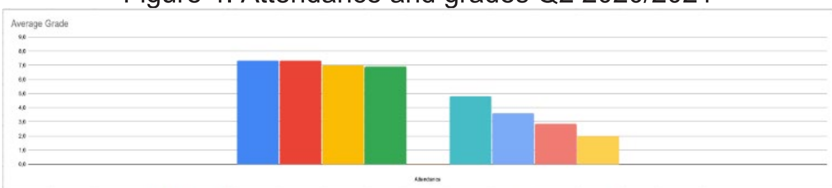
Moreover, we also interviewed students to find out how they have experienced the CDT chart. All students agree on the benefits of this tool as development becomes visual and insightful and helps reflect upon actions. For some students the tool helped "*looking at the skills from different angles. It provides a progression in perspective and help think critically about what still needs to be done to adjust to reach goals and ambitions*", said students. Some students overestimated themselves and therefore, the CDT chart supported in realizing the gaps to bridge by getting a better understanding of how it grows throughout the weeks. Also, the fact that the tool allows for other additions to the criteria, helps look individually but holistically to the personalized development of the student. The tool, however, was considered to have some shortcomings as it was not clear what the scales represent and what the levels from beginner through professional or master really mean.

Regarding the influence of the self-assessment on sketching skills on quality of sketches or course achievement, we cannot draw a relation between the effect of the CDT and the quality of students' sketches and sketching skills. We are however careful to make a relation between the attendance to the course sessions and the students' grades being higher grades for students attending more sessions (See Figures 4 and 5). High attendance also correlated with a more intensive use of the CDT, but it is still unclear how these two factors influenced each other.



ATTENDANCE: #SESSIONS	8	7	6	5	4	3	2	1	0
AVERAGE GRADE			7,1	7,1	7,3	6,5	6,4	5,4	4,8

Figure 4. Attendance and grades Q2 2020/2021



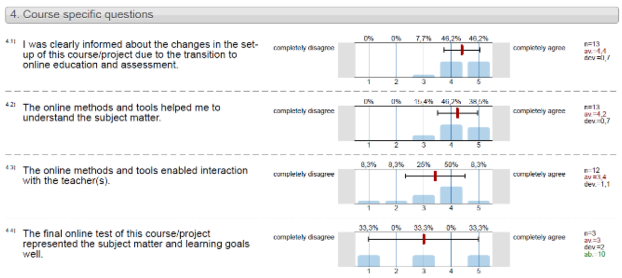
ATTENDANCE: #SESSIONS	8	7	6	5	4	3	2	1	0
AVERAGE GRADE	7,3	7,3	7,0	6,9	0,0	4,8	3,6	2,9	2,0

Figure 5. Attendance and grades Q3 2020/2021

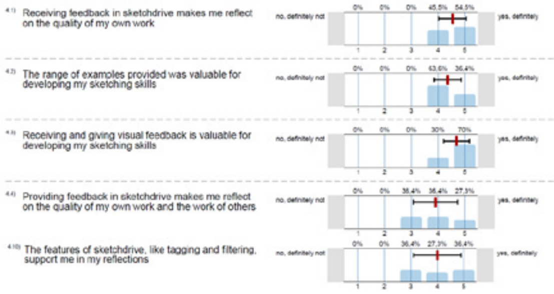
The teacher mentioned a positive effect according to the dashboard variables that allowed to monitor the overall progress and address students for improvement based on individual levels and progress. This made it possible to prioritize feedback on students that reported little progress by checking in on their portfolio on Sketchdrive first.

RQ2 – What are students' perceptions about the self-assessment online *Competence Development Tool a* suitable method to enhance competence development?

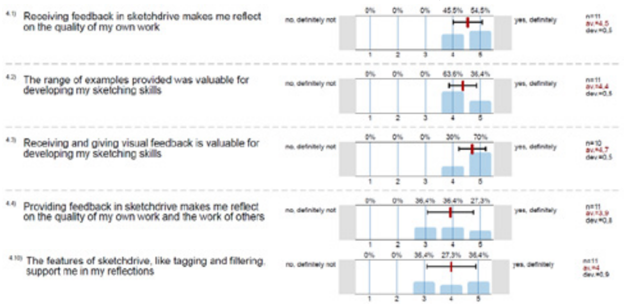
We collected the students' perceptions through the formal course's evaluations. The quality assurance system of the department and at the whole TU/e consists of evaluations that includes both open questions and Likert-scale 1 (low) to 5 (high) questionnaires. Students filled in the survey at the end of each course. As appreciate in Figure 6, students from different cohorts were positive the online methods used in this course. Students appreciated highly the feedback received from the teacher and from the tool as it helps reflect and adjust study behavior and evaluate quality of own work.



Cohort 2019/2020 – Q4



Cohort 2020/2021 Q1



Cohort 2020/2021 Q2

Cohort 2020/2021 Q3

Figure 6. Students' perceptions on online methods used in this course

6 CONCLUSIONS

This study has been conducted to explore the effects of online tools that support students' self-assessment and stimulate the development of competences. Results of this study are positive and indicate the added value of the online *Competence Development Tool* chart. Students indicate that the CDT stimulates regular revision of own progress by self-assessing the development of the sketching competences. However, students pointed out that the CDT still needs to be adjusted as the scale degrees (i.e. beginner, competent, advanced, professional and master) and the description of what is expected from each competences are to be added to facilitate better understanding and use of the tool.

The results of this study add value to the body of knowledge regarding self-assessment and motivation for students to take actions regarding own progress. It shows commonalities with the insights of the research literature. As the findings in research, we argue that online feedback can be of great benefit to enhance students' development of competences, in this case, relevant to develop the sketching skills of future generations of Industrial Designers. Finally, this study sheds light on self-directed learning as a metacognitive skills crucial in engineering education that contributes to build the capacity of future engineers.

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CHANGING TO THE BETTER? EXPERIENCES FROM TURNING A HANDS-ON INNOVATION COURSE INTO AN ONLINE COURSE

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***Conference Key Areas**: Please select two Conference Key Topics*
***Keywords**: online innovation teaching*

ABSTRACT

During the times of Covid-19 and the different degrees of lockdowns, we had to rethink central elements in a hands-on experiential course on innovation and cross-disciplinary teamwork, turning it into a fully online course or blending a few physical campus activities with online elements.

In this concept paper, we report on and reflect on our experiences, experiments, and learnings from transforming a hands-on experiential course on innovation and cross-disciplinary teamwork into a fully online course or blending a few physical campus activities with online elements during the Covid 19 lockdown.

The paper builds on three full course runs from spring 2020, summer 2020, winter 2020, and a fourth run started up in spring 2021.

Our experience, challenges, experiments, learnings, and reflections are organized into six themes; prototypes and prototyping, collaboration within the team, collaboration with external partners and data collection, online team formation, the facilitation process, and the presentation of the solution to the company.

Among others, the results include experiences like this: Without having access to campus and workshops, the students worked with a broader range of prototypes and

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created more of them during the innovation process. This experience draws more attention to the prototyping process than the prototype itself and highlights the learning potential for more iterations than just one version of the solution. The paper includes similar examples and reflections for all six themes.

We discuss what we can learn from these experiences and which elements are relevant to maintain and develop further in a post-corona setup. The discussion also includes which initiatives are needed to support further development and implementation of these elements both from a course organizing perspective and a learning-enhancing perspective.

1 INTRODUCTION

1.1 Background

During Covid-19 and the different degrees of lockdowns, we – a teaching and organizing team of three - had to rethink central elements in a hands-on experiential learning course on innovation and cross-disciplinary teamwork and turn it into a fully online course or blending a few physical campus activities with online elements.

Experiential learning is about learning from experience and training skills through actions and reflection on the experience [1]. This is a learning process that is designed for the students to learn from natural consequences, mistakes and successes and emphasizes the opportunities for the students to take initiatives and learn by doing by being actively involved in the experience [2],[3]. During the lock-down the conditions for ensuring this was clearly challenges and limited.

This concept paper report on and reflect over our experiences, experiments, and learnings from this transformation. The paper builds on three full course runs from spring 2020, summer 2020, winter 2020, and a fourth run started up in spring 2021.

Our experiences, challenges, experiments, learnings, and reflections are organized into six themes; prototypes and prototyping, collaboration within the team, collaboration with external partners and data collection, online team formation, the facilitation process, and the presentation of the solution to the company.

1) Prototypes and prototyping in an online setting. Not having access to campus and workshops, we saw the students using a broader range of prototypes and creating more of them during the innovation process. This experience draws more attention to the prototyping process than the prototype itself.

2) The lockdowns created a need for finding new ways of collaborating within the student teams. The students could not meet in person, which naturally entailed moving the teamwork to online platforms. This draws attention to how teamwork and student learning can be supported in a (partially) online environment.

3) When not being able to meet in person, both students and participating company partners had to be creative to arrange company visits, user interviews, and observations, and so forth. This experience opened up to new types of collaboration being more independent of time and place due to online collaborations

4) Online team formation emphasizing diversity, team roles, competencies, and motivation still had to be carried out despite limitations on the number of students who could meet physically. This challenged the pre-Covid19 set up in the course. The course coordinators had to experiment with different online group formation formats.

5) Changes in the way the facilitation process unfolded due to an online or partially online format. A key element in the course is the facilitation of teamwork by collaboration with teaching assistants and lecturers. Moving this to an online format created several challenges concerning the level and the depth of interaction with the different teams.

6) A final experience has been concerned with changing the delivery format of the student's solution to the company. Here it was decided to move the presentations into a video format instead of a live pitch.

1.2 Course context

The course context for the experiences we report on in this paper is a multidisciplinary innovation course offered to Bachelor of Engineering students at The Technical University of Denmark. The course is a hands-on experiential course involving real-life cases provided by a large number of companies. The course is focused on teaching and training an innovative mind set and enabling students to participate in innovation processes and organize and implement a multidisciplinary innovation process using relevant innovation models and methods. The course is a mandatory element in 18 study programs and placed in the last part of the study programs. [1]

The outline for the course is that the students work in multidisciplinary teams with specific real-life challenges offered by the involved companies. The companies provide open-ended projects, which take a starting point in actual challenges observed by the company. 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. [2] Coming from different study programs, the students do often not know each other before forming the teams they work in.

Students are expected to research the problem during the course by doing observations, site visits, and interviews with relevant actors such as users, customers, experts, problem owners, etc. Thus, the course allows for a high degree of interaction and collaboration between students and external partners, but also among students themselves. Moreover, central elements in the course are pitching and prototyping solutions in campus workshops.

Due to the course's interactive, outgoing, and hands-on character, course activities and collaborations were rethought to nevertheless still reach the course's learning goals during lockdown times.

2 METHODOLOGY

The paper builds on three full course runs from spring 2020, summer 2020, fall 2020, and a fourth run started up in spring 2021.

The semester courses (spring and fall) runs once a week for 13 weeks with about 250 –350 students and 20-25 companies. The summer course is an intensive 6-week course with about 150 students and 6 companies.

We have experienced different degrees of lockdown during these four course runs and implemented many initiatives and refinements in response to the lockdown situation. Since the first lockdown, lectures, meetings, supervisions, etc., have been offered online, making it possible to follow and participate in the course online; however, some sessions have been offered physical whenever possible with an online option.

A summary is below:

Course Term	Lock Down	Initiatives
Spring 2020	Startup as usual Complete lockdown halfway through the semester	Online collaboration in teams and with external partners Video pitch Online DEMO Day Prototyping with no access to workshops
Summer 2020	No lockdown Social distancing and restrictions on gathering (max 50 people together)	Group formation: face-to-face combined with preselection and questionnaires Mixed collaboration (online/physical) in teams and with external partners Video pitch Online DEMO Day Prototyping with limited or no access to workshops
Fall 2020	No lockdown Social distancing and restrictions on gathering (max 50 people together) Lockdown by the end of the semester	Group formation: face-to-face combined with preselection and questionnaires Mixed collaboration (online/physical) in teams and with external partners Formal and pre-scheduled facilitation meetings Video pitch Online DEMO Day

		Prototyping with limited or no access to workshops
Spring 2021	Lockdown throughout the course. Limited re-opening by the end of the course.	Online group formation Online collaboration in teams and with external partners Formal and pre-scheduled facilitation meetings Video pitch Online DEMO Day Prototyping with limited access to workshops

The paper focuses on lessons learned and identifies patterns in our experiences rather than a detailed analysis of the implemented initiatives. In the section below, we report on the experiences from the different types of initiatives.

3 RESULTS

In the following sections, we will briefly go through our significant observations and experiences emerging from the transition from a physical to an online format of the course.

3.1 Prototypes and Prototyping

During the close-downs, the students had little or no access to campuses and the workshops and labs. This challenged the students' work with prototyping and prototypes. Developing prototypes is a critical element in the course as the students are expected to develop prototypes and use the prototypes to test and validate their solutions with users and other stakeholders. In the pre-covid-19 setup, the students would often spend considerable time in the prototype lab creating elaborate prototypes - 3D-printing was a preferred tool for creating prototypes. There would often be several iterations involved in the prototyping process - both from user feedback and working with the prototype itself.

Limited or no access to workshops and labs forced the students to change how they worked with prototypes and prototyping. To a large extent, we observed that students moved away from developing physical prototypes and began to develop "simpler" prototypes using digital and virtual means. In many cases, these digital and virtual prototypes were simpler and more focused on the customers' general use instead of demonstrating concrete product features. Furthermore, as discussed later in the paper, the students were also forced to engage with users and other stakeholders in non-physical manners due to covid-19 restrictions. These developments resulted in the students developing a larger number of prototypes and engaging users in new digital ways. The students were able to spend more time validating their prototypes instead of refining the prototypes

3.2 New ways of collaborating within the teams

As a result of the close-downs and the associated limits on the number of students who could meet, they had to find new ways of collaborating within their teams. The students quickly managed to move their activities to different digital platforms – for example, Zoom, MS Teams, and Discord. Naturally, many teams needed time to adjust to the new situation. However, most teams were able to continue their teamwork without significant disruptions.

Not being able to meet physically created many challenges for the teams concerning collaboration and coordination. Before the covid-19 lockdown, a lot of collaboration and coordination was done informally during the physical teamwork at the campus. The teams had to focus more on a structured approach to the distribution of work within the teams and also on following up on this. Many teams had to formalize their work processes, knowledge sharing, and coordination mechanisms. This formalization entailed using project management tools to keep track of activities, using log-books to capture major events and insights, and appointing a project manager. In many teams, this role of project manager was temporary and shifted from week to week. Finally, the groups that had spent time together during the start of the course found it easier to shift to digital collaboration.

3.3 Working with external partners in new ways

The third observation concerns the collaboration with external partners and informants. A vital element of the course is that the students and their teams should "get out of the building" to meet their company contacts, users, customers, experts, and so forth. Furthermore, the students should ideally do user observations as well as testing their solutions with prospective users. This collaboration is considered essential for the quality of the solutions developed by the students. Furthermore, the collaboration with external partners is vital for the knowledge creation by the students during their work on the company challenges.

Again, not meeting in person challenged this interaction. Data collection from external partners was difficult. Our observations have shown that the students managed to migrate to new formats for collaborating independent of time and place by drawing on digital platforms. However, the limited "bandwidth" connected with digital interaction provided challenges in some cases. It was not easy to do observations and interact closely with users. As discussed, in connection with prototyping, it was more challenging to get feedback from users. It also proved to be difficult to engage some users due to concerns about the risk of infection. Finally, it was observed that it is easier for users to dismiss contacts from student teams when they were being approached through a digital channel. The "depth" of answers from and discussions with external partners seemed to become smaller when using a digital platform for the interaction. On the other hand, some teams also found they could reach out to a larger and more diverse group of external partners as they were unbound by time and place. Social Media Platforms were used more to reach and engage the users. Some companies managed to run live video feeds of a walkthrough of their production, replacing physical meetings.

3.4 Online team formation

In non-covid times the course commenced with a team formation process whereby the students selected which company challenge to work on and formed teams of 5-6 students. This process was a physical process where all students were present and interacted with each other. A key element in the team formation was a "speed-dating" process to physically meet fellow students they did not know beforehand. It is a requirement for the team formation that the students form inter-disciplinary teams with a maximum of two students from the same study line. As part of the team formation process, the students should also align their expectations to their desired grade in the course and discuss their professional and personal competencies.

The covid-19 restrictions forced the course coordinators to rethink this interactive process and change it to an online format. In this online format, the student firstly would pick the company challenge they would prefer to work on. Following this, the students should form teams. Here the students were to fill in a digital tag with their name, personality type based on the Meyers Briggs test (for example, ISTP-I), preferred team role (based on a Belbin test), task preference (product, technology, project management, team or business), and line of study. The students were then asked to place their tags in an online document (in MS Teams). The course's facilitators supervised the process to ensure that the formal requirements were met, i.e., that the teams were interdisciplinary and that there was an appropriate mix of personality types and team roles within the teams. This online process of team formation proved to be successful, and it did relieve some of the stress that had been associated with the in-person pre-covid-19 physical team formation processes. We have not observed any differences in the teams and the quality of their work due to this change in the team formation process. There has not been observed an increase in the amount of conflict within the teams either.

3.5 The facilitation process

The fifth observation is concerned with the facilitation process. In the pre-covid-19 runs of the course, facilitation has largely been ad-hoc and informal - student teams and facilitators interacting several times a day, often due to the facilitator dropping in on a team. Naturally, there have formal meetings between facilitators and teams in connection with critical milestones. However, most of the contact was based on both teams and facilitators being present at campus and the opportunities for interaction created by this. During covid-19, the opportunities for physical interaction became limited and non-existent at some points in time.

The meeting activities between teams and facilitators (both the formal and the informal) had to move online. A key observation from the facilitators was that many student teams were reluctant to interact with facilitators ad hoc online, and the facilitators often lost track of the teams as they moved their activities to digital platforms outside the ones recommended by the course coordinators – activities were moved to, for example, Discord or Miro. As such, the facilitation process needed to be formalized, and it has been necessary to increase the number of scheduled meetings with the teams significantly to compensate for the loss of informal ad-hoc interactions at the campus.

3.6 Changing the delivery format

A final element, which has been changed as the result of covid-19, is the delivery format. Usually, the students would present their solution in a joint public poster session where the team would show/demonstrate their solution and in a pitch session where the team would pitch their solution to a panel including facilitators and company representatives. These sessions would entail that up to 300 persons were gathered in on location. It has therefore been necessary to rethink these sessions. It was decided to transform the delivery format to video.

The poster session has been replaced with a video gallery where all teams upload a short video pitch presenting their solution. The video gallery is in a closed you-tube channel which only is open to the persons involved in the course. The pitch session has been maintained, even though it has been transformed into an online format where teams show their video pitch and receive feedback on their solution. It has been observed that the teams approach the task of producing a video in a variety of ways – some teams use a PowerPoint presentation with voice over other teams are making small films of very high quality. This change in the course has, in general, been well received by all involved in the course. Creating videos is a valuable skill for the students since more and more content on the internet is videos.

3.7 Summary of the results

In the table below, our observations have been summarized.

Table 1. Summary of the results

Element:	Observations:
Prototypes and prototyping	- Simpler and more digital prototypes - Increased focus on the overall use of the solution - Less focus on detailed product features
Collaborating within the teams	- Easy to move collaboration to digital platforms - More formalization and structure within the project work
Working with external partners	- Difficult to establish a close collaboration with external partners - Lacking depth in answers from external contacts - Possible to reach out to a larger and more diverse group of externals, especially through Social Media channels

Team formation	- Successfully moved to a digital format - Digital format less stressful for some students - No increase in conflicts within the teams
Facilitation process	- More structured (less ad-hoc) facilitation process - Increase in formalized meetings
Delivery format	- Successful change to a video pitch format

4 DISCUSSION

At first sight, transferring a hands-on experimental course into an online course with limited physical interaction between students, external partners, and stakeholders, and only limited access to workshops, seemed like an emergency action that would usually call for cancellation.

However, to our own surprise the result was better than expected especially with regard to the course's practice-oriented nature. It showed that going online and introducing more digital tools opened op to new ways of collaborating, to new learnings and to new ways of accessing empirical data and knowledge in the student teams and project work.

Many of the initiatives that was developed and introduced during these four "pandemic" course runs, will be maintained and developed further in the future course runs as well as looking more in to the students' experience and learning outcomes due to these changes. Especially looking more into our observations on prototypes and prototyping and the shift in focus from the (technical) prototype to the prototyping process and the overall solution when access to workshops was limited. The team formation process and use of the digital format is also worth looking more into with regards to how it can support the students awareness of own role in a team and the general discomfort many students experience with team formation processes.

During the past year many new experiences and experiments with online teaching have been made. In this case being forced to go online and rethink the course has been a welcome provocation and a nice opportunity to break away from existing behaviors and idiosyncrasies on how to teach and train innovation, and try out new learning elements that we otherwise might have postponed or been reluctant to.

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PACE – PEDAGOGY FOR ACADEMIC COLLEGE ENGINEERING - NEW VARIANTS ON HYBRID LEARNING

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ABSTRACT

Education methodology is a constantly developing field. From kindergarten to academy new methods and approaches are suggested almost daily. Many of the methods are excellent for some age ranges but have no advantage for others. In this paper we scan through the main pedagogies used in the academy for engineering education and focus on the advantages and disadvantages of the flipped classroom. Next, we target the asymmetry problem of the Flipped Classroom and suggest several novelties we call PACE (Pedagogy for Academic College Engineering). First, we suggest a periodic approach for teaching (the Sine-wave approach), we will show that this approach corrects the main problem of the Flipped Classroom but might be over-symmetric. Next, we suggest an improvement in a new non-symmetric approach (the Sinc-function approach). Finally, the previous learning method portrayed by an even function will be replaced by an approach portrayed by an odd function (the signed-Sinc approach). While the Sine-wave approach allows perfect symmetry between on-campus and off campus activities (or between lecturer responsibilities and students responsibilities), the Sinc-function approach requires more time on-campus and more responsibility falls in the lap of the lecturer. The signed-Sinc approach regains the temporal symmetry between on-campus and off-campus activity by generating asymmetry between pre-lecture and post-lecture activities. All these new approaches are explained in detail in terms of benefits and disadvantages, thus allowing the college lecturer to use either of these methods or to transform them into his own.

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1 INTRODUCTION

1.1 General Background

In recent years, much work was directed at engineering education research [1-6]. New methodologies were suggested and there was a wide understanding that the classical approach of frontal theoretical lectures on-campus and exercise assignments off-campus must change. Some approaches suggested incorporating distant learning into the curriculum [7-9], this approach was adopted by many academies around the world due to the COVID-19 plague. Other approaches suggested a flipped classroom [10-12] where the students are expected to study the theory off-campus and the on-campus activity should become a more interactive practical discussion with the lecturer, we will elaborate on this approach in the next subsection. Different researchers suggested a combination of distant learning, flipped classroom, project-based learning (PBL) [13-16] and other methodologies in a framework called hybrid-learning or blended-learning [17-19]. In the next section we look closer at the concept of the flipped classroom, try to understand its pros and cons, and establish motivation for novel pedagogies.

1.2 The Flipped Classroom

The flipped classroom was first introduced by Bergmann and Sams in 2012, in the context of high-school chemistry teaching. The concept was later adopted in various degrees of education from kindergarten to academy. One of the possible implementations of the flipped classroom is shown in Figure 1.

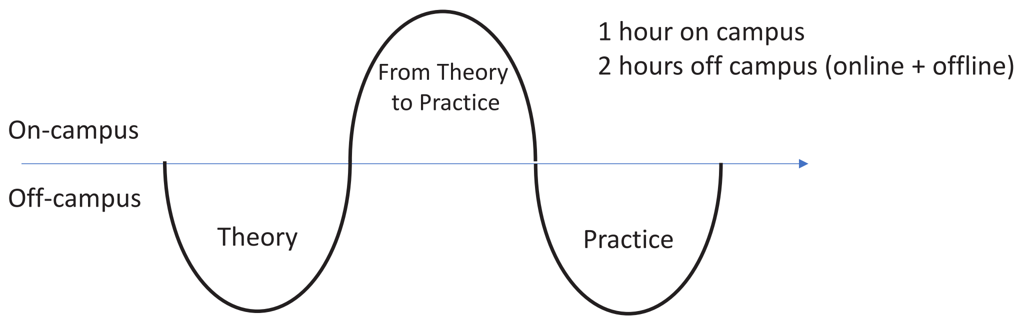

Fig. 1. Model for the flipped classroom teaching method for a single session.

As seen in Figure 1, before the lecturer meets the students, they must read the theoretical material (and perhaps watch clips on the net or prepare some preliminary exercises). Next, the lecturer meets the students on-campus and they discuss the applications of the theory and solve practical problems together, where the lecturer serves as a coach rather than a teacher. After the lecture, the students return home and prepare off-campus assignment (either analytical exercises or practical mini-projects).

This seems like a refreshing change from the somewhat outdated classical pedagogy. However, this is true when addressing a single session. when we observe two successive sessions along the timeline, as In Figure 2, we begin to see the problem.

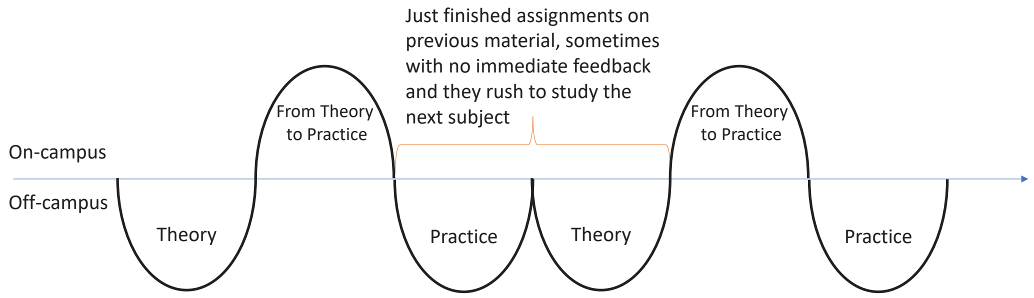

Fig. 2. Model for the flipped classroom teaching method for two successive sessions.

In the third step, shown in Figure 2, the students have just finished practicing the previous subject and they must start reading the theory of the following subject without getting a real feedback from the lecturer on the previous work. This way if a student failed to understand a single subject, he/she might be trapped in a loop of not understanding the following subjects, and off-campus feedback might just not be sufficient. Thus, the lack of symmetry between on-campus and off-campus activities might generate a problem. When referring to periphery College students whose ability to face the material alone without guidance is much smaller than that of University students this becomes a huge drawback.

In the next section, the author suggests several alterations to the classical flipped classroom pedagogy in order to adjust it to the periphery College students.

2 NEW PEDAGOGY FOR ACADEMIC COLLEGE ENGINEERING (PACE)

In this section we demonstrate several novel pedagogies that are all related to academic studies in peripheral Engineering Colleges. All the following are adjustments that may be used in other establishments but are most appropriate for teaching a bachelor's degree in engineering in small Colleges in the periphery where most students have slightly lower high-school achievements than those who attend the Universities. We call these methods of teaching (and learning) Pedagogy of Academic College Engineering, or PACE for short.

2.1 The Sine Wave Model

First, one has to correct the un-symmetry of the original flipped classroom model. The College students need more on-campus time with the lecturer to fully understand the material. To do this the author suggests adding an extra on-campus meeting to each session as shown in Figure 3a.

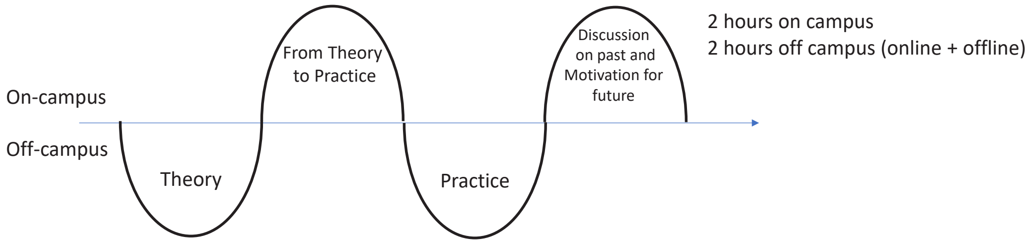

Fig. 3a. The Sine wave model for a single session.

As shown in the model, the off-campus practice is followed by an extra on-campus meeting with the lecturer where he/she discusses the expected outcomes of the off-campus practice and draws a line from the session just finished to the one that will start next, by giving the students motivation and direction before they return home to study the theory of the following session. This way, the students and lecturer discuss issues on assignments and conclude on previous material before the lecturer gives a brief motivation for next subject.

If we look at several successive sessions as in Figure 3b, we can see the resemblance of the model to a Sine wave, giving the model its name.

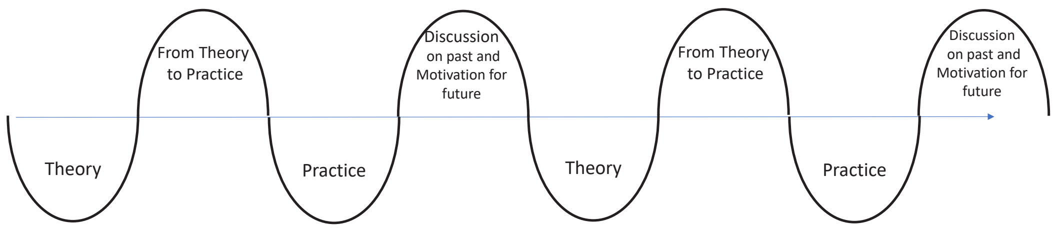

Fig. 3b. The Sine wave model for two successive sessions.

Unfortunately, reality is not fully symmetric and the time the students need for pre lecture off-campus studies is not equal to the time they need for post lecture off-campus studies; thus, a correction must be made.

2.2 The Sinc Model

The standard classical teaching approach requires 1 hour off-campus for every 1 hour on-campus, original flipped classroom requires 2 hours off-campus for every 1 hour on-campus and the Sine wave model requires 2 hours off-campus for every 2 hours on-campus. However, most College students in the periphery work for a living during the studies and many of them are already raising their own families, so they have less time on their hand. For this reason, a new time-division method must be used to transfer more activity to the campus without harming the quality of learning. To do this the author suggests to uses a slightly non-symmetric approach as shown in figure 4a.

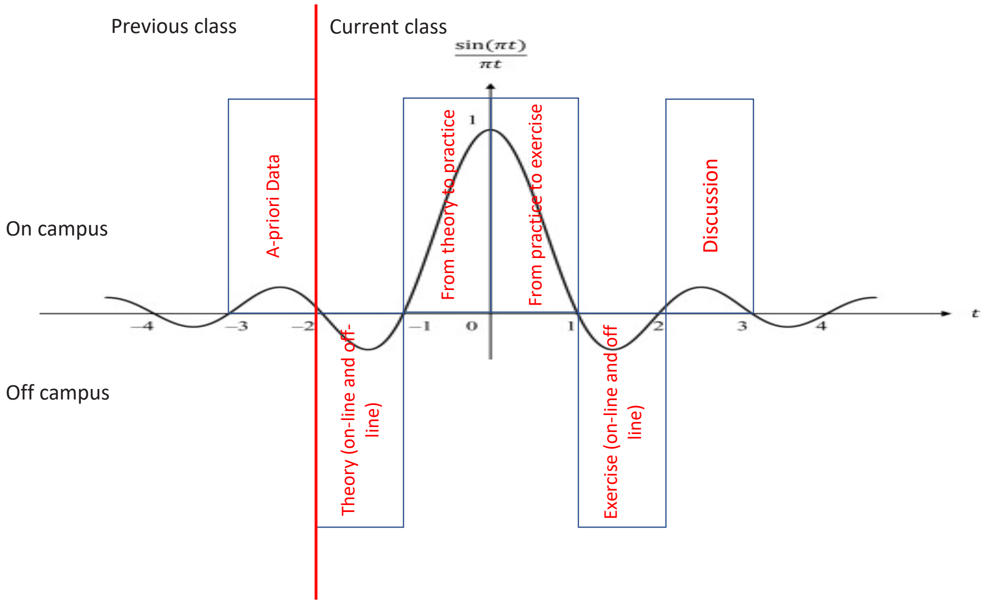

Fig. 4a. The Sinc model for a single session.

As shown in the figure, the timeline is now divided into six nonsymmetric regions. First the lecturer meets the students for a short introduction on the upcoming subjects. Then, the student return home and read (or view) the theoretical background. Next, the lecturer and students meet on campus for a long session divided into two parts. In the first part the lecturer and students discuss the theory and give examples, in the second part the students try to solve various problems that might have been given as home assignments in other circumstances. The lecturer serves as a guide in this sub-session, directing the students rather then telling them the solutions. At the end of the 2nd part the lecturer gives the students guidelines for solving the homework assignments. In the next step, 5th in total, the students solve small scale problems off-campus, and at the final stage the lecturer meets the students for a short session where he/she explains what was expected in the assignments.

When looking at the shape of the model we can see something similar to a Sine over its argument (SA) function, as in Equation 1.

$$SA(x) = \frac{Sin(x)}{x} \tag{1}$$

Since we are talking about engineering students, who prefer to use the Sinc function given in Equation 2, we call this model the Sinc Model.

$$Sinc(x) = \frac{Sin(\pi x)}{\pi x} \tag{2}$$

In Figure 4b one can see several successive sessions. When looking at several sessions, one can understand that the course must begin with an on-campus short meeting where the lecturer describes the course's syllabus and pedagogy and gives primary motivation before the first off-campus task. One can also notice that not only the two large-scale on-campus meeting can be combined into one extensive meeting, but also the two smaller sub-sessions of Discussion and A-priori data can be combined into one single meeting.

In the Sinc model, most studying is done on-campus, thus the lecturer must use a large percent of the time for small group discussions and problem solving. But what if the lecturer can't divide the class to small groups for discussions and problem solving? E.g., a class of 200 students (very hard to monitor and access all the groups or even to find a lecture hall) or only 2 hours on-campus meeting with students (not enough time for real discussion and deductive reasoning.). In such a case, we need a different approach as depicted in the next subsection.

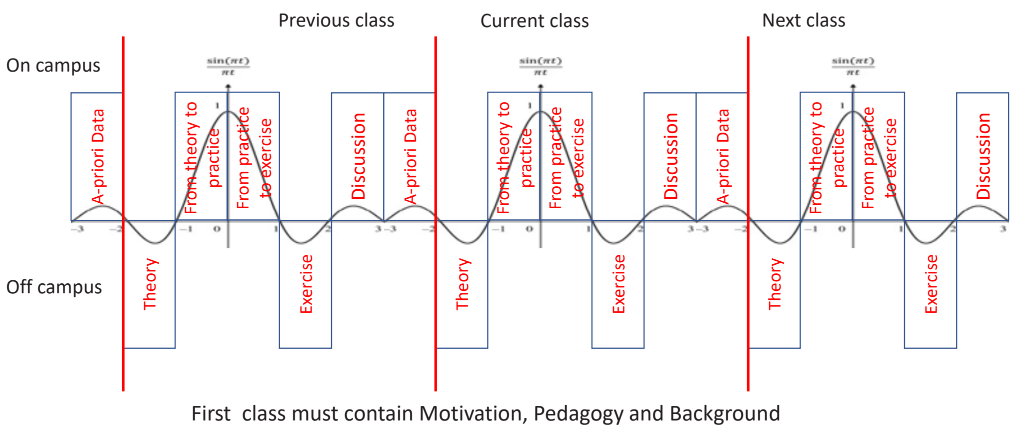

Fig. 4b. The Sinc model for three successive sessions.

2.3 The Signed-Sinc Model

We are looking for a variation in the model to allow more symmetric time division between on-campus and off-campus activity in case significant part of the practice must be off-campus either offline or online. Since the time required for obtaining theoretical background is expected to be smaller than the time required for post-lecture exercise and since the time required for the lecturer to convert theoretical knowledge to practical knowledge is expected to be larger than the time required for post-lecture discussion, the author suggest the model shown in Figure 5a.

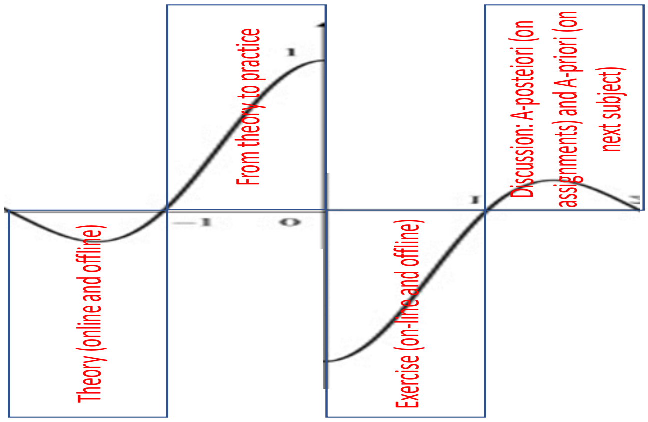

Fig. 5a. The Signed-Sinc model for a single session.

Since the model appears to be similar to the Sinc model with the exception that the right half is the inverse of the left half, we call this a Signed-Sinc model. When considering several successive sessions, we obtain the diagram shown in Figure 5b.

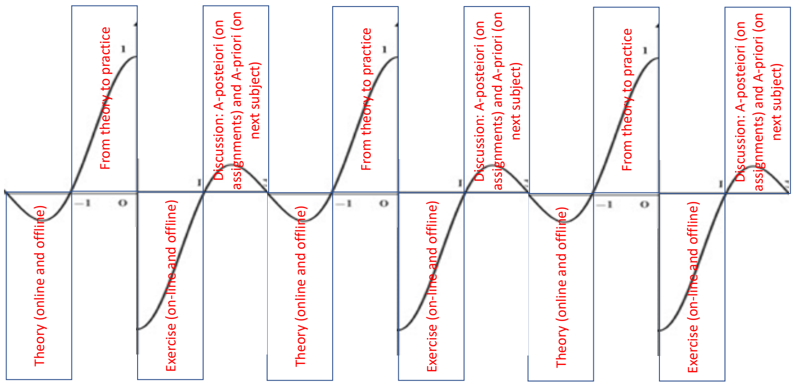

Fig. 5b. The Signed-Sinc model for several successive sessions.

Since the ending of one session is actually the beginning of the following session, Figure 5b can be redrawn as in Figure 5c to demonstrate the flow of the entire course. As shown in the diagram, the first meeting on-campus is used for defining the pedagogy, giving an introduction and a-priori motivation for first subject. During the semester the students build (physically or virtually, depending on the course) a small-scale project, and at the end of each session they can add a new part to that project. The Signed-Sinc model will be presented to the “2021 Innovation in Engineering Education” Forum at the author's College as a preferred option to improve teaching and learning potential.

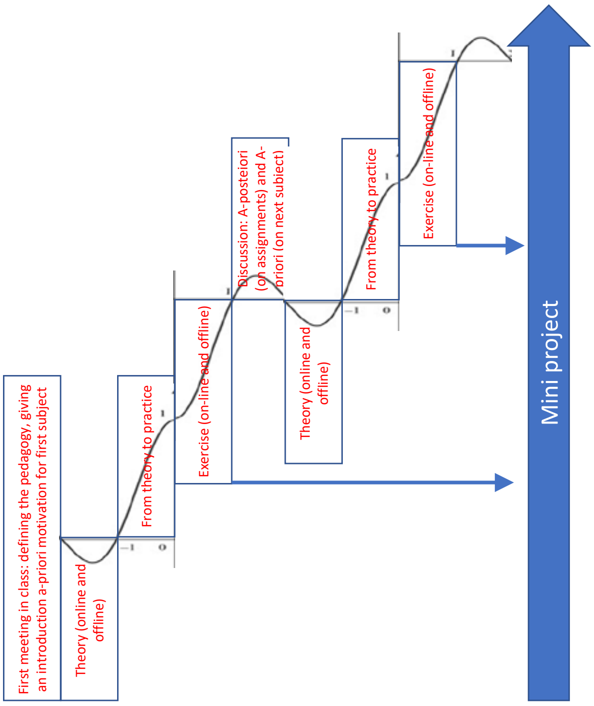

Fig. 5c. The Signed-Sinc model for several successive sessions.

In all the three suggested models (Sine, Sinc and Signed-Sinc) the curriculum requires a 2 meetings per week scenario (or that each session lasts two weeks). In case were a session lasts only one week and there is only one weekly on-campus meeting we suggest a slightly altered version of the Sinc approach, shown in Figure 5d. in this approach the discussion and motivation are given on-line via Zoom. A summation of all methods suggested in this paper is given in Table 1, as different methodologies might be suitable for different establishments or courses.

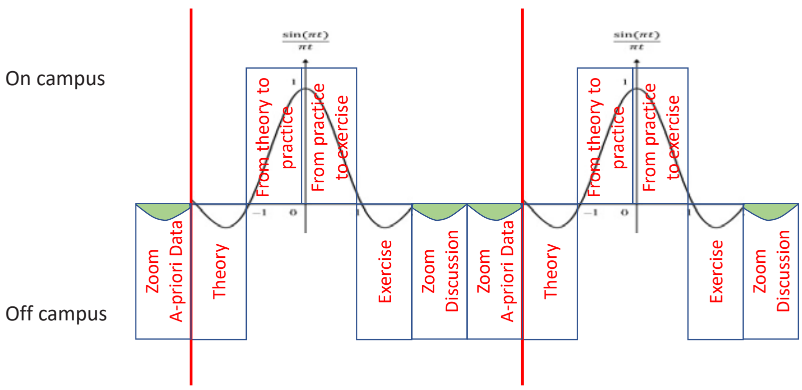

Fig. 5d. A revised Sinc model for single weekly on-campus courses.

Table 1. Comparison of PACE models

Pedagogy	Advantages	Disadvantages	Best for…
Classical Flipped Classroom	Meaningful on-campus activity	Requires a lot of self-preparations off-campus	Students that have twice as much time off-campus than on-campus
Sine	Symmetry between on and off campus activity	Pre and post lecture activities are not balanced	Students that need feedback after every home assignment
Sinc	Balanced Pre and post lecture activities	Requires many hours on-campus	Students that have little time off-campus
Signed-Sinc	Balanced Pre and post lecture activities	Requires many hours on-campus	Students that want symmetry between on and off campus activities.
Revised Sinc	Symmetry between Pre and post lecture activities	Discussion and motivation are given via Zoom.	Students that have little time off-campus

3 SUMMARY AND CONCLUSIONS

In this paper the author suggested several new pedagogies for academic teaching, with regards to Engineering Colleges in the periphery. The author described the advantages and disadvantage of each approach in such a manner that every educator may choose the appropriate pedagogy most suitable for their courses. This work is part of the “2021 Innovation in Engineering Education” Forum at the author's College.

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Since we are using double-blind reviewing process, also references revealing the identity of the author(s) should be made anonymous until the final paper.

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DESIGNING ENGINEERING EDUCATION FOR THE FUTURE, TODAY

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ABSTRACT

Students rely on institutions of higher education to prepare them for the future and few careers are more demanding than engineering. Literature is replete with reports that industry employers are desperate for engineers who can step into their first job prepared with not merely the prerequisite skills and knowledge, but the desired competence. This includes the interpersonal skills that smooth their entrance into the workforce. In addition to fundamental courses in math, science and engineering, universities need also to foster the development of social competencies such as leadership, communication, cooperation, conflict facilitation and decision-making.

Curriculum design and implementation is a relatively slow and methodical process, as it should be. Tools for swift adaptation have been accentuated in the reactions around the world to address distance teaching and digital assessments. This article explores the usefulness of systems thinking approaches to design the future curriculum for engineering education by integrating known frameworks, such as Bloom's taxonomy and CDIO, with practices such as problem-based learning and cooperative problem solving. Findings from a course that has been combining these features for the past 10 years are presented and offered as an example of immersing students in an experience that facilitates deeper learning and intellectual as well as emotional development. Students leave this course with a set of skills that they can then apply to new and unprecedented tasks. The course provides a useful proof-of-concept to explore the integration of modern teaching methods into the engineering education programs of the future.

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1 INTRODUCTION

Students and industry rely on institutions of higher education to deliver engineers who can step into their first job prepared with not merely the prerequisite skills and knowledge, but also the desired competence, including the interpersonal skills that smooth their entrance into the workforce. While many engineering students work alone, in industry, teamwork is the general rule. In addition to fundamental courses in math, science and engineering, universities need also to foster the development of social competencies such as leadership, communication, cooperation, conflict facilitation and ethical decision-making [1,2]. Vanasupa et al. [3] applied systems thinking concepts to address this challenge and propose a guide for the design of learning experiences that consider a student's holistic developmental needs, including the cognitive, psychomotor, social, and affective domains. They recognize the importance of the individual's motivation as a driving factor for learning, and the potential influence of environmental (surroundings, infrastructure) factors on the effectiveness of any curriculum design.

An essential element of curriculum design is its longitudinal implications. The student begins the program endowed with their prior life experience, their intelligence, and their potential and desire to gain new knowledge. It is precisely the changes that take place over time that Stevens et al. [4] address in their framework "Becoming an Engineer" in which they track the progress over three dimensions: disciplinary knowledge, identification, and navigation. Students move concurrently throught each of these dimensions but each journey is unique, which has implications for educators to use their brief time together to impress upon each student the significance of the contributions that engineers make to society and the importance of ethical decision-making [5]. Engineering education needs to carve out room to introduce topics that teach and encourage critical thinking, reflection, ethical and civic responsibility into already full engineering curricula [5,6,7].

A curriculum development guideline known by the acronym CDIO for its major components, i.e., conceive – design – implement – operate, has been available for nearly 20 years and gained an impressive following (Cf cdio.org). At the heart of the guideline is instruction for following good pedagogical practice and incorporating a learn-by-doing paradigm into the educational journey. With the advent of the UN Agenda 2030 educators are calling for extensions to the CDIO standard to include relevant modern topics that prepare engineering graduates to tackle the grand challenges and targets for the Sustainable Developent Goals, such as digital learning, entrepreneurship, and internationalization [8,9]. Important comparisons can be made to project-based learning (PBL) practices, which are flexible enough to be implemented in a single course [10].

This concept paper presents experiences from a standalone course that has been combining these features for the past 10 years. These observations are offered as an example of immersing students in an educational environment that facilitates deeper learning and intellectual as well as social development.

2 METHODOLOGY

2.1 Industrial background

The first author was given the opportunity to develop and teach a course on industrial engineering, which led her to reflect on her deep industrial experience as a practicing systems engineer and the skills she had acquired and relied on daily. The course was situated in the department for mechanical engineering and the content needed to fit into this environment to be accepted. Guidance was available from the Systems Engineering Research Center, an international coalition of cooperating universities dedicated to meeting systems challenges of national and global significance through systems methods (Cf. sercuarc.org).

With this support, a course design that combined the critical components from both systems engineering (SE) theory and practice emerged. The primary learning objectives established for the lab were 1) the importance of inter-team communication to achieve an integrated project result where each group built a component that must interface with other team's components; and, 2) the importance of intra-team communication, collaboration, and teamwork to meet the group commitment to the whole project.

2.2 Academic background

NTNU enforces good pedagogical practice through careful reviews of the learning objectives, skills, and general competence that are published online, before a course is approved. In addition, a program of continuous quality improvement is supported by periodic meetings throughout the semester with an elected subset of the student cohort in every course who offer feedback on the course itself and may make suggestions for helpful changes [11].

The initial challenge was to create a course that introduced an overview of SE processes with a corresponding rich set of practices, to select those practices that were most essential to a practicing engineer, and then to develop a laboratory experience that made learning about them fun. Simulations and gamification are popular today, but the buzzwork of the time was 'serious play' [12,13].

At the heart of serious play is cooperative learning which involves structuring a learning environment where students work together toward a common goal [14,15]. The aforementioned objectives were best addressed by collaborative problem solving with the anticipated benefit of enhancing the students' academic, cognitive, and social competencies. The individual group projects are self-defined and each group takes full responsibility for intra-group assignments and schedules to design, build, test and integrate their component into the finished product [16,17]. The literature substantiates the positive benefits of both collaborative learning and PBL toward educating the "Global Engineer" of the future [18].

3 RESULTS

3.1 Experts in Teamwork (EiT)

A precursor to the course in industrial systems engineering has existed in NTNU for 20 years, and was awarded a national prize for educational excellence and innovation in 2020 [19]. EiT is mandatory for all master's students, including humanities and social sciences, who come together from throughout the campus and work in heterogeneous teams with facilitators for a semester during which they develop collaboration skills by reflecting on and learning from specific teamwork situations while completing a real-world project. The history of the development of this course, its objectives and its continuous improvements have been documented since its inception, including in the SEFI 2019 proceedings [20-25].

A former student recently had this to share,

> *It is 14 years since I took the course (time flies), so I guess it has changed somewhat. I remember being adverse to spending time on a "non-technical" course, but I ended up learning quite a lot. When I started taking the systems engineering courses at USN, I saw some similarities. And after my years in the industry, I valued group work and cooperation skills much higher than I did during my masters in NTNU. So now, 14 years later, I definitely see the value of "Experts in Teamwork"* [26].

3.2 Industrial Systems Engineering (TPK4185)

The course on industrial systems engineering has been evolving for the past 12 years. PBL has been integrated into the learning objectives for the course as follows:

> *By the end of this course, the student will be able to apply the knowledge of industrial systems engineering to a project requiring multidisciplinary and multicultural teamwork; will be able to track their progress, risks and risk mitigations activities underway; and, can communicate and explain the contributions of systems engineering to system development.* [27]

Even before the changes and other disruptions imposed by the Covid-19 campus closings, the course included in-class conversations called 'beehives' to encourage interpersonal exchanges, and a complete session dedicated to student presentations of selected literature delivered to the entire class. Exams moved to a digital format 5 years ago and this greatly facilitated moving to a home-exam mode in 2020. An important component of the home exam is its adherence to asking questions near the top of the Bloom's taxonomy, i.e., questions that require the students to analyze, evaluate and create, not merely repeat memorized knowledge they can look up anytime. Answers also require the students to reflect on learning from the lab, thereby ensuring uniqueness in the content since no two students have identical experiences. The questions use clear language and the rubric for evaluators gives key words that should appear in answers for grading.

The progress of attaining the skills and competence is demonstrated through the semester through weekly lab reports that receive instructor feedback. To motivate participation, these represent 25% of total course evaluation. Since more than half the students are in the Erasmus program, the teaching and interaction language is English. All lectures are recorded, and to balance the situation, the primary lab is physical, i.e., designing and building a component using Lego™ bricks [28]. The domain of SE is very broad, so the teaching material focuses on the skills needed to succeed in the lab, with an emphasis on teaching new ways of thinking about problem solving rather than memorization. Table 1 summarizes course practices compared to other observations and their potential implications from the literature.

Table 1. Effective strategies observed in development of TPK4185

Strategy [17,29-30]	Course Practices	Observations & Implications
Heterogeneous team formation	Simple directives to avoid too many from the same university, or same country, or same line of study on a single team – and no more than 5-6 on one team	Groups that adhere to the directives experience a richer learning experience by working across cultural and disciplinary backgrounds
Positive interdependence	Each group assignment is too complicated for a single engineer – they must rely on each other to complete all tasks	By the end of the course most groups have developed a division of labor that works for them, construction, report writing, etc.
Face-to-face interaction	Important to plan for a worse-case scenario that allows work to continue online through digital engineering tools	Nearly every team has one member who would rather work digitally than with the LEGO™ bricks – every one benefits
Individual accountability; personal responsibility	Each team is solving only a part of a larger assignment, they must agree to deadlines and deliver	Every year there is a mad rush to put on finishing touches, but every year they have succeeded
Teamwork skills	No formal skills are taught other than processes for industrial systems engineering	Occasionally a team will have a member who has worked in a PBL project before, otherwise it is 100% "learn by doing"
Group processing	Weekly A3 reporting is simple, and creates a tangible record of progress and self-assessment	Students are amazed at what they accomplish by the end of the course
Professor as facilitator	Except for approving group formations and the class decision about what they want to build, there are no directions on how to proceed, or what decision to take	Students learn quickly that the answer to every question is, "what does the group think?" And soon the questions stop. Professor role is to provide resources and infrastructure
Distance learning	Under Covid-19 lectures and presentations, and the first 2 lab sessions were conducted online	Students quickly adapted to breakout rooms, and group formation worked very smoothly, however, consensus was that physical labs were preferrable

4 SUMMARY AND ACKNOWLEDGMENTS

NTNU is in the process of their 4-year review of programs and attitudes toward the next academic cycle. In the center for engineering education excellence the intention is to learn from the literature and the accumulated student feedback reports from the quality program to make recommendations for establishing curricula with an emphasis on student-centered teaching, while integrating digital teaching practices and sustainability topics in every engineering study program. Courses described in this concept paper will help inform the content and structure of engineering education for the future at NTNU, today [31].

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SUSTAINING STUDENT MOTIVATION THROUGH SELF-DIRECTED ENGAGEMENT IN SCIENCE COMMUNICATION PROJECTS - A CASE STUDY

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ABSTRACT

Technische Universität Berlin has launched two courses with an innovative concept for science communication: *lab:present* (since 2017) and *lab:prepare* (since 2019) encourage and empower students to present scientific topics in public.

lab:present fosters and rewards the commitment of highly motivated students who work on projects that are intended for public display. The sister-course *lab:prepare* provides hands-on knowledge and skills on how to take research findings out of the lab and into non-scientific contexts.

Both courses are open to students of all faculties. The curriculum includes project management, working in interdisciplinary teams, basics of making (3D design, 3D print, electronics, microcontrollers etc.), and science communication theory. In the course, students develop projects of their choice with the goal of presenting scientific topics in an accessible way.

Although presenting in the public was almost impossible in 2020 due to the pandemic, the *lab:prepare* course continued. From April 2020, we offered the course primarily online and found that interest and motivation for the course did not decrease. The quality of the projects, the dropout rate, and the time commitment of the students remained at a high level.

We claim that self-directed work in interdisciplinary teams on projects that extend beyond the university has a great impact on student engagement, which is a major issue in online teaching. We report on our teaching concepts, the general structure of the course and compare the online implementation with the pre-pandemic version of *lab:prepare*.

1 INTRODUCTION

Before the courses *lab:prepare* and *lab:present* started at *Technische Universität Berlin*, supervisors of other courses like *Projektlabor Physik*[2] encouraged students to present their experiments in public. This led to some remarkable results and was the motivation to establish a separate course on presenting science in public - *lab:present* - and later the associated preparatory course *lab:prepare* (starting winter term 2019).

The courses *lab:prepare* and *lab:present* are open to students of all disciplines. The courses are modular and can be taken independently of each other. In order to complete the *lab:present* module, students have to present a topic of their choice in the public. For example, students informed about artificial intelligence at a convention or organized an event on the applications of mathematics in various professional fields.

We also found that many students were particularly motivated to present hardware installations, such as physics experiments where knowledge of microcontrollers and new manufacturing techniques like 3D printing are crucial.

lab:prepare was founded to support students in their science communication projects and encourage them to work in interdisciplinary teams. In order to successfully communicate topics from their studies, they first develop concepts to make these complex topics accessible to a broader audience. They are free to choose the media and format they use: e.g. installations, videos, podcasts or simulations. In the first semester *lab:prepare* was offered entirely in presence. In spring 2020, at the start of the pandemic, we switched to an online format. As the *lab:present* course could hardly be continued during the Corona crisis, the focus of this paper is on the *lab:prepare* course.

In the following section, we introduce the two main teaching concepts that drive our courses: student science communication and interdisciplinary project-based learning. In Section 3 we explain how the *lab:prepare* course is structured and describe which aspects of the course facilitate the transition to an online format. In the subsequent Section we report on the motivation of the students in our course. We will conclude with some example projects and suggestions on how our findings can be implemented in other courses.

2 TEACHING CONCEPTS

2.1 Student Science Communication

Although science communication is more and more recognized as a responsibility of scientists, it is still not integrated in curricula or offered as an additional course at most universities. Giving students the opportunity to present scientific topics to the general public has many positive effects, as stated by Brownell et.al. [1].

[2] https://www.pl-physik.tu-berlin.de

In our courses students develop projects in which they present topics of their field in an accessible way. The societal role of students is predestined for communicating science to a broad audience: It is easy for them to empathize with laypersons, because they are still learning the core concepts of the scientific method as well as the terminology of their field.

Preparing a topic for a non-scientific audience deepens students' understanding of their subject and the opportunity to learn science communication early in their careers enhances their ability to express scientific topics intelligibly [2]. We also observe that communicating scientific content in an extramural context promotes identification with the subject and increases students’ motivation to engage with their field of study.

Giving students the opportunity to report results of their scientific work enables them to act as representatives of their field. We encourage the students in our courses to enter a bidirectional dialogue with the public. Allowing the audience to voice their priorities and concerns builds trust and increases the probability that the communication is successful [3]. With this we want to get away from the Information Deficit Model in science communication and promote the Contextualist Model.

Another aspect that we address in our courses is internal science communication. Professional exchange between scientists forms a large part of scientific work that students are not aware of until they start their own research. The preparation of their projects creates the necessity to talk about topics of their studies, ideally beyond disciplinary boundaries and across various academic levels.

2.2 Interdisciplinary Project-Based Learning

In our courses, students from all faculties can join. They are free to choose both the topic of their project and their project group. When forming groups, we encourage course participants to work with students from other subjects.

Interdisciplinarity in teaching has great potential to have a lasting impact on students. Interaction with students from other disciplines opens up the “third space” which gives room for critical thinking, helps to develop new knowledge and teaches to be open to different perspectives [4]. The focus of today's education on the development of professional skills should be accompanied by social competences: co-operation, communication and self-competence. This has also a positive effect on the competitiveness in the labour market [5].

Project-Based Learning (PBL) is a student-driven, teacher-facilitated approach to learning. When students are active during the learning process, learning is more effective and their understanding is improved. The use of project-based methods in science and technology has been shown to increase undergraduate students' self-efficacy beliefs beyond those of students taught using traditional methods [6]. PBL also enables them to develop better performance skills.

3 COURSE IMPLEMENTATION OF LAB:PREPARE

3.1 General Course Structure

Students learn the technical and organizational basics for presenting scientific content to the public. This includes, for example, the design and implementation of science-related installations or the generally understandable presentation of complex topics. In the three semesters that the course exists, we had 10 - 20 - 32 participants in WS19/20 - SS20 - WS20/21 respectively, coming mainly from STEM programs, but also with backgrounds of psychology, sociology or media science.

In the following we present the basic building blocks of the *lab:prepare* course. This applies to both offline (pre-covid) and online teaching (during covid).

Table 1. General Course Structure

lecture period				lecture-free period	
1. month	2. month	3. month	4. month	5. month	6. month
survey	weekly workshops in the seminar		survey	submissions	
project pitches	small homework every two weeks			individual meetings on demand	
group formation	work on group projects				

During the lecturing period we meet weekly for two hours. In the beginning of the semester we conduct a survey about the students' backgrounds, interests and possible projects to adjust the curriculum accordingly. We try to promote early group formation and encourage students to pitch their project ideas. After the project groups have formed, we offer a series of workshops and exercises that are adjusted to fit the topics chosen by the students. These workshops include mostly making skills like 3D printing or microcontroller programming, but also theoretical aspects of science communication.

The weekly two hour meetings are usually structured as followed:

- general information (10min)
- content: pitches, workshops, Q&As etc. (15-45 min)
- work on group projects, feedback (open end)

At the end of the semester we conduct another survey, the results of which are presented in part below. Most projects are finalized in the lecture-free period, where we offer meetings on demand. The final submission for the student groups is their project documentation.

3.2 Online Implementation

We began offering our course online in March 2020, when contact restrictions to prevent the spread of Covid-19 went into effect. Since then, organizational and lecture documents are managed via the online portal ISIS (*Information System for Instructors* *and Students*) of the *Technische Universität Berlin* and weekly meetings are held with the hosting service *Zoom Video Communications*.

Instead of weekly scheduled workshops in presence, we offer different asynchronous learning materials for the course including videos on 3D design, 3D print, microcontrollers, video editing and much more. This way we can focus on more interactive formats in the virtual presence sessions: open Q&A's, presentations of students concerning their projects and most importantly time for the project groups in Zoom breakout rooms[3]. We found the breakout room feature in particular is a great catalyst for good communication and self-organization inside the groups.

We encouraged the students to choose formats that work well online, like videos, podcasts or simulations. Nonetheless, some groups decided to do hardware projects and work mainly with tools they had available at home. We supported these projects by handing out material and printing 3D objects. Students picked up the hardware at the university or we mailed it.

Since the summer term 2020 we also provide our own wiki for documenting the projects and collecting resources[4]. We motivate the students to start the process of documentation early on, to collect valuable information for their final submission. The whole website is open access to promote the visibility of their projects for other student groups as well as the interested public.

Although previously simple things, such as handing out materials or demonstrating hardware applications, were more complicated in the online format, we observed that communication between students, self-management and their motivation did not deteriorate. In the following section, we identify and evaluate key indicators of student motivation to further quantify the latter claim.

4 ASPECTS OF STUDENT MOTIVATION IN LAB:PREPARE

Several studies surveying students that were forced to study online in the last two semesters show that students miss face-to-face interaction with other students [7]. Another issue is the (self-) motivation, in particular when the course lacks any interaction [8, 9].

In this section, we report on the performance of students taking our *lab:prepare* course and how this leads us to believe that our course structure and teaching approaches promote student motivation. In order to evaluate the student motivation, we identified three key indicators: the drop-out rate, quality of the projects and time commitment. We find that these indicators have not changed with the online implementation of *lab:prepare*.

[3] sessions that are split off from the main Zoom meeting for each project. The students can freely switch between them and can go to the main meeting to get in contact with the supervisors.

[4] https://www.labprepare.tu-berlin.de/wiki/doku.php

The first indicator is the drop-out rate. As the term progresses students are faced with an increasing workload, especially during the examination period at the end of the terms. As the student's individual motivation is a necessary condition for successful completion of a course, one can conclude that a comparatively low drop-out rate is an indication for a high motivation of the course participants.

In the winter term 19/20, which was held entirely offline, we achieved a drop out rate of less than 20%. Comparing this to our current dropout rate we find that it has not changed significantly with the switch to the full-online format. We rather observe even lower dropout rates, although in online courses dropout rates above 25% are common [10].

The second indicator we use to assess the achievement of students' learning goals is the quality of their projects. Our teaching staff evaluated the group projects in terms of innovation, target group-specific communication, quality of scientific content and their documentation. Despite the difficulties that come with the online format, the quality of group projects remains at a high level.

The last aspect regarding motivation that we want to address is the weekly workload. As the project goals are almost freely chosen by the students, the weekly workload is not oriented at an abstract learning goal but is determined by the ambitions of the students. Our course surveys in the two online semesters show that students spent on average about 3.5h in addition to the two-hour seminar per week. This results in a workload of 80h per lecture period. Adding the time students spend on their projects in the lecture-free period, including the final submission, the total workload of the course ranges from 90-120 hours or more. This exceeds the expected workload for 3 ECTS, which is 75-90 hours. However, according to our survey, the majority of students consider their individual workload to be appropriate. This leads us to believe that the intrinsic motivation of our students to achieve their project goals is very high.

Our evaluation shows that the *lab:prepare* course sustains students motivation in online environments. We assume that our two teaching concepts are the main reason for this success: student science communication and interdisciplinary project-based learning foster student engagement.

5 EXAMPLE PROJECTS

In the following we want to showcase two projects that meet the course requirements in an outstanding way. The first is the Helmholtz' Siren Bike, which demonstrates physical properties of sound and its production (offline semester, winter term 19/20). The second example deals with the social issue of period poverty (online semester, winter term 20/21). Both projects are interdisciplinary in that the Helmholtz' Siren Bike combines a physics experiment with a musical and artistic approach while the Period Poverty project addresses a topic from the social sciences using technology.

5.1 Helmholtz' Siren Bike[5]

This project aims to educate the spectator about the production of sound waves by combining an old approach with a new interactive method. In this installation (see Figure 3), sound is produced by means of a rotating perforated plate.

Holes are lasered into a plate in concentric circles. If a nozzle is now placed at these circles of holes so that air can flow through the holes, the pitch of the sound is determined by the speed of rotation of the plate, as well as the number of holes on one circle. This arrangement was developed by Hermann von Helmholtz and was a popular method in the 19th century for producing sound waves in a controlled manner and for studying their properties.

To introduce a performative aspect to the set-up, the plate is mounted on a jacked-up bicycle instead of a rear wheel. The performer can then control the speed of the perforated plate and regulate the volume of various sounds that can be produced with the plate via valves. The bicycle can be played like an instrument. It thus enables visitors to explore sound waves in a playful way.

Fig. 3. The playable Siren Bike at an exhibition of Akademie der Künste Berlin

[5] https://www.labprepare.tu-berlin.de/wiki/doku.php?id=helmholtz_sches_sirenenfahrrad

5.2 Period Poverty[6]

This project aims to raise awareness about period poverty and the stigma associated with period blood. Period products are expensive and therefore not accessible to people with low incomes. These people then have to resort to other means and this can have devastating, even fatal, consequences.

Through education about toxic shock syndrome and related topics, the student group advocates for free access to period products. The project also contributes to the de-tabooing of menstruation through art: the group designed an exhibition featuring an ever-bleeding 3D printed vulva (see Figure 4) and several sustainable alternative period products like period cup, period pants, period sponge, reusable / washable pad.

Due to the pandemic it was not possible to realize the exhibition during the semester. However, it should not be neglected how much education on the subject has already taken place within the course through presentations to the group. The technical setup and the 3D design for the ever-bleeding vulva were carefully planned and discussed with the teaching staff during the online sessions. The 3D print was made at the university and handed over to the students along with the other technical parts.

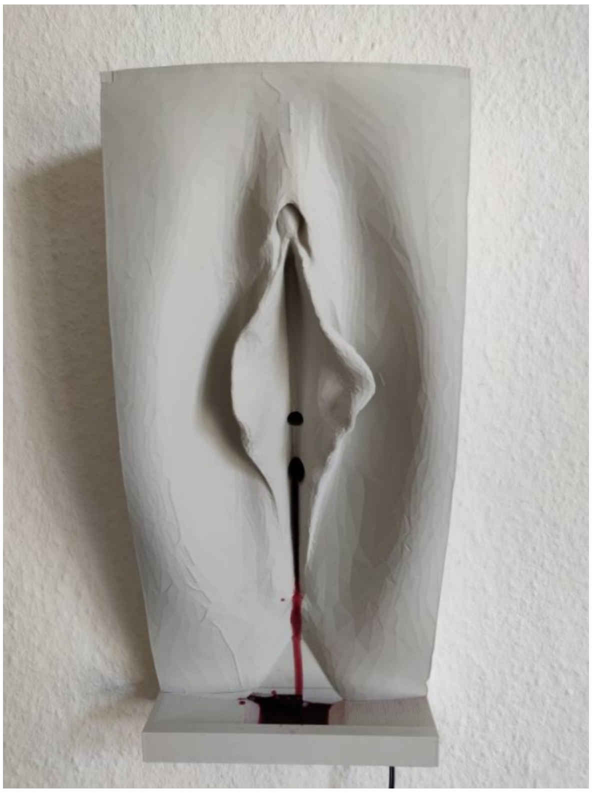

Fig. 4. 3D printed sculpture addressing the social issue of period poverty.

[6] https://www.labprepare.tu-berlin.de/wiki/doku.php?id=ws2021:periodenprodukte

6 CONCLUSION AND OUTLOOK

In this paper we presented the two courses *lab:present* and *lab:prepare* at the *Technische Universität Berlin*, which are based on the teaching concepts of student science communication and interdisciplinary project based learning. We focused on the online implementation of the course *lab:prepare* and compared the motivation of students in the online format with the previous offline format. Our observations show consistently high student motivation in both online and offline implementation, although student motivation is a major issue in online semesters due to covid-19.

For our courses blended learning formats may thus be ideal for post-corona teaching, keeping the advantages of online formats such as break-out rooms, open access project documentation platforms and asynchronous learning materials.

We also believe that project-based learning has great potential for online formats in general, since it ensures a certain amount of interaction between the students. Although we cannot provide empiric data about the effects of science communicative aspects on student motivation, we assume that preparing a topic for the general public also increases the students' motivation. Based on our experiences we suggest to implement both project-based learning as well as science communication aspects in other university courses including basic lectures. The student groups in our courses mainly work on their own, so the additional support from supervisors should be manageable. This could lead to a higher identification of the students with their subject, deeper understanding of the topics as well as lower drop-out rates.

We see the need to connect science and the public from several directions. More and more funding opportunities, such as calls from institutions like *Bundesministerium für Bildung und Forschung*, include outreach. Therefore the next generation of scientists must be trained in external science communication. A study by C. Könneker et al. surveying young scientists shows that they are open to engaging in dialogue with the public, but also that science communication training at universities is still poor [11].

We believe that science communication courses at universities have great potential. The societal need for a dialogue between the public and the scientific community as well as the variety of skills students acquire in implementing the projects, demonstrates the many levels on which our course concept can be meaningful.

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A PRELIMINARY REVIEW OF COMMUNICATION INSTRUCTION IN AN INTERNATIONAL UNDERGRADUATE ENGINEERING CONTEXT

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***Conference Key Areas**:* Resilient curricula and teaching methodology
***Keywords**:* engineering communication, communication in the disciplines (CID), communication across the curriculum (CAC), integrating content and language (ICL), situated learning, communication intensive (CI) courses, authentic integration

ABSTRACT

In this international study, we attempt to update previous research on engineering curricula that integrate communication instruction in order to explore four hypotheses: 1) where and how many institutions are involved in this work, 2) what theoretical frameworks of communication are taught or pedagogically practiced, 3) whether communication activities are supported with instruction, and 4) whether such integrative curricular efforts are assessed. Our preliminary research has identified 20 institutions that employ authentic integration of communication in the engineering curriculum. We endorse Reave's definition of authentic integration as the collaboration between instructors, in which at least one has technical expertise and another has communication expertise, to engage engineering students in a meaningfully unified course or project. Having identified four main findings within the literature, we attempt to outline a descriptive framework for researching the authentic integration of communication in the engineering curricula. These efforts are an attempt to map the field of engineering communication as it has evolved over approximately the last three and a half decades. In the next stages of this project, we hope to highlight institutions and models for integrating communication in the engineering curricula as well as provide insights and practical methods for launching or strengthening efforts at institutions worldwide.

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1 INTRODUCTION

Communication is ubiquitous in the lives of professional engineers. In their attempt “to establish a comprehensive list of generic engineering competencies … [and] their relative importance,” Passow and Passow identified the ability to communicate effectively as one of the most important competencies [1]. Indeed, because communication is both a ubiquitous and indispensable competency, Paretti et al. provide “guidelines” for introducing communication within engineering disciplines [2]. However, little is known about whether these guidelines have been adopted; for example, very few higher education institutions offer communication instruction “within engineering units” [3]. Our research so far confirms this assertion.

We are in the preliminary stage of a two-year study in which we will complete a systematic and international literature review of pedagogical practices for offering communication instruction in undergraduate engineering curricula. Our goal is two-fold. First, we expect to identify the “status quo,” or to answer the question: what are the most common features or characteristics of engineering curricula concerning engineering communication and communication instruction? Second, we expect to identify innovative engineering curricula, curricula that have found theory-based and pedagogically-sound ways of integrating engineering communication practice in concert with instruction and to share those innovations more generally.

Even at this preliminary stage, one observation is conspicuous: All the stakeholders in engineering education (with the possible exception only of novice engineering students) consider communication extremely important both for participation and advancement in the field. There is no better way to articulate this importance than to quote the MIT Writing Across the Curriculum Program – “Engineers who don’t write well end up working for engineers who do write well” [4]. Our early results indicate:

1. communication instruction is too often completely absent from engineering curricula;
2. when communication instruction is integrated in engineering curricula, there is rarely an articulated theoretical framework for understanding communication that informs instruction;
3. when communication assignments are given, many engineering faculty use those assignments as ways to facilitate learning engineering—there is little actual instruction about how to communicate; and
4. there is no valid or reliable assessment protocol that is generalizable across a single curriculum or across engineering educational curricula.

Based upon these results, we argue that, if there is an interest in integrating communications practice and instruction into engineering curricula (and given the widespread affirmation of its importance, we believe there should be interest), then articulating a theoretical framework for understanding communication, providing instruction about how to communicate, and creating a valid and reliable assessment tool are essential.

2 METHODOLOGY

Ours is a daunting undertaking. Importantly, engineering communication as distinct but not wholly separate from technical communication or science communication seems to have arrived only recently in the literature [2]. Paretti et al. further acknowledge that what "is called writing (communication) in the disciplines" or WID (CID) in the US is referred to as "integrating content and language (ICL)" or "content and language integrated learning (CLIL)" in Europe [3, p. 27]. Finally, there are references in the literature to communication in a number of different contexts with different purposes related to each, e.g., communication in teams and interpersonal communication.

In this preliminary stage of the study, we conducted a search of the relevant literature using the keyword "engineering communication" and traced the citation patterns of literature that we established were integral to the Engineering Communications Program at Cornell University [2], [5], [6]. From there, we identified a cluster of over 20 articles in scholarly conversation with one another via citation practices (see Figure 1). Our aim was to establish what Miles and Huberman [7] refer to as a descriptive framework.

Fig 1. Cluster Diagram of Over 20 Articles Cited in this Review. Green bubbles represent national programs and purple bubbles represent international programs (Finding 1); light red bubbles represent theoretical frameworks (Finding 2); the hot pink bubble represents assignments not instruction (Finding 3); and light blue bubbles represent assessment protocols (Finding 4).

Establishing a descriptive framework as a preliminary is both very important, especially with new research projects, and, unfortunately, often neglected, not considered real research. However, developing such a framework involves a number of critical steps. Researchers must determine what phenomenon they hope to study. We are studying the integration of communication practices and instruction into engineering curricula. They must formulate research questions or hypotheses. Our questions are stated above. They need to cull out their informed intuitions concerning that phenomenon. Our informed intuitions are stated in our early results. And finally, researchers need, in a prefatory way, to consult related research. They need to review the contributions of that research and, based on those contributions, select a methodology and methods that are likely to provide answers. Our methodology and methods for continuing the next stages of this project are provided in the discussion section.

In the results that follow, our paper offers that descriptive framework. We consider it to be both foundational and crucial for the credibility of our future findings.

3 RESULTS OF THIS LITERATURE REVIEW

In this section, we share examples both from literature and our own investigations of communication programs embedded within engineering colleges or departments. To date, Reave conducted the most thorough survey of the 73 top-ranked engineering schools in the US and Canada [6]. Over the next two years, our aim with this overall study is to update and expand upon Reave's efforts.

3.1 Finding 1: Few Engineering Curricula Integrate Communication Instruction

In the most expansive research thus far, Reave found that only 50% of schools "required a course in technical communication" [6]. The percentage was better for Canada – 80% [6]. However, only 33% of US and Canadian schools offered "some form of integrated communication instruction," or roughly 24 institutions [6]. In addition, only 10 schools had "created engineering communication centers" [6, p. 453] to offer supplemental and situational instruction.

Our research and experience shows multiple methods of uniting communication instruction and engineering curricula. The least common method is to integrate communication practice and instruction across the entire engineering curriculum. We have only located three such programs so far [8]–[10]. MIT is particularly unique in that *all* students, regardless of major, take two communication intensive (CI) classes, and two "CI classes in the majors [that] emphasize communication in the learning of disciplinary content and are taught collaboratively by technical and writing faculty" [10, p. 280]. Another unique program exists at Rice University [11]. The second most common are departments or units that integrate communication practice and instruction across their specific disciplinary or major offerings. So far, we have identified 16 national [5], [10]–[21] and 4 international institutions [9], [22]–[24] implementing this model. Yet more common still are schools and colleges of engineering that outsource communication practice and instruction, sending their students to other departments to take a technical and/or professional communication service course. Most common are schools of engineering that do nothing at all [6].

Throughout the literature, the word *integration* signals a shift in the model of including communication instruction in engineering curricula. We align our definition of this model with Reave, who specifies that *authentic integration* is when “a communication instructor participated in the engineering course” [6, p. 463]. As far back as 1987, Youra noted, “the most substantial approach to communications instruction actually integrates writing and speech exercises into subject-matter courses” [25, pp. 410–411]. Besides the European model for engineering communication (ICL) explicitly using *integrating* in its key term, at least nine national and international pieces of scholarship use this word in their titles [13], [14], [16], [18], [22], [24], [26]–[28]. Therefore, we have reason to believe that an integration model that blends both communication and engineering instructors’ expertise has taken a foothold in both national and international engineering curricula for roughly the past 34 years.

The most common model relies upon service courses offered by English departments and/or technical and professional communication programs. Historically, in the mid-1940s, both English and engineering faculty denigrated these service courses: “neither freshman composition nor technical writing courses were claimed or championed by either side” [29, p. 12]. In fact, these courses were mostly taught by graduate students and adjunct instructors [29, p. 14]. To read between the lines, faculty did not want to teach courses to students who they presupposed could not write well. Perhaps this stereotype has led to the current situation, and as Berdanier recently explains, “Few engineering education scholars conduct theory-driven investigations of engineering writing processes and artifacts” [30, p. 378].

3.2 Finding 2: Engineering Curricula Often Neglect a Theoretical Communication Framework

Of the network of literature in this review, two pieces stood out as the most foundational to studying how communication instruction is situated pedagogically and theoretically within engineering curricula: Artemeva et al. [31] and Winsor [32]. Artemeva et al.’s work developed a sound framework for the authentic integration of engineering communication based upon genre theory and situated learning. Primarily, the authors explain how the theoretical concepts of Miller’s genre as social action, Austin’s “do[ing] things with words,” and Swales’s discourse communities help students to develop the rhetorical skills necessary for engineering work [31, pp. 304–305]. In terms of pedagogy, Artemeva et al. argue that engineering students learn best from Hunt’s notion of adopting real contexts for their work and by “explor[ing] and respond[ing] to the rhetorical situations (Bitzer) in which they function as engineering students” [31, p. 304]. The authors also draw heavily upon Winsor’s influential book, *Writing Like an Engineer: A Rhetorical Education* [32].

Our evidence for claiming the foundational nature of Artemeva et al. and Winsor’s work lies in mapping citation patterns and practices. In terms of how we categorized the literature in this review, 8 articles related to Finding 1 [5], [14], [16]–[18], [22], [23], [33], and 4 articles related to Finding 2 [30], [34]–[36] cited Artemeva et al. The literature in this review cited Winsor nearly as often with 6 articles related to Finding 1 [3], [5], [12], [16], [26], [33], 3 articles related to Finding 2 [2], [31], [35], and 1 article related to Finding 3 [37]. However, when it came to the original theoretical and pedagogical frameworks, the citation patterns we traced revealed far fewer references to authors such as Miller, Swales, Vygotsky, and Gee. By our analysis, the citation patterns indicated that much of the scholarship on the authentic integration model is one step removed from the original theories which carefully and intentionally frame engineering communication instruction. The reason this finding concerns us is that those constructing integrated engineering communication programs are less aware of the implications of those underlying, original communication theories.

We stated that [2] was quite fundamental to the Engineering Communications Program at Cornell University, largely because we cultivated our program upon the theoretical constructs the authors cite. Specifically, we also endorse genre as social action [38], the sociocultural nature of learning by interacting [39], a semiotic or multiliteracy approach to communication [40], discourse communities, and situated learning in engineering courses [4]. While some scholarship attempts to theorize how and why the authentic integration model of engineering communication is worthwhile [2], [30], [31], [34]–[36],—particularly Paretti's extensive body of work—we predict that as we expand this search, citation patterns may continue to stay somewhat removed from sources of theory and pedagogy. We suspect this is the case due to the multidisciplinary nature of communication integration.

In some ways, this finding is literally "nothing new," as the same theory of deficiency has been espoused about engineers' writing for over a century. As [41] summarized, "In the early 1900s, engineering journals and weeklies 'decried' new engineers' writing (Connors, p. 5), even going so far as to call it 'wretched' (p. 6)" [p. 9]. More recently, a national survey of undergraduate engineering professors reported that only 22% were satisfied with their students' writing abilities [37]. Not only are professors disappointed, but also employers. A study of managers' satisfaction with engineering graduates in the Middle East and North Africa region found that while speaking clearly was one of the top three most important skills, "Communication skills [...] represented an area where managers felt graduates needed great improvement" [42, p. 46]. For over a century, newly minted engineers have been described both anecdotally and empirically as lacking critical writing and communication skills.

3.3 Finding 3: Engineering Curricula Include Communication Assignments but not Actual Instruction

Research shows that while engineering faculty often assign communicative work [6], [37], there is little to no instruction in how to communicate in particular genres or how theories of communication should be applied to this work. According to different surveys, as few as 66% of engineering faculty [37] and as many as 82% [43, p. 15] assign written work. Reave summarizes this situation best: "requiring performance is not the same thing as providing instruction" [6, p. 464]. Here we attempt to explain common reasons why assignments or “performance” are more common than integrated instruction.

Williams may have been the first to state the most fundamental challenge associated with communications in an engineering curriculum [5]. Engineering faculty and professionals are aware of the genres and conventions for communicating in their discipline/field. However, they are not aware of how to teach those genres and conventions. Consequently, they are “disinclined or unable” to teach them [5]. Engineering communication professionals, on the other hand, do understand communication pedagogy and the need for communication practice and instruction. However, as outsiders to the profession of engineering, they are not familiar with the genres or conventions for communication in engineering, even less so with how those genres and conventions vary according to discipline. This challenge was echoed years later when Paretti and McNair identified this as an “issue of expertise” [44]. More optimistically stated, it is an opportunity for interdisciplinarity and teaching partnerships.

Additional challenges include the amount of technical learning outcomes and enrollment numbers in engineering courses. Engineering curricula must reflect an “ever-expanding technical knowledge base” [44]. Therefore, finding room for communication practice and instruction is arduous. In order for students to learn how to communicate, they must be given opportunities to practice and receive instruction. Creating assignments, providing instruction, giving feedback and grading are very labor-intensive. Considering the heavy workload of engineering faculty already, adding to their workload is not viable. A compounding factor is that in many schools and colleges of engineering, class enrollments are large, making integrating communication practice and instruction almost impossible [37].

3.4 Finding 4: No Existing Assessment Protocol for Communication Instruction in Engineering Curricula

There is no valid or reliable assessment protocol that is generalizable across a single curriculum or across engineering educational curricula. Yong and Ashman [24] indirectly point to the reason. In their struggle to find a good assessment method for their integrated curriculum, they use grades and student evaluations to assess whether or not the students’ learning was positively affected [24]. Neither grades nor evaluations would be considered valid or reliable assessments across curricula or even across a single curriculum because they evaluate from a one-way perspective. An assessment is a research endeavor that is recursive and generative of new knowledge.

Portfolios seem the most likely candidate for assessment of CID, CAC, and ICL efforts. However, Williams, in her attempt to facilitate the use of portfolios, highlights just the problems that prevent their use [45]. She makes an important distinction early on concerning “individual student assessment and program assessment” [45]. In terms of individual student assessment, portfolios have a long and proud history. They encourage student reflection and reflexion. They focus instructor evaluation on situated performance. And, they facilitate the general understanding of communication as a part of and not apart from engineering practice. It is when portfolios are used for program assessment that the difficulties arise.

Williams identifies four principles for the use of portfolios for program assessment: 1) defining engineering communication, 2) identifying appropriate skills, 3) correlating portfolio objectives across the curriculum, and 4) assessing so that students, faculty, and programs improve [45]. First, while faculty may be quite accomplished communicators in engineering academic venues; they are engineers, not communication specialists who have studied communication generally and engineering communication specifically. As a result, arriving at a single theoretically-sound definition of engineering communication is unlikely. A worst outcome would be employing a definition that is theoretically misguided or just wrong. Engineering faculty are aware of the limits of their own expertise; therefore, asking those faculty to define engineering communication is a bridge too far. Second, identifying appropriate skills is always context dependent. The communications skills necessary in one engineering context may and will vary radically from other engineering contexts. Generating rubrics, thereby suggesting the necessary skills, is of course very helpful. However, rarely are those rubrics extended across an entire curriculum. The negotiation between faculty within a department and between departments across a college curriculum make such a rubric another bridge too far. Third, correlating portfolio objectives, like defining engineering communication and creating curricular-wide communication rubrics requires coordination, collaboration, and constant and committed application. In other words, the first two must have occurred and been successful before this third principle can happen. Further, in an academic world where most faculty are not rewarded for such work and believe that that work only serves to “fulfill the accreditation demands of higher powers,” the coordination, collaboration, constant and committed application are yet again a bridge too far [45]. By the way, students will not be particularly happy with all the additional work that they must undertake in a curriculum and curricula that are already extremely challenging. Fourth, assessing so that students, faculty, and programs improve would require an educational research agenda that is truly demanding. Again, engineering faculty are not educational researchers. Students are not research subjects in the sense that we can allow for or tolerate failure. There are a growing number of engineering education programs and departments situated in departments, schools, and colleges. Potentially, they could help. Still, the necessary resources to show near- and long-term improvement are prohibitive. A fourth and final bridge too far.

Williams ends her paper optimistically: “The future … [for engineering portfolios] appears bright, if we can survive the development process” [45]. We suggest that, currently, portfolios as a tool for assessment cannot. There are important outcomes that can be realized with portfolios. Paretti shows that portfolios “can provide actionable information about the extent to which ICL programs foster content and language learning” [27]. These outcomes, however, are most often situated and specific. We have emphasized the obstacles to implementing portfolios as a generalizable, valid and reliable approach to assessment. Any approach must embody each of these characteristics. There is yet another. It must be easy. To date, such an approach does not exist.

4 DISCUSSION

Exploring the four hypotheses we offered at the outset of this paper through a network of literature was a necessary beginning to this study; however, as we proceed, we must expand and complicate this search. Our research project includes three follow-up stages. In stage one, we will systematically search national and international journals of engineering education. We will focus especially on the Journal of Engineering Education, the European Journal of Engineering Education, the International Journal of Engineering Education, the Australasian Journal of Engineering Education and IEEE Transactions on Professional Communication. In stage two, we will follow up with a similar search of conference papers associated with such organizations as ASEE, AAEE, SEFI, FIE, and IEEE ProComm. In the American Society of Engineering Education (ASEE) proceedings alone, there are over 1,700 references to the keyword search of “engineering communication.” Employing methods outlined by Geisler and Swarts [45], we will use corpus data analytics to search for keywords included in this paper to identify relevant papers. After narrowing the data set, we plan to develop a coding scheme based upon the four findings detailed in the following section and systematically code the data in a qualitative analysis software such as NVivo.

Stage three involves the development and distribution of a survey instrument to national and international schools and colleges of engineering. We expect to focus on those schools and colleges integrating communication practice and instruction and will attempt to identify innovative ways to realize that integration. This stage will also include select site visits to those institutions considered innovators in any of the four findings described in the results.

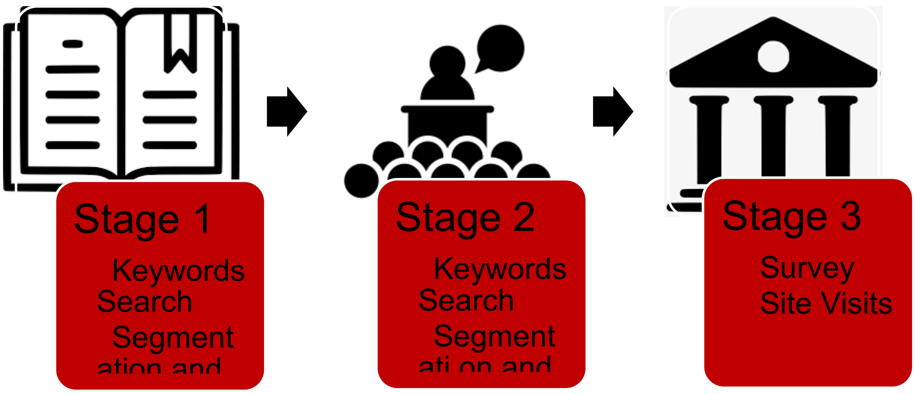

Fig. 2. Diagram of the Three Stages of this Research Project.

Indeed, ours ***is*** a daunting undertaking. Just one of the real challenges that we expect to encounter is schools and colleges engaging in authentic integration, but not publishing or presenting about their approach for or results of that integration. Eventually, we hope to be able to offer a range of possible “models” for the authentic integration of communication practice and instruction that can be fitted to the particular circumstances and situations of engineering curricula.

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INTEGRATED CLASSROOM LEARNING: HOW TO CREATE AN ACTIVATING AND SAFE ENVIRONMENT FOR ONLINE LEARNING IN KNOWLEDGE EXCHANGE AND INNOVATION EDUCATION FOR ENGINEERING STUDENTS

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ABSTRACT

The Covid-19 pandemic posed significant challenges for educators in higher education institutions to develop and implement online teaching formats at very short notice. Those challenges were felt especially in small courses such as tutorials or seminars that strongly rely on the close interaction and lively discussions among participants. In small courses students effectively develop future-oriented competencies. In order to foster learning, educators need to create an environment in which students can acquire the necessary knowledge exchange skills, innovation methods, and an entrepreneurial mindset. That requires new approaches to online teaching/learning. Educators need to use interactive learning formats to achieve those learning outcomes, yet they often lack the relevant tools or guidance.

Drawing on the experience of the past three ‘creative semesters’ (State Secretary for Science and Research in Berlin Krach), my paper develops four steps that educators can take to establish digital classrooms as safer spaces for students and teaching staff alike. The concept of safer spaces (Schutzraum) originated from gender-aware youth work in the 1970s. I adapt this concept to higher education didactics to address challenges for online teaching/learning by creating an activating and encouraging learning environment. Safer spaces can provide a framework in which students and educators interact openly. As the result of mutual respect and trust, the online classroom environment becomes a key factor in fostering deep learning.

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1 INTRODUCTION

1.1 Future-oriented competencies for STEM in higher education

Higher Education in STEM is changing. Graduates are less likely to have a career in a single profession. Higher Education Institutions (HEIs) face the challenge to adapt to this transformation from training for a specific career path to lifelong employability (from 'Berufsfähigkeit' to 'Beschäftigungsfähigkeit' in German) [1]. The past two decades saw the emergence of new skillsets and competencies that students need to acquire in order to be successful in their professional life. Although which competencies such profiles should contain remains object of a lively debate, it is widely recognized that graduates face increasingly complex challenges in their professional life that require adequate competencies [2]. Following the OECD, a 'competency is more than just knowledge and skills. It involves the ability to meet complex demands, by drawing on and mobilizing psychosocial resources (including skills and attitudes) in a particular context' [3].

In this paper, I propose to differentiate between hard skills (i.e. disciplinary knowledge and technical skills), soft skills (i.e. a combination of interpersonal and social skills), and transfer skills as a third category of competencies. The latter are based on a systemic perspective that is widely used in knowledge and technology transfer research, and refer to a systemic understanding and a norm-guided capacity to shape transformation while successfully coping with a situation in which there are unknow variables. Consequently, organizations tasked with the accreditation of programs in engineering, such as the ASIIN[2] in Europe or ABET[3] in North America, foster the integration of extra-disciplinary educational objectives in engineering education curricula. Among the most important competencies identified by studies into future professional profiles for engineering in Germany are: thinking in scenarios; systemic thinking; innovation competences; interdisciplinary understanding; and methodological competencies. Although these can be considered 'wicked competencies' because they resist precise definition, we can nonetheless identify intended learning outcomes (ILO) that are essential to master the competencies in question. To address these ILOs, educators have to implement learning and teaching activities, as well as a design of the curriculum that supports students' development of these future-oriented competencies [4]. I argue that a safer environment fosters the development of transfer skills among students thereby improving their metacognitive abilities and employability. To this end, I present a course design for online learning that catalyzes students' learning experience accordingly.

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[2] Accreditation Agency for Study Programmes in Engineering, Informatics, Natural Sciences and Mathematics e.V.

[3] Accreditation Board for Engineering and Technology, Inc.

2 SETTING OF AN ACTIVATING AND SAFE ENVIRONMENT FOR LEARNING

2.1 Stunned by a global pandemic: the severe impact of Covid-19 on teaching and learning

In the wake of the unfolding pandemic in early 2020, teaching/learning needed to adapt to formats of online learning with little time to prepare. Generally, courses adapted pre-existing forms of online learning, such as live formats or pre-recorded on demand videos. Although higher education professionals were encouraged to be creative, due to multiple reasons – a rapidly increased workload being among the most prominent – they rarely succeeded. Initial studies confirm that small and interactively designed online formats, in particular, struggle to create an activating learning environment in which learning thrives. In comparison, more traditional and frontal formats such as lectures performed well, as they were more easily adaptable to online learning [5]. A representative student survey in Germany identified the lack of opportunities for discussion, social interaction, and exchange with other students as central barrier for effective learning, so that learning was often limited to self-guided learning within one's own room [6].

For this reason, it is essential to create a learning environment that prevents students' isolation. In online formats, in particular, students are often tempted to passively consume a course and withdraw from active participation. Active participation is further hindered if students from different programs and levels take part, as students outside their own disciplinary and social comfort zone are more reluctant to participate in order to avoid being exposed to potential criticism from others. Participation is also stifled if students do not receive any feedback on their contributions due to deactivated cameras ('the black wall').

2.2 What is a safer space ("Schutzraum")?

The term refers to a learning environment that forms a safer space for interaction and open exchange of ideas. Inspired by feminist and anti-discriminatory pedagogy and practice, a safer space is a protected environment as a result of a conscious set of decisions and actions that invites to experiment and explore one's own strengths. For this reason, a safer space has the potential to establish equal learning opportunities, and to ensure an open learning climate, to encourage to ask questions, to make mistakes, and even to zone out at times [7,8]. In other words, students are encouraged to put hypotheses and undeveloped ideas up for discussion. This, explicitly, includes displaying knowledge gaps (including the educator's), and a collective effort to address them. Generally, in-person courses meet these criteria to a great extent. Online formats, however, are prone to misuse. It is possible, to name just two examples, to record and document contributions of others, or there can be private conversations that exclude third parties. In-person formats are not immune to this either, but participants are less exposed. Other factors refer to social interaction. In in-person formats, an important part of a debate is body language and non-verbal communication. Without appropriate non-verbal indicators, it is more challenging to interact appropriately, as many participants of online learning courses tend to deactivate their camera. These and other factors increase uncertainty and a lack of comfort among all participants.

In the next section I will introduce the course format ‘integrated classroom learning’ and adapt it to implement the concept, I will focus on activating measures because participation is the necessary condition to create those spaces, as safer spaces are a result of a conscious and collective practice.

3 INTEGRATED CLASSROOM LEARNING

3.1 Integrated classroom learning: *Engineering for Impact*

University regulations define integrated classroom learning as a form that combines different course formats such as lectures, seminars, practical training, and projects to enable theoretical communication of materials and practical application within the classroom. *Engineering for Impact*, the course outlined in this paper, is designed to train transfer skills and guide students who develop a concept of an innovative application of a given technology on a case basis in consecutive steps. It consists of a number of four integrated formats: a weekly 90-minute life video conference that has the character of (1.) a lecture, for which a guest expert from the field is invited, and a subsequent discussion of the lecture with the guest expert, (2.) a seminar, (3.) a workshop, or (4.) a group work session. In the lectures, students are encouraged to prepare questions and interact with an expert from the field. In the seminar-like environment, students interact with each other, and discuss and work out new problems and solutions. In the workshop-like environment, students use an online collaboration tool to apply methods or tools to a research problem. In their group work session, students have to self-organize and work on a case. For each class, students prepare by either

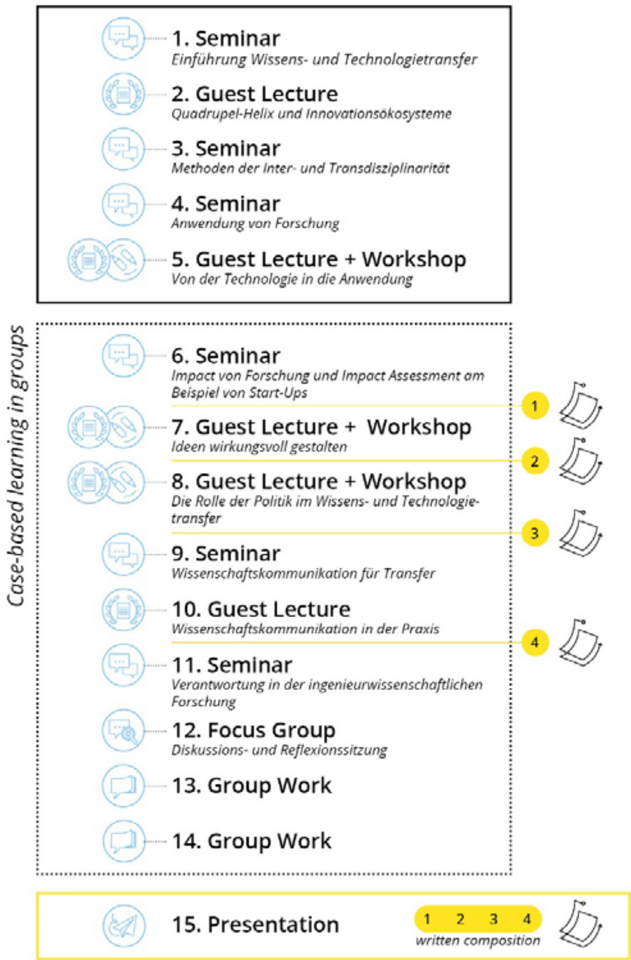

Figure 1: Course design

reading a text about the class topic, performing a small research task, or applying a given method or tool to their project. Beginning with session 6, students work on a case according to the sessions topics and compose four drafts on which they receive detailed feedback and which they revise for the final examination (cf. **Fehler! Verweisquelle konnte nicht gefunden werden.**).

The corresponding examination is a so-called portfolio examination: over the course of the semester, students complete and submit different types of work as exam elements within the course. At the end of the course, the marks from those elements are added up to produce the overall grade. In this course, two of those elements are results of group work (written composition and presentation), and one element is the result of an individual performance (learning journal). During the course, students are tasked to provide multiple written drafts and receive individual feedback and supervision. As a result, examination contributes to student development and the overall learning environment.

3.2 Conceptualizing learning and teaching (how the course is designed)

This section outlines the structure and ILO of the course *Engineering for Impact* that is currently being taught at TU Berlin. In the course, students develop future-oriented skills, i.e. transfer competencies, by using problem-based learning. Students apply theoretical content and different methods or tools (e.g. a stakeholder analysis tool) to bridge the 'gap between theory and practice, between declarative and functioning knowledge' [9]. Students research and analyze a real-world problem, and develop a strategy to solve that problem by applying an existing technology (among the choices are social technologies and self-chosen technologies or projects, cf. Appendix A) in groups of generally four. On completion, students are able to

- identify innovation and transfer opportunities within their discipline, and act on that potential by developing a strategy to increase the impact of research,
- model transfer processes, and shape transfer activities as mediators between different stakeholders, and
- apply declarative and functioning knowledge as well as models and methodology to analyze a complex problem, and develop a concept of technology-based solution.

In order to achieve the ILOs, students need to acquire and develop all three types of competencies: hard skills, soft skills, and transfer skills. As mentioned, transfer skills refer to future-oriented abilities to act successfully and efficiently in a (professional) field that is characterized by complexity and unknow variables. HEI, therefore, need to provide a favorable learning environment that is a prerequisite for learning new and developing existing competencies [3].

I argue that, to this end, a safer learning environment is an appropriate form. Higher education, however, to this day relies mostly on traditional pedagogy based on lectures, tutorials, and end-of-course tests [10]. As a result, assessment of students' learning progress and achievement of ILOs reflect that same traditional concept of pedagogy. Although evaluation is not the focus of this paper, assessment tasks and course format contribute significantly to a successful development of competencies through activating learning activities and incentives.

In the next section, I will explain how an activating and safe learning environment can be created and sustained in online learning. To meet the challenge posed by the current pandemic, the course utilizes the concept of safer spaces and adapts it for higher education didactics. The following measures have proven effective to prevent barriers and create an activating and supporting learning environment.

4 HOW TO CREATE AN ACTIVATING AND SAFE ENVIRONMENT FOR ONLINE LEARNING

In this section, I describe in chronological order the individual measures required to establish a trust-based online learning environment. Most of the measures are to be introduced at the beginning of the course, and sustained using group work and interactive exercises throughout the semester.

4.1.1 Survey

At the beginning of each semester and before the class comes together the first time, a survey is conducted among all students who register for the course using the university's learning management system ISIS/Moodle (LMS). In the survey, students are asked to share their disciplinary background, existing knowledge about the topic of the course, their motivation to participate, and anticipated learning outcomes. In addition, the questionnaire contains a field for miscellaneous comments. Most students have little to no prior knowledge and take the course out of interest. Among the expectations and motivations, I identified four main clusters for all three courses held: the majority of students wanted to be able to apply aspects of Responsible Research and Innovation (RRI) and sustainability in their respective fields. Moreover, students were motivated to take the course in order to acquire a working knowledge of inter- and transdisciplinary methodology, a practical and theoretical understanding of the course's topic, i.e. transfer processes, as well as skills in science communication. The students'

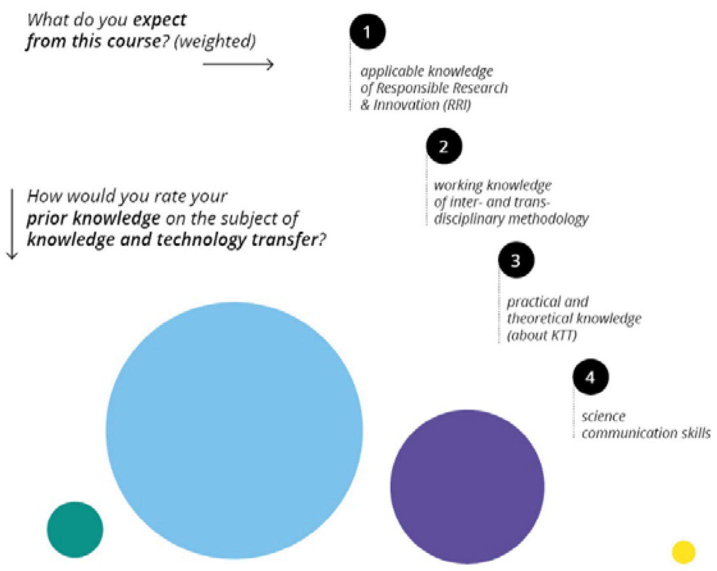

Figure 2: Results of pre-course surveys

intended learning outcomes are, thus, in line with the focus of the course on transfer skills.

The survey offers a first orientation for the educator, and allows an assessment of students' main interests and goals. In addition, based on students' expectations, teaching/learning activities and topics are aligned accordingly as the course proceeds. Most importantly, it informs the formative assessment process with the intention to guide students in their learning, as I will explain in the sections below.

4.1.2 The first session – to see and to be seen

The very first session is crucial. During this first encounter, participants decide how they are going to interact for the rest of the semester. It is therefore very helpful to agree on modalities, among which a formal arrangement is essential: at the beginning of each session, students often participate with their video camera deactivated, yet, antithetically, two-way communication is necessary to create an environment in which learning thrives. To this end, the concept of safer spaces is introduced to the students, and course participants agree to activate their cameras to establish the foundation for an activating and safe learning environment. Individual participants are addressed directly (verbally or using the chat function) if they do not react, and asked to activate their camera for the given reason: 'see and to be seen' promotes trust among all participants. In order to live up to the promoted standards, however, the educator must be sensitive to matters of privacy and the distinct, sometimes disadvantageous learning conditions among the student body [6]. It helps to keep in mind that students are asked to provide intimate insight into their housing and living situations, which can vary according to their socioeconomic standing.

4.1.3 Intended learning outcomes (ILO) and teaching/learning activities

In addition to formal measures, the course design, transparency concerning ILOs and teaching/learning activities are very important to authentically establish a trust-based learning community in the course. Relevant criteria of an effective online learning environment are thus intertwined with elements of the course design. At the beginning of the course, I therefore explain the formal set-up of the course by addressing ILOs, teaching/learning activities, examination, supervision, and feedback so that students understand how the elements of the course relate.

A good example of an effective teaching/learning activity is group work. It proved to be effective and received very good feedback from students. I have used buzz groups where students work on small tasks, and jigsaw groups in which each group works on a sub-task that is then put back together in the plenary to solve a main task. Group work in an online course benefits from online collaboration tools such as Miro (https://miro.com/). Miro provides a virtual board that students can use for simultaneous, collaborative work. In addition, virtual boards can be used to apply in-class activities to online learning, for example empty outlines which requires students to fill the outlines that an educator provided on a class topic:

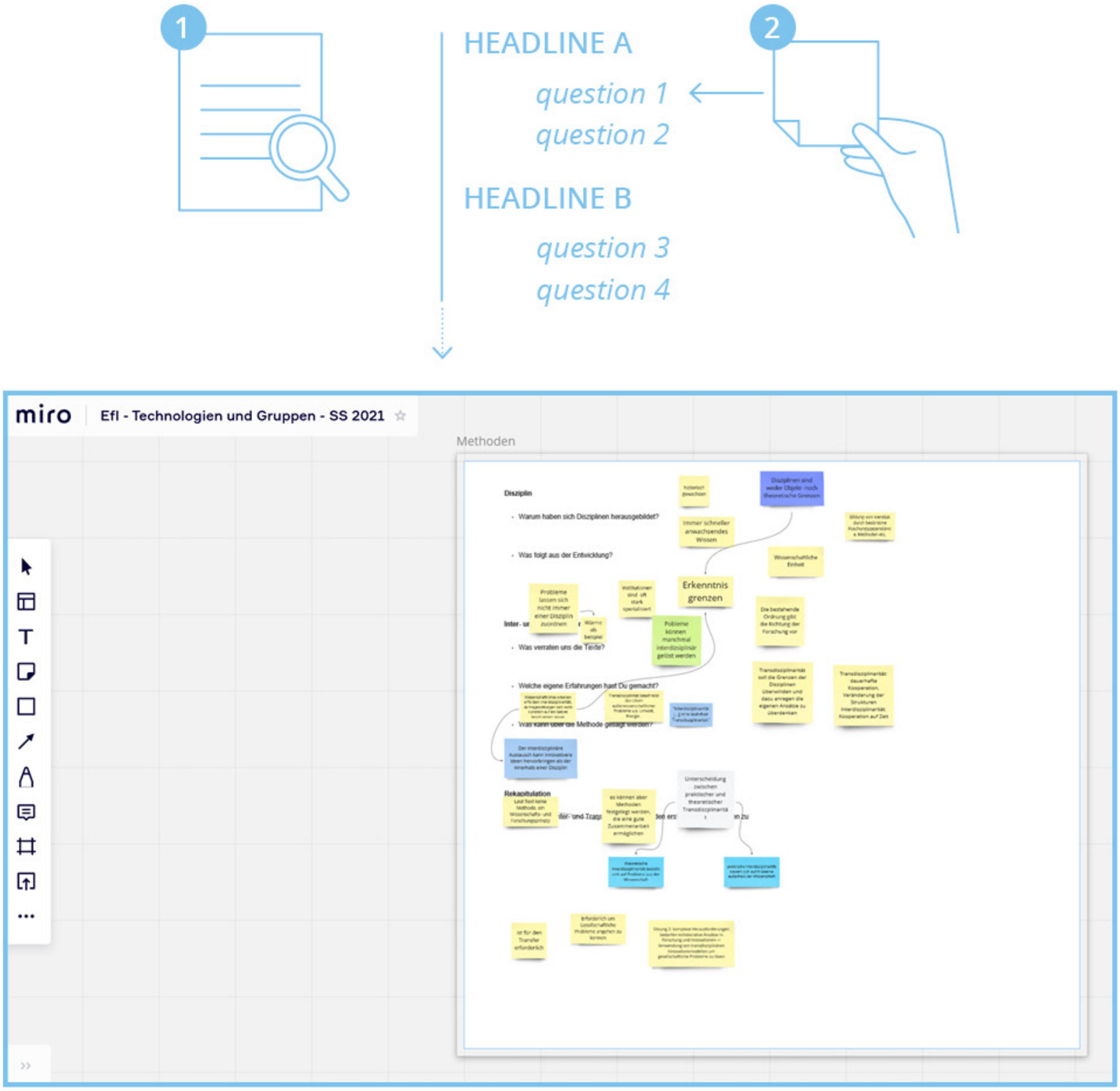

Figure 3 - Activating learning activity 'empty outlines' on the online collaboration tool 'Miro'

Over the course of the semester, students work on a case in an interdisciplinary group. The groups bindingly come together for the rest of the semester in the 6th session, during which students choose a problem of their interest. Each group then develops a case based on a real-world problem to which a given technology is applied. Students in each group are expected to coordinate and manage their work independently when not in class, thus developing social and organizational skills. For assistance, students are introduced to various tools and methods to collaborate online. Among the tools are the university's LMS, as well as multiple board templates for Miro.

4.1.4 Examination, supervision and feedback

Examination forms and assessment practices are chosen to allow for rich learning experiences that contribute to understanding rather than coverage [9]. In their written and oral examinations, students present their individual case in which they apply a technology to a real-world problem. Throughout the course, students consecutively apply methods and tools which require them to research the context and aspects of an individual case in their groups. Applying these methods and tools, they need to research topic-related information. During this research process, they are closely supervised, receive advice and are – if necessary or asked for – guided in the process. Before they hand in their written examination at the end of the course, students will have written multiple drafts. They receive detailed feedback on each of their drafts, and are offered individual supervision meetings. This, however, is very time-consuming for the educator, and is not advised for large classes with more than thirty students.

In addition, students are tasked to keep a so-called learning journal to reflect their learning activities in respect to what they intended to learn, the course content, or design of each session. For each session, students are provided with optional questions that can help to relate each given topic to their individual experience. Obviously, it can be delicate to assess learning journals, as they contain personal content. Students, therefore, are strongly and repeatably assured that not their position, opinion, or experience is considered as part of the examination, but instead how thorough they reflect on their individual learning process. To ensure a maximum of objectivity, an assessment matrix with criteria is made available on the LMS. Students are encouraged to reflect on and criticize didactics and class design if they feel there is reason to do so. Incidentally, the most constructive insights into motivators and barriers for student learning were achieved through three questions from a Teaching Analysis Poll (TAP) that were integrated into the reflection in the learning journal and at the center of the focus group session at the end of the course which I will cover in the next section [11]:

1. What aspects of this course help you learn? Please be specific.
2. What aspects of this course impede your learning? Please be specific.
3. What suggestions do you have for improving your learning in this course? Please be specific.

In summary, portfolio examination with formative feedback allows students to focus on their interest within the course and encourage deep learning. Iterative feedback-loops and supervisions guide students' case-based learning which, as a result, combines declarative and functioning knowledge. Within this context, students' mastery of competences and achievement of ILOs is reflected and assessed repeatedly by peers and the educator, respectively.

5 EVALUATING ENHANCING AND IMPEDING ASPECTS OF THE COURSE

Utilizing three questions from a TAP and adapting qualitative research methodology for formative assessment and reflection processes, I was able to gather data that supports my hypothesis that the concept of safer space can productively be adapted to higher education [12]. Using focus group settings, students reported back on factors that enhance or impede their learning and made suggestion how to improve learning in the course. By documenting and analyzing these results, I identified the following clusters as illustrated in Table 1*: Cluster of course evaluation results*: learning activities,

activities to help students reflect on their learning progress, aspects based on the course design, formats for feedback, and transparency and structure of the course.

	What aspects of this course help you learn?	What aspects of this course impede your learning?	What suggestions do you have for improving your learning in this course?
Learning activities	• *workshop with tools* • *group work*	• *presence of educator in break out sessions* • *limited time of work-shop phase* • *technical problems (IT)* • *isolated groups* • *lectures without activating learning activities*	• *longer workshop phase* • *activating learning activities in all sessions*
Reflection	• *learning journal* • *reflection of last session at the beginning of the next*		
Course specifics	• *(small) size of the course* • *familiarity with other participants* • *discussion (culture)* • *agency (for design and learning out-comes)*	• *discussion in online format* • *„COVID-19 lethargy"* • *timeslot (4-6 pm)*	• *reading guide for the preperation materials*
Supervision	• *supervision and feedback* • *writing drafts*		
Transparency	• *clear structure*	• *intransparent structure and intended outcomes* • *missing clarity on tasks for drafts*	• *clear communication of requirements and expectations* • *best practice examples*

Table 1: Cluster of course evaluation results

Generally, students profited most from activating learning activities such as workshops. Here, they were guided to apply knowledge from preparation material and their own research using tools in small groups in which they participated interactively. Although, limited time in the workshops and individual sessions without such interaction were hindering factors, this nonetheless helped to create a safer environment within the course that drew from familiarity. Students identified with their project, their group and the course community. Guiding students rather than teaching them contributed significantly to their individual development and has been reported to be highly motivating. Given that most students have a background in STEM they profited from the experience that a statement (in the context of this course) is rarely right or wrong but rather depends on the strength of an argument. As one student reported, the barriers to participate actively in the course have been significantly lower compared to other courses.

Factors that impede learning, on one hand, mostly correspond with the aforementioned aspects. The absence of and suggestion to implement interactive learning activities in each session, for example corresponds with students' evaluation of workshops. On the other hand, and in accordance with recent studies, students reported that restrictions in line with the Covid-19 pandemic affected their learning significantly [5,6]. Online learning poses a unique challenge regarding concentration, motivation and interaction. Moreover, some students reported that organizing and structuring their studies and finding motivation engage in learning activities was challenging and often frustrating. A final cluster that impeded learning concerns transparency of the courses structure, expectations and requirements. Although this is controversial as not all students agree, it nonetheless is very plausible as students in the course are confronted with an approach 83% of them have little to no prior knowledge about and are expected to work a case addressing a real-world problem. Suggestions to address these problems cover best practices as well as a better, i.e. more frequent, communication.

6 LIMITATIONS

Online courses bring about new challenges for teaching and learning. Drawing on the concept of safer spaces and adapting it for higher education didactics contributes significantly to creating and sustaining an activating learning environment in which deep learning processes thrive. There are, however, limitations that have to be considered. Among those, the two most important ones are the sample size of the courses and the subjectivity of formative evaluation.

Most importantly, the sample size of the course described in this paper is too small to allow for statistically significant statements and generalization. Based on only three courses, the data collected and experience is too specific and cannot be generalized. In addition, using qualitative research methodology, especially drawing on formative evaluation of learning journal entries and the development of written assessments, results are partly subjective. In addition, data collected in focus groups is likely to be influenced by the educator-student relationship as the university did not have the resources to provide a neutral third party as intended for a TAP.

7 AVENUES OF FURTHER RESEARCH AND CONCLUDING THOUGHTS

In this paper I have presented an integrated classroom learning course design with didactical elements to create an activating and safe environment for (online) learning in higher education. Evaluation results and student feedback support the hypothesis that measures presented in section 4 are suitable for establishing digital classrooms as safer spaces and meet the challenges that online learning during a global pandemic bring about.

Given that the data reported is based on a small sample size and a specific course format further research is needed to establish whether these results can be reproduced in varying settings. Such research will benefit greatly from a common set of criteria for evaluation that allows for comparison. Furthermore, it needs to be investigated whether or not a correlation between learning/teaching objectives and learning activities and course design respectively can be established. As mentioned above, the course *Engineering for Impact* prepares for activities in the field of mission-driven and innovation-oriented knowledge and technology transfer with a special focus on transfer skills.

In conclusion, I have demonstrated that integrated classroom learning provides a format in which portfolio examination as well as teaching/learning activities can be adjusted to students' needs, and create and sustain an activating and safe learning environment. With this paper, I sincerely hope to inspire educators to reflect on the concept of safer space in higher education and implement learning/teaching activities (in courses with a larger number of participants) accordingly.

8 SUMMARY AND ACKNOWLEDGMENTS

Challenges of online teaching and learning can be addressed by creating an activating and encouraging, i.e. safer learning environment. Integrated classroom learning provides a format in which teaching/learning activities as well as assessment tasks can be used to foster deep learning by drawing on the concept of safer spaces.

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APPENDIX A

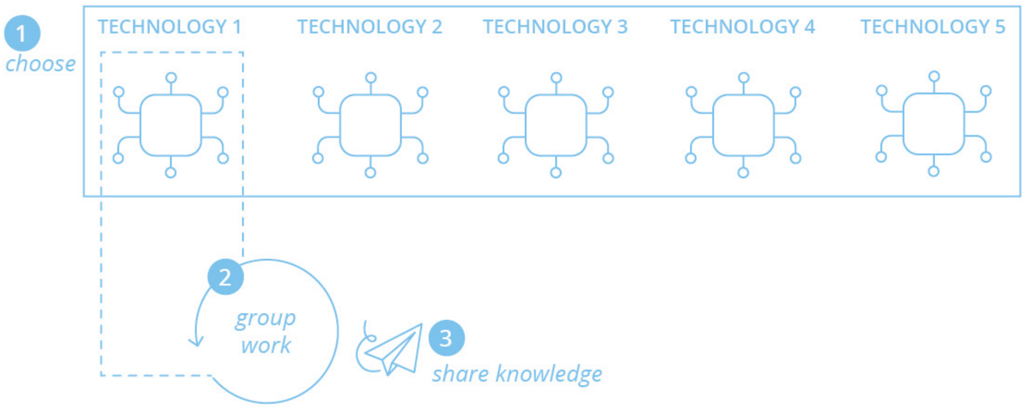

Figure 4: Miro board with technologies for case-work

APPENDIX B

Teaching/Learning methods	• *problem-based learning* • *group work* • *lecture* • *workshop/application of tools*
Course content	• *knowledge and technology transfer as research paradigm* • *innovation ecosystems and models* • *inter- and transdisciplinary methodology* • *ideation processes* • *stakeholder analysis* • *science communication* • *responsible research and innovation*
Learning outcomes	⊸ *On completion, students are able to* ***identify innovation and transfer opportunities*** *within their discipline, and act on that potential by* ***developing a strategy*** *to increase the impact of research,* ⊸ *model transfer processes, and shape transfer activities as* ***mediators between different stakeholders****, and* ⊸ *apply declarative and functioning knowledge as well as models and methodology to analyze a complex problem, and* ***develop a technology-based solution****.*
Assessment methods	1 – *Four written assignments (during the course with detailed feedback; formative assessment)* 2 – *Written composition (based on 1.; criterion referenced assessment [9])* 3 – *Presentation (based on 2.; criterion referenced assessment [9])* 4 – *Learning journal (written reflection of each session, including an adaption of TAP [11]; criterion referenced assessment [9])*
Evaluation methods	• *pre-course questionnaire* • *integrated TAP [11] (cf. learning journal)* • *focus group* • *post-course questionnaire*

Table 2: Course content and methods

T-CAP: FRAMEWORK TO DESIGN STUDENT-CENTRIC COURSES USING EDUCATIONAL TECHNOLOGY TOOLS

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Keywords: *Online Learning, Blended Learning, Education Technology, Course Design, Faculty Development, TPACK*

ABSTRACT

The use of educational technology tools has been steadily increasing in higher education in the last two decades. However, we have witnessed a widespread adoption of educational technology tools during lockdowns imposed by governments as a result of the COVID19 pandemic. Faculty were forced to identify technology tools that support online mode of instruction and continue their teaching virtually. The lack of training and time required to successfully adopt educational technology tools has impacted the quality of teaching and learning. Due to a lack of necessary knowledge and skills, faculty ended up focussing on identifying and utilizing technology tools that were convenient to them without trying to understand how they need to be contextualized based on the course outcomes and the learning requirements of the students. Students therefore would struggle to transition from in-person to online mode of teaching as the course were not anymore student-centric in nature. In this paper, we propose a framework T-CAP (Technology-Content Assessment Pedagogy) that could be employed by faculty to design and integrate educational technology tools in a student-centric way. T-CAP emphasizes the need for faculty to constructively align technology tools to all the three elements of a course – content, assessment, and pedagogy – and highlights how technology-content, technology-assessment, and technology-pedagogy should be aligned so

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that courses designed using technology tools are student-centric. The T-CAP models is being proposed as an extension to the widely known TPACK framework which emphasizes the need for alignment of technology tools with the content and pedagogy of the course. T-CAP encourages instructors to also think about the relation between technology and assessment and would be a valuable resource to faculty who intend to make blended/online learning their primary mode of teaching in a post- pandemic world.

1 INTRODUCTION

Higher education in the last two decades has witnessed a steady but gradual rate in the adoption of technology tools to support instructional practices. Inspite of the numerous research available that indicates the benefits of using technology tools for classroom instruction for both students and the instuctors, traditional lecturing continued to be the predominant mode of instruction for STEM courses [1]. The slow rate of adoption has often been attributed to the lack of knowledge and skills among the instructors to identify, learn, and make use of technology tools that could support and enhance their instructional practices. Prior faculty development efforts taken up to train the instructors have been reported to focus more on the technology usage with limited efforts spent to contextualize the technology tools based on the requirements of the course, students, and instructors [2]. The improper integration of technology tools has been reported to have a negative impact on the students' learning due to increase in cognitive load [3]. Mishra attempted to address these concerns as he introduced the Technological Pedagogical Content Knowledge (TPACK) framework which emphasized the thoughtful alignment of the technological knowledge with the pedagogical content knowledge of the course [4].

The TPACK framework has been widely adopted in the last decade by various faculty developers and technology experts to train instructors in K-12 and higher education to thoughfully integrate technology tools by understanding the integration between technology and content and technology and pedagogy. However, the TPACK framework has failed to elaborate on the alignment between the third important element of a course i.e. assessment. It overlooked the need to also understand how the technology tools being adopted can support the design, implementation, and evaluation of assessments in a course. In this paper, we attempt to fill this gap through the introduction of T-CAP (Technology-Content Assessment and Pedagogy) framework that will guide course instructors to utilize educational technology tools and design technology-enhanced courses. T-CAP emphasizes the need to constructively align the technology tools with content, assessment, and pedagogy of the course. The COVID19 pandemic has forced all instructors to rethink about education through the lens of technology and we believe the T-CAP framework will be an essential guide to all instructors in the post pandemic world to redesign their courses using technology tools through student-centric approach.

2 LITERATURE REVIEW

2.1 Adoption of Educational Technology in Higher Education

There is a large body of literature available that highlights the benefits of utilizing technology tools to support instructional practices [5]. The usage of technology was observed to specifically support students in developing deeper learning skills such as criticial thinking and problems-solving [6], collaboration in teams, and self-regulated learning [7]. However, the slow adoption of technology in courses has been attributed to multiple reasons such as lack of knowledge of technology, skills on how to effectively integrate technology tools, and resistance to change their teaching practices [8]. It was observed that the process of adoption of technology tools was a time consuming process [9], as most faculty were required to rethink their course design process and change their conceptions of the affordances of technology tools in education. The common practice, to identify and replicate technology tools in different courses, has shown to be largely ineffective as it's important to adapt technology to the learning requirements of the course, need of the students, and responsibilities of the instructor. With the growing calls to adopt technology-enhanced learning, there is a need to train instructors and equip them with the essential knowledge and skills to be able to design learning environments that are situated to their context.

2.2 Technological Pedagogical Content Knowledge (TPACK)

Mishra and Koehler introduced TPACK as a conceptual framework and defined it as a body of knowledge that would enable instructors to effectively integrate technology tools based on their context of operation [4]. They believed an instructor who posseses TPACK should build 1. Technological Content Knowledge (TCK) – which indicates the relationship with technology and content, as the use of technology would allow newer and varied flexibility to represent the course content; and 2. Technological Pedagogical Knowledge (TPK) – understand how the affordances of technology could support and hinder the implementation of innovation pedagogical practices. The development of TCK and TPK along with pedagogical content knowledge would lead to the construction of TPACK which would include knowledge of what makes concepts in course easy or difficult to learn, knowledge of challenges encountered by students in attaining the learning ourcomes of the course, knowledge of the challenges they encountered as part of their responsibilities as an instructor, and knowledge how technology can help overcome all of these challenges. Although the TPACK framework has been widely appreciated and adopted especially to train instructors, the framework overlooks the important connection between technology and assessment. This study addresses this gap by proposing a new framework T-CAP which promotes the essential alignment of technology to all three elements of a course – content, assessment, and pedagogy.

2.3 Content Assessment and Pedagogy (CAP)

CAP is a course design framework which is adapted from the Backward Design process and is a useful guide to help instructors make student-centric design decisions during the development of courses [10]. At the core of the CAP philosophy is the need to constructively align all the three elements of the course – content, assessment, and pedagogy [11]. The CAP framework guides instructors to reflect and make a decision on what content needs to be emphasized and less emphasized depending on the learning outcomes of the course. The framework suggests that assessments, both summative and formative, need to be designed with a goal to evaluate the appropriate learning levels as indicated in the enduring outcomes of the course. Open-ended assessments should be designed through the use of rubrics so that the learners are aware of the instructors expectations. The student-centric nature of the CAP model asserts for the need to think about assessment as a way to give students feedback and improve their learning instead of merely utilizing them for the purpose of grading. The pedagogical activities being designed and implemented should be aligned to the levels of assessments so that appropriate teaching practices are implemented to teach content that require higher cognitive levels of learning. The CAP framework therefore provides instructors with design guidelines to thoughtfully create or redesign courses in a student-centirc approach.

3 T-CAP

In this section, we introduce the T-CAP framework which is an extension of the CAP framework and addresses the limitations of the TPACK framework. T-CAP as shown in Figure 1 introduces technology as a fourth element of course design process and elaborates on the alignment required between technology and content, technology and pedagogy, and technology and assessment. The required understanding of the relation between technology and assessment for a course is currently overlooked in the TPACK framework and we aim to highlight it’s importance to successfully design technology-enhanced learning environments.

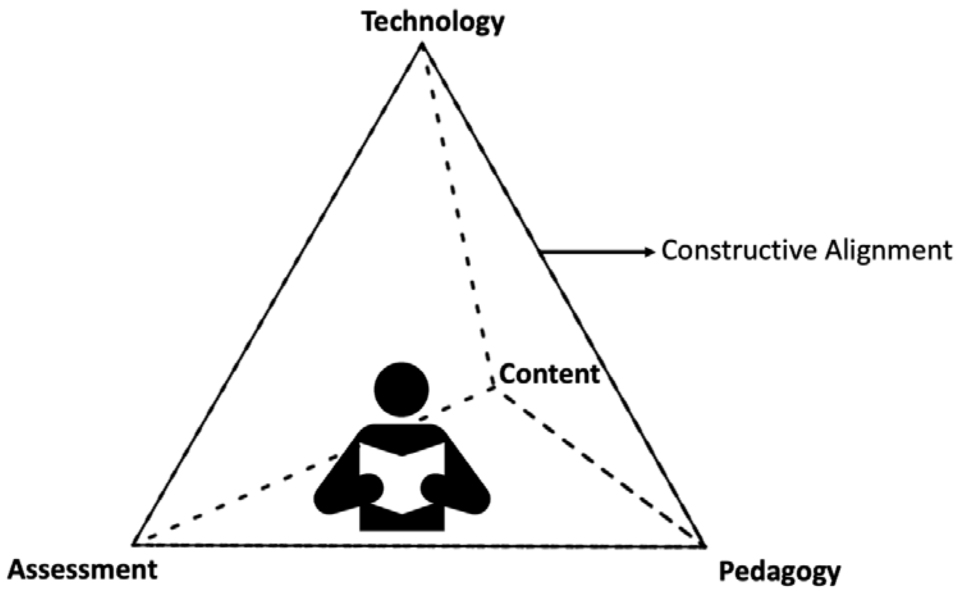

Fig. 1. T-CAP Design Framework for Technology-Enhanced Learning

3.1 Technology and Content

The CAP model recommends instructors to prioritize their course content into three categories created by Wiggins and McTighe: Enduring outcomes, Important-to-know outcomes, and Good-to-be-familiar-with outcomes [11]. This categorization is important as most course content are presented as a list of topics and instructors give equal importance to all of them. However, it is not possible for students to retain all the content after the completion of the course. The instructor should have an understanding of which content they expect students to retain long after the end of the course and categorize that content as Enduring Outcomes. Similarly the course content that would support students understanding or attainment of the enduring outcomes should be included as Important-to-Know. The content which is not cruicial to the learning experience and students would benefit from just hearing about it should be categorized as Good-To-Know. This categorization is important as it helps the instructor build an understanding of how to prioritize the course content and manage their instructional time efficiently.

Technology tools allows you have the flexibility to present content through varied representations. For example, content provided to students can be made available in the form of text (book chapters, articles, paper publications), audio (podcast, audionotes), presentation (Powerpoint, Prezi, Piktochart etc), and videos (animated, multimedia etc). It is imperative for the instructor to reflect and decide on how should different content in the course should be represented. Content that is included as Enduring Outcomes should be represented in formats such as presentation and video as the technology being used provide you with the tools to design and generate content for deeper conceptual understanding. Similarly, the instructor should align the choice of technology tools used for content representation with the category of the content. Its important to note that usage of same technology tool to design and present all type of content would not be a student-centric approach as the technology usage will not be aligned to the learning outcomes of the course. The selection of the technology tools should therefore be decided by the type of the content, the appropriate format for representation, and technology tools available to create content in that format.

3.2 Technolgy and Assessment

Assessments are often designed and administered to students to grade them and provide a report. However, CAP emphasizes on need to rethink assessments and see them as tools to provide student feedback. It is important for the instructor to give the learners regular feedback throughout the duration of the course so that they are guided during the learning process to potentially achieve mastery in the graded assessments. Both summative and formative assessments should be designed mainly to evaluate the students learning of the enduring outcomes and important-to-know outcomes. As enduring outcomes are the core of students learning experience in the course, formative assessments should be targeted to provide students regular feedback on their understanding of the enduring outcomes so as to help the learners to attainment them by the end of the course. The levels of mastery expected from students to successfully complete the course should be communicated to them at the start of the course through the design and dissemination of rubrics, which will be used to grade the open-ended assessments. Rubrics could be used a tool to provide transparency of the instructors expectations from the students to achieve the mastery in the course.

The summative assessments being designed need to be aligned to the learning outcomes of the course and should take into account the taxonomy and learning levels mentioned in the outcome. The learning levels of the outcome would drive the format of assessment and the instructor should therefore identify appropriate technology tools to design, administer, and evaluate the assessments. Most insturctors do not use formative assessments as it’s a time consuming process to administer, assess, and provide regular feedback to the students. However, there are many innovative assessment tools available for instructors to facilitate formative assessments and provide students with immediate feedback. For example, there are many technology tools that would now allow instructors to administer various types of formative assessments such as discussion questions prior to the start of the classes, poll questions during the class, and quizzes after the completion of the class. The many features available in the current technology tools makes it easier for the instructors to administer, collect, and analyze the data. Instructors could now also use built in data analytic tools made available in learning mangemenet systems to automate the data analysis process and get real time instantaneous feedback on the students learning [12]. The use of technology for assessment could therefore open many opportunities for instructors to facilitate formative assessments and provide students with regular feedback on their learning.

3.3 Technology and Pedagogy

The design decisions for the pedagogies to be implemented in a course should be aligned to the content and assessment of the course. The pedagogy should be able to provide students with enough opportunities to practice needed to achieve expected mastery of the enduring outcomes. The practice opportunities provided should be deliberately distributed through the duration of the course. The multiple opportunities provided to the students to practice would help them to store the content in the long term memory and as a result retain it for many years. The mode of the pedagogies implemented should be aligned to the learning levels of the enduring outcomes. Chi’s Interactive-Constructive-Active-Passive (ICAP) framework categorizes various pedagogies based on the students’ expected actions, engagement, and outcomes during the activities [13]. With regard to the impact, interactive activities are expected to be most effective, followed by constructive, active, and passive.

Instructors who use a range of pedagogical activities need to identify the appropriate technology tools that support their implementation. Attention should be given during the selection of a technology tool to ensure students will have the opportunites to perform all the actions as required by the type of ICAP pedagogy. For example, instructors implementing cooperative learning (an interactive pedagogy) should use technology tools which allow students to enter into breakout rooms and collaborative with each other to perform the given task [14]. Students could be made active during the classroom by asking them to reply to the instructors questions in the chat box or by responding to poll questions. The usage of technology for instruction also provides flexibility to the instructor to make use of a combination of both synchornous and asynchronous mode of learning. Course content which is good-to-know and sometimes important-to-know can be taught by providing asynchronous learning resouces to students. We encourage instructors to reflect on various aspects of the course pedagogies and select a learning management system that supports all their requirements.

4 DISCUSSION AND SUMMARY

We presented the T-CAP model in this study as a design framework to guide instructors looking to adopt technology tools and create technology-enhanced learning environments. The T-CAP model is an extension of the well recognized CAP model that encourages instructors to become designers during the process of developing the course. T-CAP emphasizes on the need to reflect and constructively align technology to the three important elements of the course – content, assessment, and pedagogy. We guide instructors with range of questions that would prompt them to reflect and understand the alignment between the four elements. Students are considered to be at the core of the T-CAP model and it’s important to also consider students acceptance of the technology tools being utilized in the course. Instructors should evaluate students digital literacy level and the availability of necessary ICT resources to access the technology tools being integrated into the course. The usage of technology for instructional purpose will be the forefront of conversations during and post the COVID19 pandemic and the instructors should put significant efforts to ensure the technology tools would be aligned to the content, assessment, and pedagogy of the course. Instructors who fail to not align the technology tools being used would create technology-enhanced learning environments which are not student-centric. This could run the risk of overburdening the students with improper technology usage instead of supporting them to achieve the learning outcomes of the course.

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WERE WE READY TO TEACH IN TIMES OF SOCIETAL CRISIS? LESSONS LEARNED FROM A PRACTICE-BASED DESIGN ENGINEERING COURSE

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Conference Key Areas: *Sustainable changes beyond covid-19, Engineering Education Research*
Keywords: *Industrial Design Engineering, Online Teaching, Experience Design, Online Peer assessment*

ABSTRACT

In March 2020, the Corona Virus Disease 2019 (Covid-19) outbreak forced the Dutch Government to close the schools at all levels to fight the spread of the virus. Immediately, education at the University of Twente was suspended, and all on-campus teaching had to be transferred to online platforms. It soon became apparent that conducting an online assessment, especially in practice-based courses, was challenging. This paper reports the challenges that were faced in the online student assessment of one of those courses. The topic of this paper is a third-year Industrial Design Engineering bachelor's course that employs peer assessment to teach industrial design engineers (IDEr) the importance of user testing of physical products in the design process. Unfortunately, this type of assessment, which had initially been planned synchronous and in-class, had to be adapted to the 'new normal'. While the test results showed that students could accomplish online peer assessment, the results of an online survey carried out with 24 students illustrate the multitude of challenges students faced. In the paper, I reflect on the lessons learned from the online peer assessment experience and provide suggestions for similar industrial design engineering courses of higher education.

1 INTRODUCTION

More than a year has passed since the World Health Organization announced that the new coronavirus resulted in a global Covid-19 outbreak. Immediately afterwards, governments began to announce their measures to tackle this global challenge. On March 13, 2020, the Dutch Government announced lockdown and suspension of education at all levels. Higher education had to move off-campuses, and academics had to find ways to continue education online. While the new situation pressured academia to find creative ways of teaching and testing, students had to cope with the uncertainty created by this transition in education.

Equipping the students to be critical and independent evaluators of their and others' works, higher education prepares them for the world's changing values [1]. However, the Covid-19 pandemic illustrated that higher education itself was not ready for the unexpected changes. As a result, many academics struggled to find alternative ways of transforming teaching and testing to online platforms, which sometimes resulted in downsizing higher education ambitions.

The paper's subject is a practice-based experience design course offered in the third year Industrial Design Engineering (IDE) bachelor's programme in one of the high-ranked Dutch universities. One of the course goals is to teach future IDErs how to test the designed experiences with users. To this aim, the course replicates user-testing and prepares the students for real-life testing in peer assessment. In this form of testing, the students test and evaluate each others' experience design prototypes, and provide feedback.

Unfortunately, only six days were left to the in-class peer assessment activity when the Dutch government announced the lockdown. Immediately, the course faced the challenges of online peer assessment. Some students were not ready to present their product prototypes, while others depended on pitching their ideas to their peers during the peer assessment.

This paper reports the changes enforced in the online testing of the aforementioned practice-based experience design course. It reflects on the effects of those changes and reports 24 students' views on how the Covid-19 crisis affected their assessment results. In the end, I provide suggestions for online peer assessment practices of practical courses of higher education.

2 EXPERIENCE DESIGN AND ASSESSMENT IN DESIGN ENGINEERING EDUCATION

2.1 Design and Meaning: The Experience Design Course

The context of this paper is a 2.5 ECTS, third-year industrial design engineering course. Before taking the course, all students take the same courses, except their one semester of minors studies. Therefore, the entry-level of all students who take the course is considered equal.

This practice-based course focuses on the role of human-centred design at various levels of people's experiences with products and systems. The course is designed as an experimental course, in which students get acquainted with the theory that unfolds people's meaningful experiences with products. The goal of the course is to recall the student's human-centred design knowledge and incorporate the theory by using their sketching, product design, prototyping and critical thinking skills. In addition, the course aims to help students (1) identify opportunities to influence and design for people's experience and (2) design and test a product by evaluating the relevant theory of design for experience [e.g. 2]. In that sense, the course helps students comprehend the product qualities that create meaningful human experiences through design.

During the course, around 20 hours in total is taken up by lectures, feedback sessions and prototyping workshops. The course is designed to spend the rest of the course hours on research, design, prototyping, and preparing the deliverables.

2.2 Peer Assessment as Testing Experience Design

The course of this paper is ambitious about teaching how to design products that create meaningful experiences for their users. A body of knowledge brings out the importance of product qualities on people's experiences with products and their connection with their contexts [2]. Meanwhile, several attempts have been made to develop an agenda for integrating this knowledge into industrial design education [3, 4]. While it is already challenging to assess design works in higher education, users' subjectivity and uniqueness make the assessment even more challenging for teachers.

There are several assessment methods that teaching experience design courses significantly benefit. Peer assessment is one of those activities [5, 6]. This type of evaluation aims not to end up with a grade but to promote student learning [7]. By definition, this type of assessment requires the students to 'showcase' what they learned rather than 'repeat' what they learned or memorized [8]. This type of assessment can be time-consuming [9], while it perfectly fits teaching user experience design goals. It measures the outcomes of the experience-design process and improves students' evaluation skills by being critical about the work of both others and their own [10].

The topic course of this paper is the first course of the relevant IDE educational programme, in which 'peer-testing of prototypes' is employed as an assessment method. Students first carry out research and understand the experience they would like to design (Figure 1) in the first three weeks of the course to facilitate this type of learning. Following, they (1) design a product that enriches the human experience, (2) prototype the product, (3) bring the prototype to the class. Finally, in week 6, during an in-class peer assessment activity, students (4) act as the users of the designed experiences and (5) test and assess the products according to the experience design goals. During in-class peer assessment activity, students undertake two roles: a designer and an expert user. As expert users, students test the designed product by using the knowledge they gain in the course. As expert users, they provide (and write) constructive feedback to the designer group. At the end of the course, they submit a visual essay to document their design process.

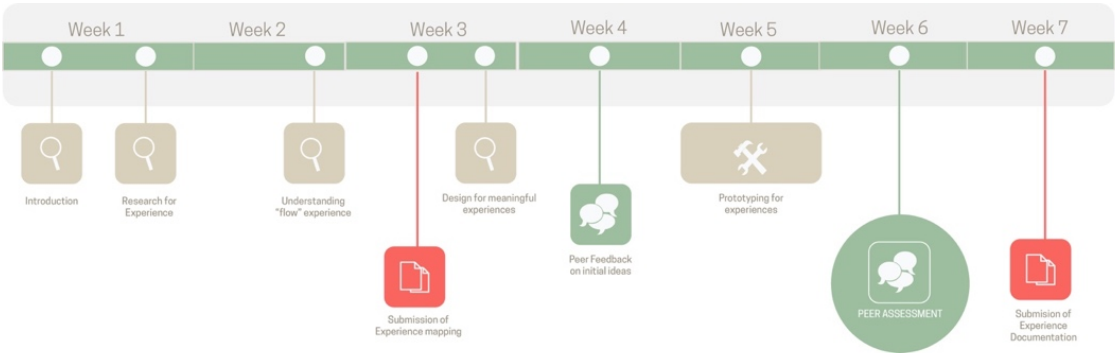

Figure 1. Plan of the Experience Design Course

2.3 Changes Enforced due to Covid-19 Global Pandemic

In the previous years, the peer assessment of experience design prototypes had been held in class. However, in 2020, it had to be deployed via online tools and asynchronously due to the Coronavirus pandemic. Therefore, as soon as on-campus education was suspended, students were asked their opinion about the best possible way of explaining their experience design concepts via the university's online-class platform. In the end, it was mutually agreed that the students submit a 2-minutes' video pitch, in which they describe their experience design, the ideal use case of their prototype and the way they think the product could enhance the experience. Students were given ten days to submit the videos to the university's online teaching platform.

After the deadline, all the videos and shared were downloaded and were shared with two peer groups. Then, the peer groups had one week to assess the experience designs articulated in the videos and submit their feedback to the designer groups in separate Word documents via the online education platform of the university. Finally, the written feedback was collected and communicated to the designer groups. In this process, to ensure the reliability of the peer assessment results [11], none of the groups gave feedback to and received input from the same groups. In the end, except one group (out of 24) all passed the course without having a resit assignment.

3 ONLINE SURVEY

After the announcement of the final grades, the students were asked their opinion about the peer assessment and the course overall. The survey consisted of closed and open-ended questions. Students were asked about their overall rating of the course and the effectiveness of peer assessment in achieving the goals of the course (1=very poor, 3=average, 5=very good). In the open-ended question, students were also asked about their opinion about the role of the global Covid-19 crisis in their peer assessment results. In the online survey, no personal data was collected, and all the collected data was anonymized. In total, *N*=24 students (out of 86) responded to the survey.

3.1 Course Evaluation

Overall, the students rated the course with *M*=3.79 out of 5.00 (*SD*=0,59). When students were asked about the effectiveness of peer assessment in achieving the goals of the course, the goal of “identifying opportunities to influence and design for people’s experience” was scored with *M*=3.88 (*SD*=0.80). However, the goal of “designing and testing a product by evaluating the models and frameworks of experience design” was a score relatively lower with an *M*=3.21 (*SD*=1,06).

3.2 Online Peer Assessment of Experience Design Concepts

The answers to the open-ended question of the survey were clustered around three main themes: (1) decreased quality of the feedback due to lack of interaction between peers; (2) the difficulty of understanding and explaining the concept in 2-min video presentations; (3) difficulty of assessment.

The majority of the respondents (*N*=14) stated that the lack of interaction made it difficult to understand the concepts, resulting in a low quality of feedback provided to their peers. One student noted that it was sad not to touch and use the prototype (P22), while P23 regretted missing the interactive part of real-life peer testing. P24 explicitly stated that the feedback became shorter and possibly less extended due to this lack of interaction among the peers. According to P18, the groups that gave them feedback focused on many things but little on the things they wanted to test and get feedback on.

As was signalled by the students, some students (*N*=5) found it challenging to explain their experience design concepts in a 2-minutes’ video. This also was the case for understanding the peers’ concepts from the video presentations. P8 found it more difficult than explaining the process in person and having people test the functions of the prototype. P2 found it hard not to ask questions to the groups, which could have positively affected the results of their peer assessment. P13 stated that they wanted to give a more general overview of what they wanted to achieve with the experience design instead of explaining their prototype in their video. This respondent thought this way of presenting affected the feedback they provided negatively, as most of their feedback concerned the lack of a prototype. Their conscious decision was to put more effort into the movie.

Eventually, these challenges resulted in difficulties in the assessment of the experience designs (*N*=3). Especially P1 mentioned that the prototypes were difficult to assess through videos, while P2 stated that the group they assessed did not articulate how they fulfilled the assessment criteria. This made it difficult for the groups to critically and fairly evaluating the prototypes presented in the videos.

On the other hand, a few students (*N*=3) stated that video presentation was a good alternative to on-campus testing. P5 thought that every group reviewed the other groups’ material thoroughly and formulated feedback carefully. This respondent stated that doing this on the spot would not have made that much of a difference.

4 DISCUSSIONS

The assessment results showed that students successfully passed the course, while an online survey carried out with *N*=24 students illustrated how the students struggled while fulfilling the peer assessment requirements. Results showed that the students rated the course and the effectiveness of peer assessment to achieve the course's goals lower than the rating scale's good score (*M*=4). There were several reasons listed for these low scores. First, the peer-testing had to be held online due to the lockdown. Second, the students' lack of communication and interaction during peer testing turned into a significant limitation of the test results. Finally, not being able to experience prototypes fully (e.g. seeing ad touching) made the outcomes of peer assessment superficial for some students.

The enforcement of the global pandemic made it clear that the changes that had to be made at the last minute in in-class peer assessment were not suitable for the learning goals of the course. Furthermore, since the students did not see the designer groups, it became difficult for them to embrace the "user role" in peer testing. This was also evidenced in the results. Therefore, the way the online peer assessment was formulated should be redesigned to facilitate engaging and effective communication among peers. One way to do this is to arrange synchronous question-answer sessions among the students. This would help the assessor groups to ask questions while the designer groups could have the opportunity to answer the questions live.

Finally, even though it was not reflected in the online survey results, the role of the teachers in organizing the peer testing should be reconsidered if the peer assessment would be held online. It was time-consuming for the teachers to embrace the mediator role between the groups. Due to the time constraints, the teachers had to work overtime to arrange a smooth transition to online platforms. In the future, online platforms could be utilized to make the exchange of files more accessible.

5 CONCLUSIONS

This paper presented the setup and challenges faced in the online peer assessment of a third-year Industrial Design Engineering, experience design bachelor's course. It showed a promising way of teaching user testing (i.e. peer assessment) in higher education and the challenges the students and teachers faced due to the sudden changes enforced due to the global Covid-19 pandemic.

Results showed that even though most of the students of the experience design course passed the course successfully, there are several improvement points in applying peer assessment and other practice-based assessments online. Accordingly, asynchronous prototype presenting and testing is not the best way to facilitate this type of assessment, as it nullified the potential positive impacts of peer assessment on student learning. This experience showed that even though academia expects design engineers to be ready for the world's changing views, academia was not fully prepared to adjust to the sudden changes.

I invite future engineering education to report more evidence that showed their struggles with online education transfer. Only with such an open discussion can we learn from each other and make engineering education prepared for similar global societal challenges.

6 ACKNOWLEDGMENTS

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HOW TO EMBED 'THE REFLECTIVE ENGINEER' IN HIGHER ENGINEERING EDUCATION

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Conference Key Areas: *Challenge Based Education & Engineering Skills*
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ABSTRACT

In 2019, the authors came up with a vision of the future university for engineers. It describes a future situation and behaviour of 'reflective engineers" who interact and behave in a particular way while engaging with technology. The vision is created with a Vision in Product Design (VIP) methodology from Hekkert & van Dijk. This vision of the future university starts with the idea that every one of us has personal ambitions, talents and interests that drives our interests and ways of working for the good of society at large. Nevertheless, at the start of our career, we may not be aware of these ambitions, talents and interests, and one needs to explore and reflect on a variety of challenges to discover:

(1) In what way we would like to engage with technology
(2) How would we like to work together in the technological domain
(3) Whether we prefer to engage in slow/fast production cycles

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A reflective portfolio including engineering roles as a vehicle to become a deliberate professional will be embedded in the interdisciplinary master curriculum of biomedical engineering at the 3ME department at TU Delft. In this conceptual paper, we will expand on the design implementation process of the reflective engineer in challenge-based education following the vision of the future university.

1.1 INTRODUCTION

In the future, we expect students to want to engage either by addressing societal needs or unravel a phenomenon, to collaborate based on trust exploring new fields or within a system and last but not least, to work on short projects or long term projects. Each of these dimensions requires a different engineering role to be enacted and, most importantly, continuous reflection on whom we want to become as a person and as an engineer [1].

This process does not stop after "formal" education stops but is a lifelong and ongoing activity, which requires technee's (life longer learners) to reflect on their personal, professional and ethical development across different engineering themes from different role perspectives. Becoming a deliberate professional as defined by Trede [2] requires the technee to (1) question their assumptions and (re)consider their place in the world. (2) Learn to think and act critically for themselves and being responsible for their choices (3) and use critical thinking as a tool to think beyond their discipline, culture, policies and develop moral /non -categorical thinking capabilities [2].

1.2 DELIBERATE PROFESSIONAL

This Deliberate professional is a concept introduced by Trede [2] in her book on the transition of HE students into becoming a professional. The book considers the complexity of practices, workplace cultures and environments and states that students in the transition phase from master student to professional need to;

(1) understand what is probable, possible and impossible concerning existing and changing practices;
(2) take a deliberate stance in positioning oneself in practice as well as in making technical decisions;
(3) be aware of and responsible for the consequences of actions taken or actions not taken in relation to the 'doing', 'saying', 'knowing' and 'relating' in practice; and
(4) be aware of the multiple agencies one has to acquire to exercise free will, innovate, act on prescribed roles, and focus on long-term goals across various domains.

As we are implementing the vision of the future university, we try to integrate the deliberate professional model with the faculty's ambitions to grow reflective engineers by challenge-based education.

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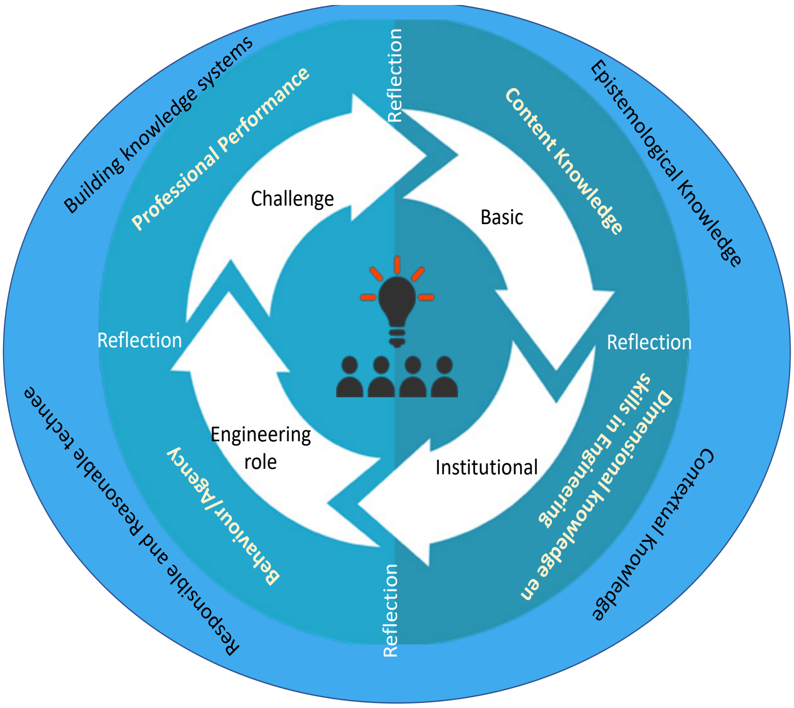
1.3 VISION OF THE FUTURE UNIVERSITY

The Vision of the University of the future is shaped around a curriculum in which **basic** fundamental knowledge is addressed derived from particular disciplines or themes with an epistemological knowledge base. This fundamental knowledge allows students to identify and evaluate the probable and the (im)possible in ongoing practice. What basic knowledge do I need is the critical question? In this case, the implementation is taking place in the Biomedical field but could be addressed in any engineering domain.

Fig. 1 Reflective Engineering Model



At the next level, **Institutional** knowledge is applied in a particular context, which requires generic methods and tools to work in (1) systems or interpersonal settings, in (2) short and long production cycles and on(3) knowledge focused on phenomena or societal needs. Naturally, these generic methods and tools should be applied in a thematic (sub)domain ((inter)discipline). Which methods/tools/collaborative ways of working are used for my area of interest is the critical question.

As a result of these dimensions, **Engineering Roles** are emerging. Due to the active agency of the technee to do or to stop certain activities, specific behaviour will become more or less prominent. This level mainly requires transferable skills, such as creative thinking or leadership, attributes of behaviour in a specific context and agency based on values related to ethics and sustainability, amongst others. Ultimately, the Engineering Roles will be guiding roles on how a technee wants to operate in the future technical domain. Whom do I want to be and which behaviours basic, institutional, transferable, and interpersonal level belong to my role is the crucial question.

Ideally, these different levels of knowledge creation are practised and experienced in a challenge-based education environment where students can enact appropriate and professional behaviour, feedback and reflection are needed to become a deliberate professional engineer who contributes to different knowledge systems in society. What professional behaviour is expected of me? (values, culture, attitude, and how does it fit my Eng. Role?)

Even though these knowledge levels are related sequentially, they will be taking place in parallel and need proper guidance and facilitation. The connections between the levels of knowledge building include iterative moments of reflection, formative 360 % assessment across several challenges. These challenges are embedded in the curriculum, creating an student determined learning path with optimal flexibility in learning trajectories within a thematic Domain.

1.4 BUILDING BLOCKS FOR REFLECTION

This paragraph will briefly look at what it entails in practice for technee's to become critical consciousness-raising, autonomous, self-directed learners and critical thinkers. The Biomedical master where we are implementing this vision has three sub-tracks. For the demonstration of the model, we have chosen a hypothetical sub-track bio-medical physics. Imagine, for example, the following example of a Biomedical Challenge::

"High-tech devices often require expensive replacement parts. Due to the rugged environments of most developing countries, the devices fail frequently, and access to replacement parts is often difficult and expensive. Lack of financial resources, manufacturing equipment, and capacity to fabricate parts is non-existent."

What is the knowledge needed and what needs reflection upon?

Basic Knowledge

- Reflecting from different knowledge frames .e.g. Medical, Materials, Logistics, Legal, Economic
- Which methods and tools and knowledge are available to solve a problem?
- Epistemology of interdisciplinarity

The basic knowledge includes all the different disciplines represented in this challenge. One needs to know about high tech devices, materials, environmental, legal, cultural, political and societal impact. Possibly, the technee's need not know all of this, but they should know whom to contact. From the disciplinary perspectives, say high tech devices design and materials, one might reflect on the type of materials that could be used, design with circularity principles might be another one. However, from an environmental perspective, this might be a completely different disciplinary solution pattern. The critical question is; What is needed for this problem to be satisfactorily solved as a BME professional. (Level 1 of the Deliberate Professional)

In a reflection try out one of the piloting students stated:

"I think that oftentimes what I am lacking is a more profound interest in the fundamentals that underlie the creative process. If I want to be a biomaterials engineer, I need to find this topic interesting and learn more about it rather than just telling everybody how I find it prospective and interesting. My proactivity is often lacking in contrast to my soft skills."

Institutional Knowledge

- Reflect on the dimensions of future behaviour in profit/non-profit organisations and society you are working for, from different stakeholder perspectives?
- What does It all mean for my problem definition?

This next level, "Institutional Knowledge", mainly addresses what contextual knowledge is. In a developing nation, should he/she work based on interpersonal trust? What is the system the client is doing his/her work in? Is there a system? How long are the devices used, what type of pollution is occurring, should the legal system change. Here, the knowledge focuses on contextual issues of the challenging environment in the developing nation and requires reflection on the tools and methods, ways of working, and society's impact. (level 2 of the Deliberate professional)

Engineering Roles

- Reflect on: Whom do I want to be in this life, this story, what is my role, intention, stance, values with respect to this problem I'm working on.
- What do I want to keep/what do I want to change
- Behaviourial aspects creating Agency

The Engineering Roles level is focusing on what type of values ethical and in terms of sustainability should be adhered to, what is the role (leadership) one would like to demonstrate as an engineer, how to communicate and have critical thinking skills in this type of setting. Should we educate people, built a factory, import cheap devices? The reflection here focuses on "whom I want to be in this setting", "whether I want to be in this situation?", and "how I can act responsibly towards myself, the people, and the environment, while delivering an optimal product to provide medical support in the developing country. (level 3 of the Deliberate Professional)

To give an example from a pilot reflection session on the engineering roles:
"This assignment makes me think about the fact that during this course/specialization, I like to be more focused on the societal aspects than the technologies. I think maybe be since during my studies there is hardly room for issues like that. That is just not the focus of my study programme, so it makes sense."

Challenges

- Professional Attitude/Deliberate Professional.
- Which Challenges (BME) do I want to engage with my knowledge, values, roles and the idea of impact I would like to have on the world
- Conscious performance of Engineering Profession

Finally, at the Challenge level, students should encounter different types of challenges such that they will be able to contribute to different knowledge systems such as industry, government, society, environment and personal knowledge [3]

Ideally, each challenge creates an authentic learner experience in which the different levels of

- Basic ((inter)disciplinary) knowledge,
- Institutional-Dimensional knowledge,
- Engineering Roles- Individual knowledge and
- Agency levels are addressed to become the Deliberate professional ultimately.

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A professional who is aware of multiple agencies necessary for innovation, free will and the growth in different engineering roles across a wide variety of future contexts (level 4 deliberate professional)

1.5 CONCLUSIONS

This paper has shown the conceptual design of reflective engineering in Bio-medical Education for the future university. This proof of concept is a reflective journey within a first challenge-based course and will be tested and evaluated as a minimal viable product. After this 1st pilot, the conceptual design will be expanded to a framework for the entire master programme and related to the final attainment outcomes and future job prospects of BME master students.

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Experiences from a multidisciplinary student project with simulated robots and digital project work

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Conference Key Areas: Methods, formats and essential elements for online/blended learning, Lab courses and projects in online/blended learning

Keywords: online project, multidisciplinary project work, cps/ embedded system education

ABSTRACT

The challenges of software engineering for cyber-physical systems (CPS) are hard to teach in normal lectures. To understand, students have to experience these challenges by themselves. Thus, we offer a project where students have to develop a multi-robot system in a small team. Besides the challenging task, the students also have to face the challenges of multidisciplinary project work and have to give convincing presentations of their progress. Due to Covid-19, we have converted our project into an online project with simulated robots instead of real hardware. Students have to record their milestone presentations and upload them to the learning platform Moodle. Other students can ask questions about the presentations and have to review assigned presentations. During the project work, we support the students with supervised online meetings and modern tools for software engineering. As an introduction into project management, we provide an interactive lesson on Moodle. Our experiences have shown that the usage of simulated robots increases the creativity and the spectrum of topics, e.g. industry 4.0 or autonomous driving, as no hardware has to be purchased and ideas can be tested quickly in the simulator. The online meetings provide a spatial and temporal flexibility that enables students with Family commitments to participate. The asynchronous format of the milestone presentations also increases the flexibility and lowers the inhibition threshold for the communication between students. We have also witnessed an increase in the quality of student talks that was caused by the possibility to record the talks several times.

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1 INTRODUCTION

Many things in our daily life, like household appliances, cars or multimedia devices, and in the industry, e.g. automated production, are controlled by cyber-physical systems. Nonfunctional requirements like concurrency, real-time behavior or heterogeneity, as well as the complexity of the physical processes that need to be controlled, make software engineering for embedded systems a challenging task. With the increasing connectivity and automation of these systems, even more engineering challenges arise. Moreover, the ability to work in multidisciplinary teams [1] and remote collaboration become increasingly important. These challenges and the required abilities to meet them are hard to teach in traditional lectures. Instead, they require new formats. To meet these challenges, we usually offer a project where students have to develop a multi-robot system in a small multidisciplinary team (see [2]). Besides completing a challenging task, the students also have to organize project work and give convincing presentations of their progress. Our target group are students of Computer Science, Computer Engineering, and other related degree programs (e.g. Automotive Systems) at the end of their bachelor studies or in their master studies. Bachelor students focus on embedded software engineering and master students focus on quality assurance for safety-critical applications and on optimization for real-time and restricted resources, like memory or energy. We make sure that the groups include students with different degrees and majors, to enable transfer learning and let students practice work in diverse teams. To us, this is among the essential experiences of our project and highly valuable to a future career in the industry, as also highlighted in [1].

Due to Covid-19, we were forced to develop a concept for teaching the same skills in an online environment with simulated robots instead of real hardware. In this paper, we present our concept and first experiences with seven project groups in summer 2020 at TU Berlin. Our experiences show that using simulated robots increases the creativity and the spectrum of topics, e.g. industry 4.0 or autonomous driving, as no hardware has to be purchased and ideas can be tested quickly in the simulator. In the previous format four groups had to share five LEGO Mindstorms robots and one project room. To solve multi-robot tasks they had to agree on 1-2 robot designs and assemble them themselves, thus limiting both the range of available topics and the motivation to test different designs. Moreover, the online project meetings provide a spatial and temporal flexibility that enables students with family commitments to participate. We have also witnessed an increase in the quality of many student talks that was caused by the possibility to record the talks several times.

We first present our course concept in Section 2 and then summarize our experiences and results of our course evaluation in Section 3. We end with a conclusion in Section 4.

2 ONLINE COURSE CONCEPT

The aim of our project is to teach the students to work together in a team of 5-8 students on a complex embedded software design task. Besides the challenging embedded software design task itself, we want the students to gain experience in project management and organization. They should learn how to plan work packages and interfaces so that multiple teams can work on subsystems, which are later integrated into one system. Furthermore, they gain experience in milestone presentations and learn how to give constructive feedback on the presentations of the other project groups. We offer different project tasks that are related to current research topics in embedded system design, such as autonomous systems and AI, or quality assurance and programming of safety-critical control tasks. The application areas range from autonomous exploration and rescue robots over autonomous cars to industry 4.0. With this, we can integrate recent research results in teaching and inspire students for research.

In the following subsections, we first introduce our course structure and then go into details on how we organized online teaching and online project work. Afterwards, we describe our asynchronous presentation mode and how we kept students involved in the course organization with continuous feedback.

2.1 Course Structure

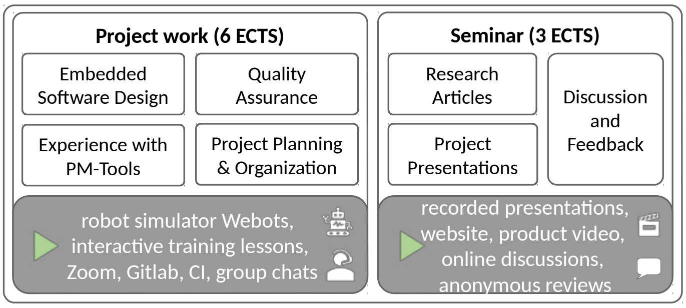


Figure 1: Course Structure and Online Realization

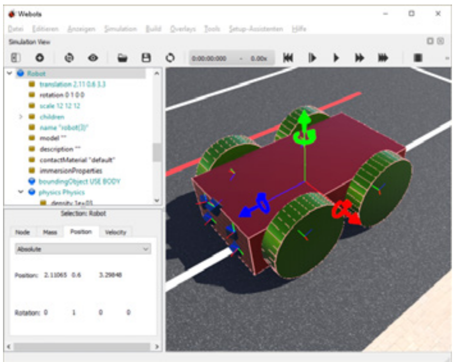


Figure 2: Virtual robot design of a student group

Our project is worth 9 credit points (ECTS) and consists of two parts: a project with 6 ECTS and a seminar with 3 ECTS (Figure 1). In the project part, the students work on their project task with a focus on embedded software design and quality assurance. To increase the team effectiveness, we have included some recommendations from team effectiveness research [3] on grading and project management. The grades reflect individual effort (avoids social loafing), participation in management tasks, and the ability to explain all aspects of the project in an oral exam (promotes collaboration and communication). Students have to manage their project as a team. They have to divide the challenging task into sub-tasks and agree on a project plan. They have to define responsibilities for time, resource and technical project management and agree on strategies for integration and quality assurance. To support them, we have weekly supervised project meetings, where we observe the current state and give hints to solve problems before they become critical. In the seminar part, the students read and discuss recent research articles on the project task, present their project progress in milestone presentations and review presentations of their fellow students.

For our online course, we have carefully transferred all course elements into online activities. As the general restrictions due to Covid-19 already challenge all participants, we put a special focus on offering great flexibility while maintaining a realistic project setting and offering important experiences. In the following, we go into details on our online activities.

2.2 Online Teaching

Traditionally, we began our project with introductory lectures on project management fundamentals and the Lego Mindstorms environment. For the updated project, we provide material on the learning platform Moodle instead. We created a mandatory interactive training lesson on project management with the same content as our lecture but with the material split into small sections that students can take repeatedly and at their own time. After each section, we provide study questions for self evaluation. For Webots, we exploit the extensive material already available online and select and link suitable tutorials and documentation. Moreover, we provide additional learning material and research papers related to the project topics.

2.3 Online Project Work

In our original project, teams met regularly to work on LEGO *Mindstorms* robots [2]. To enable collaboration in our online project, we replace all physical hardware with the open-source robot simulator *Webots*[1][4]. Figure 2 shows the Webots GUI with a robot design from our summer 2020 project. Robot simulators like Webots or *Gazebo*[2] have proven effective in educational projects [5, 6]. They provide many advantages over actual hardware, like faster prototyping, integration with automated tests, and no physical or monetary limitations on the robot and environment design. Hence, compared to previous topics like maze exploration or autonomous driving on a track, they also allow us to provide more diverse tasks, including areas of current research, like *Reinforcement Learning* [7].

In addition to Webots, we offer students a suite of modern software engineering tools. We choose tools that ensure privacy of student data and communication, and that are commonly used in the industry. For communication within groups and with us, we provide messaging with group forums on Moodle and the tool *Slack*[3], and the video conferencing solutions *Zoom*[4] and *Jitsi*[5]. Moodle group forums and Slack enable students to communicate asynchronously, so that they do not need to respond immediately. For project resource and time management, we offer access to the development platform *Gitlab*[6]. Gitlab integrates version control, issue tracking, and continuous integration. Jitsi and Gitlab instances are hosted by TU Berlin, and Slack communication and Zoom conferences are encrypted, guaranteeing privacy.

Putting remote collaboration at the center greatly increases flexibility. Previously, students had to compete for a limited number of project rooms in order to meet. If a room was booked by another group, they had to reschedule. Also, many students lived in different areas and had to take a long journey across the city if they wanted to meet, requiring careful planning in advance. In our project, students can communicate more frequently and spontaneously, because all communication is online and does not always require a direct response. With this new flexibility in time and place, we also allow more groups of students to participate. This includes students that are abroad or have restricted schedules, e.g., due to childcare. Finally, experiencing remote collaboration with state-of-the-art tools and methods gives our student a great advantage for later work in the industry, where distributed software development has been common practice for many years.

Remote collaboration also allows us to get an overview of a current project status and student contributions more easily, because Gitlab tracks all changes to code and documentation. Thus, by analyzing this data, we can estimate the current and overall workload per team member, to give fair grades. Moreover, we can identify problems with time management and raise attention to these early during the semester, so that the group can work on these and still deliver a successful product. We can also analyze most group communication because Slack and Moodle record all discussions. Based on this data, we can identify students that participate frequently or rarely, as well as potential conflicts.

2.4 Milestone Presentations

We complement online project work with three milestone presentations during the semester, where students should exchange ideas and improve their presentation skills. In the previous format, the groups presented their work in succession on fixed milestone days, with a short discussion after each presentation. Now, we updated this process to an asynchronous format. Instead of presenting in person, groups record their presentations as video. Each video should feature 2-3 speakers, with a length of about 25 minutes. We publish all videos on our course page on Moodle and provide three channels for discussion and feedback. For content related questions, students can comment publicly on presentation videos. Each student must ask at least one question per milestone, to initiate discussion. In turn, each group must answer all questions related to their videos. For feedback on the presentation, we provide anonymous

[1] `http://www.cyberbotics.com` [2] `http://gazebosim.org/` [3] `https://slack.com`
[4] `https://zoom.us` [5] `https://jitsi.org` [6] `https://about.gitlab.com`

review forms about the form of the presentation and performance of the speakers on Moodle. Each student must review presentations of two other groups per milestone. We assign these groups randomly and uniformly, so that all groups receive the same amount of feedback. We collect all reviews and send them to the corresponding groups. Finally, all supervisors give feedback to each speaker.

Our asynchronous milestone process has many benefits. Recording presentations in advance gives students the chance to improve their presentation skills more easily. They can watch their recording and retake problematic sections. Also, other students and supervisors can pause between presentations and watch videos repeatedly, allowing them to focus on different aspects, and thereby, asking more detailed questions and writing more helpful feedback. This feedback can also be more critical. As reviews are anonymous, students must not fear spirited reactions from other students. At the same time, we ensure that reviews are objective and do not contain insults before sending them to the reviewed groups. Moreover, our text based feedback process enables students that are not fluent in English to participate easily.

2.5 Final Presentation

At the final presentation at the end of the semester, students should learn how to present their finished product convincingly and creatively to outsiders and potential customers. We split this presentation in two common formats, a video and a website. The video should be 15 minutes long and show all product features in action. The website should give an overview of project goals, major design decisions, and results. We evaluate the submissions by content, creativity, and appeal. As incentive, we publish all websites on our research group site. Moreover, we hold a contest, where students and supervisors elect the best website and video anonymously (students cannot vote for their own group). We show the winning video on our research group site and highlight the winning website with a prominent banner.

2.6 Continuous Feedback

Our primary objective is to deliver a project that is effective in teaching and enjoyed by our students. However, we do not yet know if our new teaching methods work as intended. Therefore, we collect and evaluate student feedback continuously throughout the course and adapt our approach where necessary. We collect feedback from three sources. First, we use the feedback activity type built into Moodle to collect data through anonymous surveys. Second, we discuss our methods with students in our weekly group meetings. Third, we use data collected by Moodle, like the view counts from milestone presentation videos. These allow us to identify formats that work well, or ones that need improvement, e.g., as indicated by low engagement. After collecting the feedback, we respond to it, for instance, by discussing it, or adjusting our methods. Thereby, we increase the quality of our teaching continuously. Also, we show that we value the needs and opinions of our students, resulting in more feedback and a friendly and productive atmosphere.

3 EVALUATION

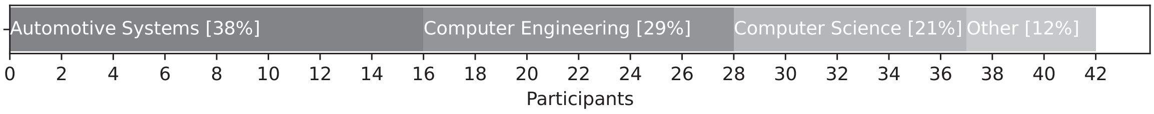


Figure 3: Participants of the project in 2020 by major

We implemented our project at TU Berlin in summer 2020 with 19 bachelor and 23 master students. Figure 3 shows the distribution of their majors. As it can be seen, most of our 42 participants were enrolled in *Automotive Systems* (16), *Computer Engineering* (12), and

Computer Science (9). The remaining participants majored in *Mechanical Engineering* (1), *Economical Engineering* (1), *Mathematics* (1), *Information Systems Management* (1), and *Innovation in Information and Communication Technology* (1). After an initial vote for a project topic, we assigned the students to 7 teams with 5-7 members each.

Overall, our project was received very well. At the end of the project, we asked all students to give us feedback in an anonymous survey on Moodle. Almost all of the 17 respondents were very satisfied with the project in general and our supervision. 14 rated the project *good/ very good*, only three students thought the project was just *satisfactory*. No student chose *sufficient* or *weak*. Most students were also satisfied with our supervision. 13 students thought it was *good/very good*, three rated it *satisfactory*, and only one student thought it only was *sufficient*. No participant thought it was *weak*. We also asked students how much they learned about project management and teamwork. They could respond *very much*, *much*, *some*, *not much* or *little*. The results indicate that our use of large, diverse teams is effective. 14 of 17 participants said they learned *much/very much* about project management. Only three said that they learned *some*. Similarly, almost all participants appear to have improved their teamworking skills. Four respondents said that they learned much and nine even learned very much. Only four students responded with *some*, but no one chose *not much* or *little*. Also, 11 students answered that they have learned much/very much about interdisciplinary teamwork. Four students learned some, while two students said they did not learn much about it.

We evaluate our teaching methods in more detail in the following, using data from our continuous feedback process. We use two anonymous surveys with 24 and 35 participants, respectively, that we published after the first and second milestone, and our final survey, with 17 participants. In addition, we use oral feedback from our weekly and final group meetings, and internal statistic from our course page on Moodle.

3.1 Online Teaching

Our introductory lesson on project management was very well received. After completing the lesson, 98% of our participants expected it to be helpful during the project. We did not ask about the lesson in the final feedback again, but several students reported that it had helped them. Our additional learning material was also welcomed.

3.2 Online Project Work

The online project work mostly met our expectations. All teams were creative and explored different robot and environment designs in Webots. Still, many groups would have preferred to have both a simulation and physical hardware. No physical hardware also meant that students could not gain experience in low-level embedded programming with resource constraints, a key component of this project previously. However, it gave them more time for other equally important aspects, including algorithm design and quality assurance. Still, this additional time was limited, due to new tasks like environment design or continuous integration.

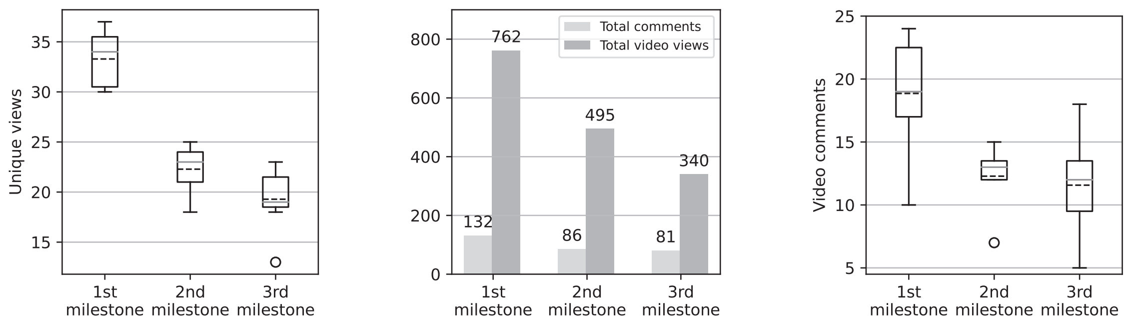
As expected, remote collaboration requires more coordination and discipline within the teams. As in a normal project, team members in an online environment must be able to work on features in parallel, and integrate these features later easily. This requires components with well defined interfaces, and regularly testing, to ensure that components satisfy their specification. Otherwise, the team cannot share the workload effectively and likely fails to complete the project in time. In an online environment, specification and testing are even more important, because group members cannot meet in person and regularly test the integrated product when collaborating virtually. This was a challenge to some groups. One group in particular defined interfaces very late. Consequently, they could not distribute work effectively, because some students waited for components from other students, that these were still working on. They also failed to integrate their components later, due to incomplete testing. Ultimately, they met in person and integrated most features manually. Most teams that defined interfaces and set up continuous integration with unit tests early, in contrast, could distribute work effectively and meet their project plan.

All groups also exploited the flexibility of online communication. All groups communicated on Slack. Often, groups split into smaller teams, and met in these subgroups. From the communication on Slack, we know that there were several spontaneous meetings, often at least once per week. Moreover, we had several students from China that could not leave their country due to Covid regulations but were still able to participate in the project. Despite this flexibility, most students would still prefer to meet their team members in person. In our final survey, only seven of 17 students said they would continue to meet online. The student feedback from our final group meetings also supports this.

Finally, remote collaboration simplified supervision, as we hoped. Often, we could get an accurate overview of the current project status by looking at open issues and the continuous integration pipeline on Gitlab, and discussions on Slack. Moreover, using the tool *Gitinspector*[7], we could often identify individual project contributions, allowing us to ask more directed questions during the oral consultation at the end of the project. However, we observed that the commits to the repository did not always provide us an accurate view. Some students were using the same Gitlab account, because they met in person and worked on the same computer, or could not access the repository themselves, due to regulations. Hence, their contributions were associated to another person. Therefore, although intended, we could not use the Gitlab statistics as direct input for the final grade.

3.3 Milestone Presentations

Our updated milestone presentation format increased the general quality of most student talks and feedback, and lead to more engagement. A direct comparison of grades with previous years is not possible, as we have modified our evaluation criteria.



(a) Unique video views *(dashed line = mean)*

(b) Total video views and comments

(c) Video comments *(dashed line = mean)*

Figure 4: Student engagement with group presentations across milestones

As intended, many groups took advantage of the asynchronous format and submitted appealing and skilled presentations. As shown in Figure 4a, these presentations attracted much interest. At the first milestone, most of our 42 course participants watched all videos, although not required. The view counts declined at the second and third milestones, but all but one video were still seen by at least 42% of all participants. Hence, giving all groups large audiences. Likely, most students wanted to get a general overview of all groups at the first milestone and

[7] `https://github.com/ejwa/gitinspector`

then focused on the teams they were interested in. The aggregated views per milestone (figure 4b) show that students watched videos repeatedly, as we intended. We also exploited this feature and found that pausing and rewinding allowed us to give more precise feedback.

Our review process led to high engagement as well, likely due to our incentives and lower language barriers. Similar to a real discussion, not all viewers commented on all videos and not all videos received an equal number of comments (see figure 4c). However, all groups received at least a few questions. Students commented most at the first milestone (see figure 4b). There, they asked significantly more questions than we required. This correlates with the view counts and our experience. At the first milestone, students are still in the concept phase of the project and open to input from others. Despite that, 12 of 24 respondents of our first survey thought that the comments were not an adequate replacement for live discussions. During the semester, most students also valued the reviews. In our first survey, most students agreed that writing (67%) and receiving (96%) reviews helps them to improve their own presentation skills. However, we found that some reviews were very unspecific, and many students complained about an overwhelming workload. In response, we updated the review form and reduced the required reviews from three to two. In subsequent feedback, 91% of 35 respondents confirmed that the workload was now manageable. Also, 77% said that our updated form helps them to formulate their feedback more precisely. Likewise, we observed an increase in feedback quality. Still, at the end of the semester, several students criticized that they received imprecise and duplicate feedback, but according to one student, the large quantity of reviews meant that there were always at least a few helpful among them.

Despite this engagement, most participants of our final survey would not continue with the current asynchronous milestone format. Only seven of 17 respondents would keep video presentations and only five would have anonymous student reviews. Based on oral feedback, we assume that the effort required for recording and cutting the videos, and writing reviews are the primary reasons for this. Still, 11 respondents would keep video comments.

3.4 Final Presentation

For the final presentation, almost all groups submitted appealing websites and videos. Still, we observed clear differences in quality and creativity among the submissions. Some websites were very attractive, but a few groups included too many technical details, few pictures, and much text. Also, some videos did not present the product convincingly, but simply stated its features. We assume that these differences result from unfamiliarity with the submission formats. As intended, our website and video contest generated much interest. Although participation was voluntarily, 33 of 41 students voted for a website and a video.[8]

4 CONCLUSION

Covid-19 required us to reimagine a proven project design for an online environment. But after implementing our updated concept in 2020, it not only proved effective, but also increased the perceived quality of most student contributions, general engagement, and spatial and temporal flexibility. As a result, we continue using interactive online material, our final presentation formats, and Webots directly in summer 2021. To reduce overhead, we revert our milestone presentations back to a live format and adjust our feedback process. Students no longer have to ask questions after each presentation, but they receive bonus points if submit a small anonymous feedback form. Also, we require students to write only one detailed review. Despite its success, our updated project misses hands-on experience with physical hardware. Because this is key aspect of embedded systems development, we will reintroduce actual hardware once teaching in presence is possible again, but keep Webots for prototyping and testing.

[8] All websites and the winning video can be found at `https://www.sese.tu-berlin.de/menue/studium_und_lehre/studierendenprojekte/mpsees_ees_2020/parameter/en/`

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DOUBLE JEOPARDY: EXPLORING THE COMPLEXITY OF THE SCHOOL/UNIVERSITY/WORK TRANSITION FOR DEGREE APPRENTICES

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Conference Key Areas: *Transition; Engineering Education Research*
Keywords: *Degree Apprenticeships; Transition; Work Based Learning*

ABSTRACT

This paper reports on the early stages of a PhD study into supporting Engineering Degree Apprentices in a UK University through their contemporaneous transition into work and study. After briefly setting the context and rationale for the study it considers the development of the research design and integrates this with the corpus of literature to develop a frame for the primary research developed from Laurillard's Conversational Framework and the ideas of social capital and habitus.

1 INTRODUCTION

This is a methodology paper reporting on the initial stages of a PhD, and represents a work in progress. It brings together desk research and informal investigation conducted at the 'exploratory' stage of what will be a large empirical study. Starting by introducing a relatively new form of educational apprenticeships, the paper considers the justification for the study and provides a theoretical setting.

1.1 Degree Apprenticeships

Introduced in the UK in 2015, Degree Apprenticeships (DA) are a relatively new form of degree level provision. They are designed to address the perceived short-comings of traditional University degrees in terms of practicality and breadth; issues which have long been identified, and have been a recurring theme in the literature and public discourse on the topic. In the case of Engineering DAs they are also expected to address reported shortages of graduate-level engineers working in the sector.

Unlike traditional degree level engineering programmes, DA programmes tend to be collaboratively designed; co-created with employers and professional bodies. This evolutionary approach is also unique in terms of the employment status of the apprentices, most of whom start their ‘work’ and ‘study’ careers at the same time.

2 CONTEXT & RATIONALE

The call for graduates who can ‘hit the ground running’ with appropriate skills has emanated from government and employers for many years [1], [2]. Yet it is worth noting that the demand for ‘oven ready’ graduates is not uncontested; indeed, previous studies suggest that education is about ‘higher skills’ which equip students to be leaders in their chosen professions [3], [4], [5]. On the other hand, there is some argument that the development of workplace skills is better done in the workplace [6]. The resulting tension means that there are competing definitions of ‘success’ in the world of engineering higher education; academic attainment (and by extension the implication of higher-level meta-skills and thinking) and employability; the capability of graduates to contribute effectively to their employer quickly and with minimal additional investment in training (e.g. [7], [8]). The Degree Apprenticeship, with its much more central role for employers in both design and delivery, is arguably the most recent manifestation of the attempts to hybridise the higher education system to produce graduates who are both academically and practically competent.

The issue is also by no means one-sided; a number of studies indicate that newly qualified graduates often feel ‘incompetent’ (e.g. [9]), and many researchers have identified the difficulty in transition into the workplace for graduate engineers [10], [9]. This is perhaps unsurprising, given that some studies also indicate that there is little, if any, correlation between academic performance and success in the workplace [11].

While Degree Apprentices are making a transition into work (albeit not as graduates) they are also undergoing another transition which has been recognised in the literature as both important and difficult [12]; the transition into higher education. Hence, it would appear that Degree Apprentices are presented with a unique challenge: they must transition into higher education and the world of work at the same time, balancing two new identities (student and professional) while navigating the complexities of their conjoined environments. The newness of the DA programmes means that the dualistic nature of the Engineering Degree Apprentices lived ontological and epistemological experiences of ‘becoming an engineer’ has yet to be empirically investigated, meaning there is a notable gap in academic knowledge in this area. This gap extends to pedagogic theory wherein the newness of the Degree Apprenticeship remains an under-explored academic field.

The PhD associated with this paper will explore these experiences and develop a framework for effectively supporting Degree Apprentices through these parallel transitions and compare it to the experiences of traditional students. Bringing together previous literature relevant to the new Apprentices’ experiences this paper makes a distinctive contribution to academic knowledge and discussion in the area of the early first-year experience and transition.

3 CONTRIBUTION

The primary research aim is to address the lack of research into what makes for successful transitional learning experiences for degree apprenticeship students in the field of engineering. The associated objectives are to conduct empirical research in order to understand:

1. What constitutes success in this context.
2. The unique and shared aspects of the experience between degree apprentices and traditional undergraduate students.
3. The key factors determining success.

The fourth, and perhaps most important objective is to develop a set of empirically grounded recommendations and tools for Universities wishing to maximise the success of engineering degree apprentices. The PhD will make the following contributions to theory, policy, practice and knowledge:

3.1 Contribution to Theory

Empirically grounded theoretical frameworks and models will be developed during the study reflecting a unique contribution to theory in a range of different pedagogical fields of study including: transition into higher education; supporting students in STEM education; the student experience in engineering; the ‘early first year’ experience; peer support and learning; academic and work-based mentoring; learning and teaching in ‘difficult’ subjects; the development of ‘transferable’ employability skills and competencies.

3.2 Contribution to Policy

Evidence based recommendations for policies (based on the study) will have the potential to effectively improve both the experience and the outcomes for DAs.

3.3 Contribution to Practice

Evidence based recommendations for practices (based on the policies) will have the potential to effectively improve both the experience and the outcomes for DAs.

3.4 Contribution to Knowledge

Developing an understanding of the experience of Degree Apprentices in transitioning into the role of ‘student engineer’, and the factors which affect that experience.

4 RESEARCH DESIGN

Starting from the research question: “How can the University support Degree Apprentices during their transition on to the Engineering Degree Apprenticeship Programme?” this paper develops a frame for investigation which will inform a case study-based programme of research.

There has been a long tradition of deficit-based study of students in STEM subjects in Higher Education [13]. Deficit thinking focuses “myopically” on what a student (or type of student) lacks [14]. This correlates with a focus on the barriers that students encounter rather than on what might contribute to success [15], [13]. In recent years, however, there have been growing calls to research STEM students, their experience and success using a more positive, asset-based approach [16], [17]. It is claimed that a social capital lens allows educators to develop specific actions to support and facilitate students in connecting with resources that increase their social capital, and hence, allow them to better achieve their educational and professional goals [18], [19]. This offers a potentially more fruitful approach to the research question.

Epistemologically and ontologically in this research, the researcher is interested in how the participants construct their personal understanding of their experiences rather than seeking an objective 'truth'. The study emphasises the interplay between the subject and the phenomenon, suggesting that experiences of the Degree Apprentices may be substantially common, but that the meaning made of those experiences by individual Degree Apprentices will necessarily be individual as they construct their own truth via personal social interaction – this means a constructionist epistemology is seen as more appropriate.

In considering how meaning is constructed, Merriam [20], recognises the importance of understanding and interpreting how people make sense of what goes on around them, something that is linked to Crotty's [21] use of the term "Symbolic Interactionism" to describe the approach taken by researchers who view phenomena and the meanings which actors give to them through the eyes and the consciousness of the actors themselves.

The rationale for adopting symbolic interactionism as a theoretical perspective for this study is twofold:

1. The meaning which Degree Apprentices make of their situation guides their decisions and actions.
2. These Degree Apprentices' experiences and models of interpretation evolve in a social world incorporating experience gained principally from family, neighbourhood, and school and modified by their transition into the twin worlds of work and study.

4.1 Methodology and Research Method

There are well-established contrasts between research approaches which are described by Saunders et al [22] in their research onion as 'deductive' and 'inductive'. In terms of this research, we can see that it falls into the inductive category; as noted by Strauss and Corbin [23]:

"Some areas of study naturally lend themselves more to qualitative types of research; for instance, research that attempts to uncover the nature of a person's experiences with a phenomenon."

The relatively unexplored nature of the topic, means that a flexible, exploratory and emergent approach will be required as the researcher's understanding evolves and new questions emerge due to the richness of the data. This situates the research as necessarily inductive, starting with observations from the field and seeking to build a theory from this evidence.

The approach taken is Grounded Theory [24], an inductive approach which has freedom and flexibility [25]; it focuses on collecting data through participant interviews to build rather than test theory through comparison of ideas from subsequent interviews.

Traditional Grounded Theory uses a structured analysis with a central focus on a 'hub' and additional 'categories' [26] (axial coding) shaping a model.

The principal mechanisms of Grounded Theory are comparison and integration [27] and a standard approach is [25], [27]:

- Collect data via interviews.
- Code the responses to provide the "scaffolding" [25] on which the study is built.
- As new responses are gathered conceptual categories (theoretical codes) emerge through comparative analysis of subsequent responses.
- The theoretical codes are then combined with existing literature to develop theories from the research.

The theories developed will form the basis for constructing proposed plans and policies to effect positive change in the experience of the apprentices.

4.2 Methodological tools

Semi-Structured Interviews

Interviews are a common element in grounded theory [26], and are a useful approach to gathering greater depth and breadth of data when compared to questionnaires. Silverman [28] describes the interview as "collaboratively produced" and suggests that they promote a level of involvement and self-worth for the interviewee far beyond the passive involvement of a questionnaire. It is also possible to pick up on important cues from the nuances of communication in an interview: intonation, emphasis and hesitations can be perceived to add depth to the data, and to indicate areas for further enquiry. Since this study seeks to investigate the meanings assigned by Degree Apprentices to their experiences and the social capital which help supports them in being successful as DAs, this extra information has the potential to add to the richness of the research, giving more clarity to the participant voice.

The ethical issues which may arise with this type of research has been considered, and full ethical approval obtained before beginning the primary research.

5 LITERATURE & CONCEPTUAL FRAMEWORK

An evolving body of literature has developed on graduate transition into work, and the means by which both the experience and outcomes can be improved (e.g. [29], [30]). A key theme within the literature is relationships; in particular, mentoring relationships with practicing engineers [31], [32] which is supported by studies into organizational knowledge which emphasise the importance of tacit and implicit knowledge [33], [34]. Socialisation and identity formation have also been revealed as crucial by recent studies [35], [36].

Separately, the transition into higher education has long been recognised as being complex, with seminal work by Tinto [37] forming an important basis for later studies. This text provides a solid understanding of contextual factors (both educational and social) leading Tinto to conclude that a critical component of a successful transition is creating a sense of belonging in new students, and embedding them into discipline specific narratives, cultures and identities ([37], [38]. [39] built on this research, extending the thinking to include 'academic belonging', and research by Clark et al [40] argued that a holistic sense of belonging should encapsulate academic, professional and vocational domains. This work evolved into a model focused in 3 phases: growing and nurturing engineering capital; situating student engineers as joining a distinctive profession; and developing their self-identity as engineers [12]). There are obvious parallels here with the research on transition into work with themes such as relationships, belonging and identity being common.

A related area is the concept of 'Social Capital'; the idea that relationships and experience are assets which help individuals succeed in a given set of circumstances. Bourdieu is arguably the father of the developed concept of social capital [41] with much of the literature in the field developed from his seminal works. While Bourdieu was principally concerned with the creation and maintenance of advantage in societies, his work has been widely used in the literature on University attendance and success (e.g. [42], [13]). Two key concepts in Bourdieu's work are:

- ***Field:*** A social space of specialist domains with rules, structures and practices. Examples of fields would be education, engineering and law.
- ***Habitus:*** The idea that as one becomes familiar with a field (and one's role in it) one develops a set of specific and identifiable principles, attitudes and behaviours. These dispositions are not static, but will be moulded and reformulated over the course of one's life gradually becoming ingrained and form the habitus [43].

These ingrained ideas and attitudes can be changed [44] but Reay et al [45] point out that, despite this propensity for evolution, significant change of habitus such as from school to university can result in internal conflict. New players in a new game can feel alienated and powerless because they understand the new game (University) through the lens of their own perceptions and habitus; formed at school [44]. Familiarity with the habitus for a particular field allows one to fit in like a "fish in water" [45], but when the habitus is disrupted it is more akin to being a "fish out of water": frightened, thrashing around, unable to make sense of the new surroundings or work out what to do. The potential relevance to DAs where apprentices are required to swap between field requiring very different habitus on a regular and frequent basis is clear.

An extension of the notion of habitus is the concept of Engineering Habits of Mind (e.g. [46]) which builds upon Shulman's seminal work on 'Signature Pedagogies' (e.g. [47]) seeking to understand the linkage between the way fledgling professionals are taught about how to 'think, perform and act with integrity'.

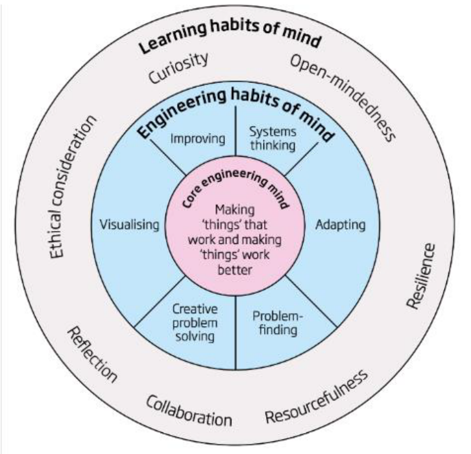

Figure1. Engineering Habits of Mind: [46]

In a model which pre-dates Engineering Degree Apprenticeships but incorporates the two key aspects of 'academic' learning and practice, Lucas and Hanson [46] defined the learning habits of mind and the engineer's habits of mind.

As presented here, and in the 'wider 'signature pedagogy' literature the habits of mind for learning and engineering are broadly consistent, but this may neglect the cultural context of the habits (or habitus). The presentation of 'Learning Habits of Mind' and 'Engineering Habits of Mind' as bounded and universal is not entirely helpful since the former are situated within the culture of the university and the latter are situated within the culture of the organization. The stress caused by the change of habitus from school to university is equally evident in the transition from university to work. For a student on the traditional path of a full-time degree followed by full-time employment the transitions happen in series and over a period of time. However, for a Degree Apprentice the transitions happen in parallel and they are asked to switch between the two on a regular and reasonably frequent basis.

Although no research has been done from this perspective, constant and frequent moving between fields and adjusting to different rules will likely take its toll on at least some students. And, of course, it may lead to the apprentice operating like a "fish out of water" in one or other of the fields.

There are a number of frames for looking at the development of students through the learning experience at University. Perhaps the most useful in this context is Laurillard's [48] 'Conversational Framework', which considers both student thinking and practice in terms of their interaction with the learning environment and their peers. The model recognises that learner's concepts and practice evolve in a co-dependent (and social) fashion; putting concepts into practice and drawing on practical experience to develop more robust and practical concepts.

The Conceptual Framework

The conceptual framework brings together the research stance and epistemology of the researcher with the literature from the field, and will inform the early stages of the research.

The initial Research Frame for this piece of work (figure 2) builds on Laurillard's conversational framework [48] to integrate the ideas around application and linking into a work context which is central to the notion of a Degree Apprenticeship. Laurillard's original model is at the centre of the diagram, showing the way students develop their concepts and practice (or schema) through repeated (social) learning loops involving their tutors and peers. The first loops are the students interacting with the designed learning environment and associated concept. The second is when they discuss or collaborate with peers (other students). Both loops impact the student's concepts and practices. This is sufficient for a student on a traditional degree route (although Social Capital Theory would suggest that they will be influenced by upbringing, tastes, class, etc.) but fails to consider the additional contexts which are relevant to Degree Apprentices:

- ***Enculturation*** as an employee within the company (including organizational hierarchies, norms of behaviour, and valued skillsets)
- ***Professionalisation*** as a putative engineer in the profession (including professional ethos, norms of behaviour and valued skillsets).

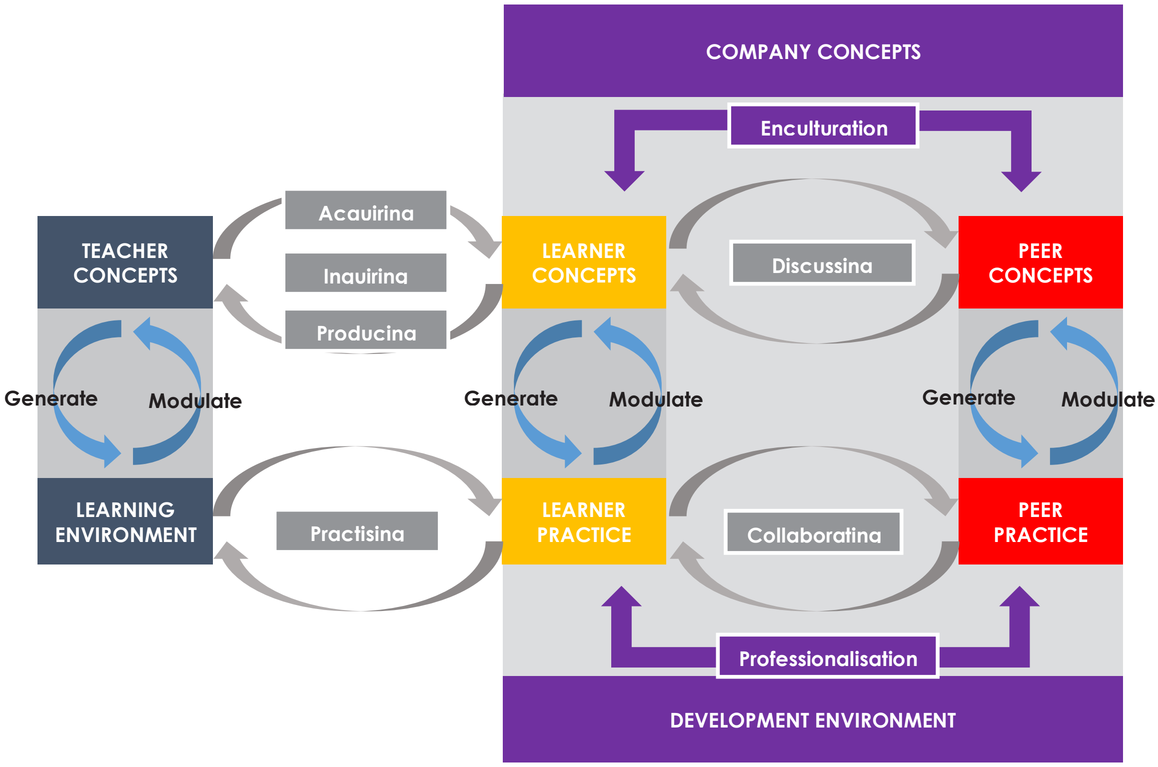

Figure 2. Conceptual Research Frame: Modified Conversational Framework

This is consistent with the characterisation of Degree Apprentices developing the identities of employee (enculturation); professional (professionalisation); and student (as in Laurillard's original model) contemporaneously [49] and allows for examination of the field and habitus associated with the areas.

6 SUMMARY

A research frame has been developed which responds to the unique circumstances of Degree Apprentices and to the area of focus for the research question. Next steps will involve developing appropriate sample fields and approaches, observational frameworks and developing guiding questions for the interviews.

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OPEN EDUCATIONAL RESOURCES FOR ENGINEERING STATISTICS

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ABSTRACT

It is well known that mathematics courses are particularly challenging for engineering students. In the wide range of ways to address this problem, we use digital technologies to develop new approaches for students in order to better understand and apply mathematical concepts. In intensive cooperation between mathematics education and statistics departments, we develop learning materials for the field of probability theory and statistics, which will be used in engineering courses and other fields of study. These materials include interactive applications, instructional videos and digital mathematical tasks. In this contribution, we focus on digital tasks implemented with the assessment system *STACK*, which uses a computer algebra system to evaluate the user input automatically. We elaborate on the potentials of digital mathematical teaching materials, such as the numerous possibilities of automated feedback in digital tasks. One possibility to realize feedback messages is to implement graphical representations of stochastic concepts that can also include interactive elements. This enables students to make adjustments to their solution by interactively exploring the underlying concept. For these features, we make extensive use of the JavaScript library *JSXGraph*. All materials are already being used in courses and evaluated by students with questionnaires and qualitative interviews in order to optimize them.

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1 INTRODUCTION

In engineering studies, mathematics courses take an important part as math skills are needed in the engineering profession. However, mathematics courses are very challenging, especially for beginning students, and in many cases the reason for dropping out [1, pp. 70-71]. Therefore, it is important to address these issues and develop measures to support students in learning mathematics. Taking advantage of the possibilities based on the use of digital media in university teaching, we develop digital materials from the field of statistics in a team of mathematicians and mathematics educators from three German universities. These include three types of materials, namely interactive applications, instructional videos and digital mathematical tasks. The focus on the field of statistics is reasonable as working with data and extracting information from them is required when developing, designing or improving a product or a production process for engineers [2, p. 2]. With the completion of the project, all materials will be made available as Open Educational Resources (OER) free of charge on the state portal ORCA.nrw, so that lecturers and students can use them. Since they will be provided open source, it will also be possible for lecturers to change details or even large parts of the materials to customize them to their courses. To ensure that the materials are designed in a way that they are really helpful to the students, regular evaluation of our work is essential.

All of our materials are intended for use in engineering statistics classes. Therefore, it is important to consider the needs of engineering students. For instance, Wolf (2017) points out that there is a desire among engineering students for tasks with engineering applications [3]. Regardless, it is important to provide students with the (mathematical) skills they will need for their future careers. In this respect, Barry and Steele (1993) state that "there is a cornerstone requirement for engineers to model and to be able to solve modelling problems" [4, p. 225]. The four educational objectives they specify in this context include interpreting and solving modelled problems, efficient communication, understanding mathematical models of engineering problems and self-education [4, p. 226]. Thus, it should be the goal of teaching engineering mathematics to promote these skills in order to prepare students for their future careers.

In this paper, we elaborate on the potentials of these digital learning materials for engineering statistics. We do this by explaining our approach to development and by introducing some examples in consideration of a theoretical framework. While all three types of material mentioned above are considered below, the focus is on digital tasks that are implemented using the open-source assessment system *STACK*, especially the versatile possibilities of automated feedback such as providing graphics depending on students' individual answers. In addition, we present the methods we use to evaluate and improve the materials as well as first results from this evaluation. Finally, we discuss the next steps of the project and give an outlook on our further research.

2 THEORETICAL BACKGROUND

In this section, we give a brief overview of some theoretical considerations about digital materials in mathematics education. Furthermore, we introduce the assessment system *STACK* and the technical and didactical possibilities of digital tasks.

2.1 Interactive Applications

In the context of mathematics, we identify *interactive applications* as digital materials that show a graphical representation of one or several specific mathematical objects such as graphs of functions, geometric elements or diagrams. The interactivity is supplemented by giving the user the possibility to influence this graphics, which can be done in various ways: For example, it is possible for users to change the value of a slider, move elements such as points, click on buttons or checkboxes to execute different kinds of actions or entering an expression into an input field. All these actions lead to a change in the graphics (i.e., the mathematical objects in the graphics). With that in mind, interactive applications provide students with the possibility to explore the mathematics behind phenomena by changing something and then observing the changes in the graphics resulting from this [5, p. 105]. These features can bring benefits to the learning of mathematics according to *discovery learning* [6, 7]. As with any type of learning material, interactive applications should not be given to students without context. It is important to find a good way to integrate them into the students' process of learning. However, this does not necessarily mean that it is inconceivable to use them as part of a self-study. But it is indispensable to make sure that conventions are consistent with those from the associated courses [5, p. 104] and to provide the application not separately, but as a coherent overall package. This should include all necessary information, which interactive action is to be done and what is to be observed. In this context, Alfieri et al. (2011) state that "the effects of unassisted-discovery tasks seem limited, whereas enhanced-discovery tasks requiring learners to be actively engaged and constructive seem optimal" [7, p. 13].

2.2 Instructional Videos

On the internet, there is an immense number of video tutorials on mathematical topics. Google, for example, returns 134 million results when typing in "tutorial mathematics". In this wide range of products, we can find videos of different quality. Ratnayake et al. (2019) developed quality criteria for mathematical videos, that are to be tested with teachers. For example, the videos should be technically correct and well designed [8]. In this context, Mayer et al. (2020) [9] provide some results on the possibilities to increase the effectiveness of instructional videos by introducing some principles. Accordingly, creators should draw graphics by hand (or at least display them little by little) instead of showing them completely at once. Moreover, the speaker should alternately look to the board and to the viewers and activate the audience, for example, by inciting them to summarize the contents for themselves. Finally, the video should be filmed from a first-person perspective when showing a demonstration and should contain subtitles if the video language differs from the viewers' first language. Guo et al. (2014) [10, p. 2] found that shorter videos are more engaging for students and thus recommend to keep instructional videos shorter than six minutes. Beyond that, they state that videos are more engaging when there is a "personal feel" and the speaker's head is displayed when it is convenient. The latter implies that it is not important to set the focus on a professional setting but rather on authenticity. This is supported by the finding that instructors should "speak fairly fast" and "with high enthusiasm" [10, p. 2].
Likewise, Kulgemeyer (2020) supports that videos should meet quality criteria, like, for example, the structure of the video or the adaptation to a group of addressees. He presented science explanation videos to two experimental groups of students, with the one group watching a video that met a predefined set of quality criteria. The other group watched a video that was also scientifically correct but did not meet the quality criteria. The result was that the group that watched the video meeting the quality criteria performed significantly better concerning declarative knowledge on the subsequent test [11].
However, the answers to some questions of design depend on the context. An example is the question if the speaker should be visible in the video. Guo et al. suggest to show the instructor's talking head [10], while other authors make the argument that for videos with explanatory character, the speaker's view can be distracting [12, p. 155].

2.3 Digital Mathematical Tasks using STACK

STACK (System for Teaching and Assessment using a Computer algebra Kernel) is an open source assessment system for digital mathematical questions. It is available as a plugin for the learning management systems Moodle and ILIAS in English and many other languages and

is free of charge [13]. For mathematical tasks, *STACK* has some significant advantages over other assessment systems. First, *STACK* is working with the computer algebra system (CAS) *Maxima* in the background. All answers that students enter into an input field are sent to the CAS. This results in the fact that *STACK* is not only able to compare the given answer to a predefined sample solution, but can also check it for mathematical properties. The CAS also makes it possible to generate random values for a question so that each student gets a different task when opening a test. The second advantage of *STACK* is that it gives creators the option to provide their students with a detailed and differentiated individual feedback. When the feedback is well-conceived and implemented, *STACK* flags the mistakes that students made. In this way, students can be provided with individual feedback messages and with hints that suit them. It is even possible to automatically generate a graphic that depends on a student's solution. In a mathematical context where clearness of abstract concepts is important for learning, this can be a very useful feature. While all of these aspects can reduce the effort lecturers need for correction, this especially applies for tasks where students are asked to give an example of a mathematical object with given properties. These kinds of tasks usually have infinitely many solutions and lecturers would have to check each student answer by hand.
Beyond the wide range of feedback options, it is also possible to extend *STACK* using the programming language *JavaScript*. For example, students can be provided with a couple of subtasks after failing to solve the initial task. This was implemented with the aim of increasing student interactivity with feedback on their solutions [14].

3 MATERIALS

In this section, we introduce some examples of our digital materials and illustrate how we tried to address the theoretical considerations mentioned above.

3.1 Interactive Applications

One of the interactive applications deals with the geometric distribution (Fig. 1).

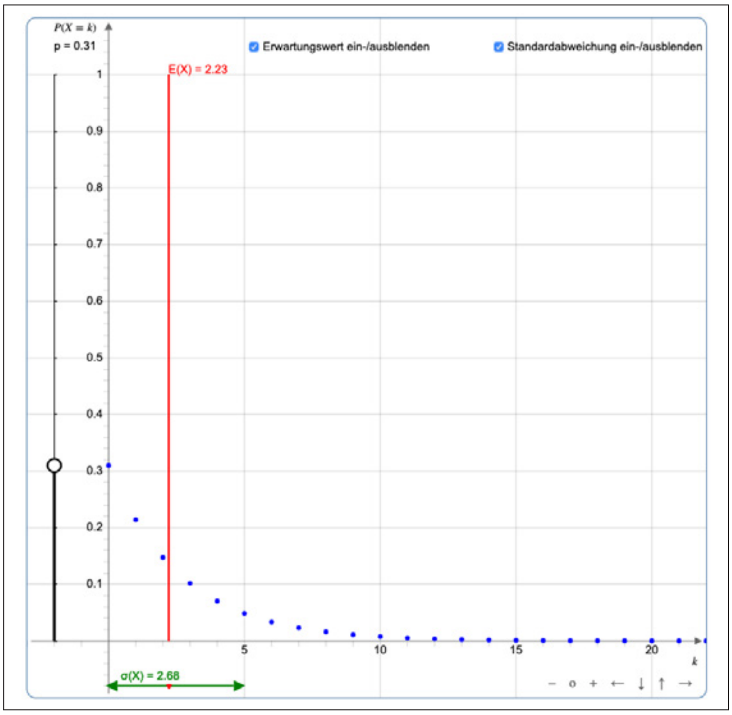

Figure 1: Interactive application on the geometric distribution.

Using a slider, students can change a parameter p and observe the changes in the probability mass function $P(X = k) = p(1-p)^k$, the expected value $\mathsf{E}(X) = \frac{1-p}{p}$ and the standard deviation $\sigma(X) = \sqrt{\frac{1-p}{p^2}}$. In order to keep the application clear, the students can display or hide the expected value and the standard deviation by using checkboxes. As the use of the interactive application should be framed, we added an introductory text as well as some tasks such as "What happens when p is close to zero? Give an explanation for your observation". By clicking on a button "Show possible solution", a sample solution appears and the students can verify their answer. With the theory of discovery learning [6, 7] in mind, this interactive application can be used as an introduction to the geometric distribution. The application was created using the JavaScript library *JSXGraph* [15].

3.2 Instructional Videos

For the instructional video, we decided to explain the definition of a random variable (see Fig. 2 for screenshots). According to the considerations from the theoretical part, we kept the video short (1:59 minutes). In the first half of the video, a random experiment is performed live by the speaker. In the process, a bag of chocolate beans is opened and the content is sorted by color. After noting the number of the blue chocolate beans on a board, the experiment is repeated with a second bag. The audience sees that the number of the blue beans inside the second bag is different from the number inside the first one. This leads to the formal definition of the term "random variable" and its "realization". As a compromise concerning the different opinions on the visibility of the speaker in instructional videos, we have opted for the speaker to be visible during intro, outro and explanations and the speaker's hands to be visible while performing the random experiment. During the formal introduction of the definition in the second part of the video, a set of slides is shown and the speaker is not visible. This combination will hopefully bring in a "personal feel" but will not cause distraction when the formal part is done. The example in the video is chosen so that there is a clear reference to topics of interest of engineering students, namely randomness in production processes.

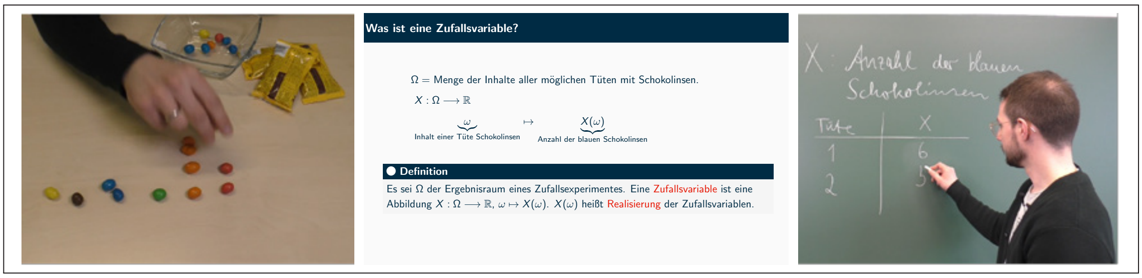

Figure 2: Screenshots from the video on the definition of random variables.

3.3 Digital Mathematical Tasks using STACK

In order to illustrate some possibilities for digital tasks, one example is given in Figure 3. When failing to solve the task, subtasks will be presented within the same *STACK* question after clicking on a button (Fig. 3, upper screenshot).
The subtask appears as a subproblem of the initial problem and is aimed to foster the students' understanding of the mathematical concept [14]. When performing this subtask correctly, students can choose if they want to get another subproblem or if they now feel comfortable to try answering the initial question again (Fig. 3, lower screenshot). If they fail answering the subtask, they are provided with an instructional video that should help them. Since this is a fairly new kind of task, we hoped to get some thought-provoking impulses for future development. The task is about voters of a party in an election. In the current version, this

context is not yet directly related to engineering. However, a similar task is currently being planned, which will deal with no-shows in air travel.

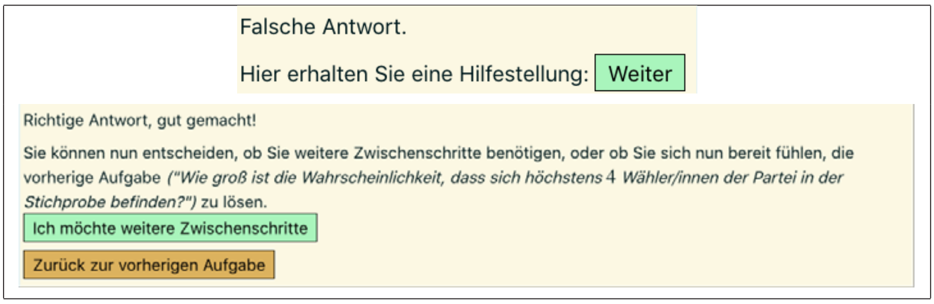

Figure 3: Screenshots from the digital task on voters of a party.

Another example illustrating the great potential of automatic and individual feedback that *STACK* provides can be found in Figure 4. The task is about box plots, but instead of calculating the values in order to draw the box plot as usual, a graphic with a box plot is given and the task is to specify a data set which would fit the given box plot. After entering a solution, *STACK* checks if it produces the correct box plot. If this is not the case, a graphic in the feedback shows both the given box plot and the one that results from the proposed data. Thereby, the two box plots can be compared and it is even possible to display dashed lines that help seeing if the values of the box plots differ or not. This task not only illustrates the enormous possibilities of feedback in *STACK* tasks including graphics that directly depend on a given answer. It is also an example of a problem where an inverse calculation has to be performed, requiring a higher level of understanding and preventing the use of a schematic calculation without thinking about the task. As stated in the theoretical section, this kind of task with infinitely many solutions would lead to an immense effort needed for correction – and drawing a graphic for each student like *STACK* does in this example would be almost impossible for lecturers. As for the interactive application on the geometric distribution, the graphics in this task are generated using *JSXGraph*.
This task is planned to be tested in the second run of our interview study along with other materials on descriptive statistics.

4 EVALUATION AND FIRST RESULTS

In order to improve the materials, they are evaluated in different contexts. In this section, we introduce our methodical approach for this evaluation. Afterwards, we present first insights into the results by giving quotes from students and summarizing our impressions.

4.1 Methodological Considerations

The digital materials are used in various courses, including those for engineering, pharmacy, and mathematics students. This is advantageous for several reasons: On the one hand, problems concerning the fit of the materials to the lectures and their (conventional) tasks used can only be uncovered this way and not in studies detached from courses. On the other hand, by using the materials in lectures, a large number of students can be addressed at once. Specifically for designing digital tasks with individual feedback, data is also needed to find out common mistakes made by students. This is an effective way to implement the automatic feedback so that the system recognizes when students have made this mistake.
In the winter semester 20/21, first materials were ready for use. In this paper, we focus on the lecture "Introduction to Probability Theory and Mathematical Statistics" (IPS) where a number of digital tasks was tested. This lecture addresses second-year students of mathematics. On the one hand, the focus was on student's use of the materials, on the other hand it was

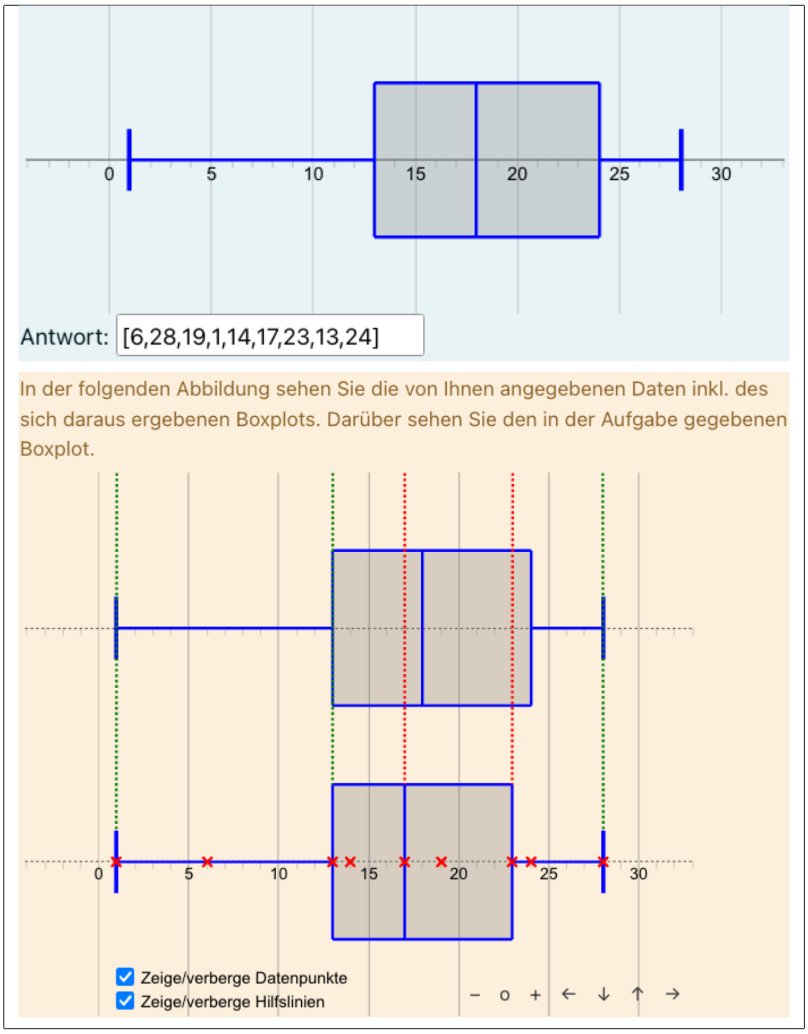

Figure 4: Screenshots from the digital task on box plots.

important to find out if lecturers who have not collaborated on the production of materials can still integrate them well into their courses. Especially, this includes different scenarios for implementing the materials in one's course.

In addition to the test of tasks in courses, a qualitative interview study was conducted with $n = 5$ students. The aim is to identify and analyze possible difficulties or ambiguities in order to consequently improve the materials. After testing the materials with students from different disciplines, semi-structured interviews were used. For this purpose, an interview guideline based on Helfferich (2011) [16] was created. It includes questions on content and design-related aspects for each type of material (interactive application, instructional video and digital task). The interviews were recorded, will be transcribed later and analyzed in order to improve the digital materials. In addition to surveying students from different disciplines to adequately address the students' heterogenenity, it is important to include both beginning and advanced students. Furthermore, the participants had different previous experiences with digital learning materials and students with limitations, such as visual impairments, were also included. Each type of material has been the subject of the qualitative interviews, and the analysis of these interviews is yet to be completed. In the following section we present first results, including some quotes from students who have already participated in the interviews. Their significance for our further procedure will be explained thereafter. Below, we present first results from both the test in practice and the qualitative interviews.

4.2 First Results from the Evaluation

As part of the test of digital tasks in the lecture "Introduction to Probability Theory and Mathematical Statistics" (IPS), two tasks on the topic of combinatorics were given to students with a style similar to the task on the voters of a party. Through this test, helpful results were obtained. For example, we received a favorable feedback through the anonymous forum of the course: *"Dear IPS team, the self-study task on combinatorics was really terrifically designed! I'm really a combinatorics dummy, but these intermediate steps were so incredibly helpful and helped me so much in understanding. Thank you so much! I would love to see more tasks of this type, this was fun. And by being able to repeat it as many times as you like, you can take breaks in between and let the insights "sink in". Very nice. Thank you very much and best regards!"*[1]. This reinforces our opinion that this type of task can help students learn mathematics and is consistent with the theoretical findings mentioned above (cf. section 2.3). Moreover, the cooperation with the lecturer who was not involved in the production of the materials worked very well. In response to a written inquiry, she wrote: *"The tasks we used received very positive feedback from the students. In my opinion, these tasks are very well suited to enable students to deepen (and thus understand) the theoretical content they have learned during lectures. Especially theoretically weaker students (i.e., those who have a harder time with theory) benefit immensely from the repetition and feedback."*

Semi-structured interviews were conducted with five students, one of them was an engineering student. On a rather rough level, it can be stated that all materials were well received by the students. Nevertheless, there are some aspects that will be changed in the materials based on these students' remarks. The interactive application was highly appreciated by the students. An advanced mathematics student said that the interactive graphic would be *"very suitable, especially for students who can't imagine such things so well, because then you can just visualize it, because that's missing a bit. There is always a bit of intuition missing"*. To the question whether he now has a better understanding of the geometrical distribution, the engineering student answered: *"Yes, I think with such gimmicks you think differently about something than if you just have some task or something. I find it pleasant. [...] Such a gimmick is always very nice and... yes, it's just illustrative."* Only the introductory text, the observation tasks and the sample solutions were criticized by some participants, for example for not being as precise as they would have wished them to be. In the case of the instructional video, the choice of example was considered to be very suitable. One student commented that it would take out the *"seriousness"* of mathematics and that it would take on the role of an *"icebreaker"*. Another student said about the video: *"I liked it very much. Also that it was based on such a nice example. You definitely remember that, and it's always important to remember things from examples, because then you don't forget them. And so I would remember it again and again, because you always think about it, about these chocolate beans."* In general, the length of the video was considered adequate by the students, but some of them would have liked a slower pace when the definition is introduced. The design aspects of the video were not explicitly commented and the video as a whole seemed fairly professional to them with some room for improvement, for example with regard to the sound quality. Likewise, the students appreciated the digital task on the voters of a party. One student would recommend the task: *"It's just for self practice, get clear again what the binomial distribution is, what it does, etc. Definitely I would recommend it."*. Another student especially liked the idea to provide students with subtasks including the possibility to go back to the initial task: *"And what I find very, very good [...] is that I don't have to go through all the other intermediate steps here, but can say: "I'd like to try it again now". And my guess would be that if I mess up again, I'll be offered this help loop again, where I can click on "I'd like to try more intermediate steps"*

[1] All quotes are translated from German to English

if I do it wrong again." Among the students, there was a little controversy about the length of the feedback messages. Some students identified them as particularly detailed and informative while other students said that they probably would not read the whole text because it was too long.

5 DISCUSSION

First responses from students in interviews reveal some interesting aspects: One the one hand, students point out various benefits of the materials that can also be found in the literature. Examples include the length of the video [10] and the possibility to try things out using the interactive application [6]. On the other hand, students address some points for improvement, like, for example, the audio quality of the video and partly the length of the feedback messages within the digital task. The use of the tasks in the IPS lecture gave us some useful implications on how a cooperation with an external teacher can be organized. The written responses from the lecturer, who was not involved in the creation of the materials, can be considered as a starting point for future implementation of the materials in other courses. However, different scenarios for implementation of the materials in one's courses should be considered in the future.
These and other digital materials will be tested with more students, both in the context of qualitative interviews and courses. Especially, it is also scheduled to survey the students participating in the lectures in a quantitative way using questionnaires. In the questionnaires, both the usage behavior with the individual digital elements and cognitive, motivational and emotional components of learning, for example mathematics performance, motivation and acceptance, are surveyed in a standardized way.

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STUDENTS' EXPERIENCES WITH CHALLENGE-BASED LEARNING AT TU/E INNOVATION SPACE – OVERVIEW OF FIVE KEY CHARACTERISTICS ACROSS A BROAD RANGE OF COURSES

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ABSTRACT

Challenge-based learning (CBL) has emerged in the last decade as a response to the complexity of problems faced by modern society, new competencies needed for the workplace, and insights from cognitive sciences on knowledge acquisition and learner motivation. In CBL, students work on real-world problems which are open-ended and require interdisciplinary knowledge and entrepreneurial mindset. In the last three years, over 70 CBL experiments have been initiated at Eindhoven University of Technology (TU/e), in order to develop a broad range of CBL teaching practices. Half of these courses have taken place at TU/e innovation Space, which is a learning hub and expertise centre for CBL and entrepreneurship education. We use students' evaluation surveys to analyse the experiences of Bachelor and Masters students in these courses. In particular, we are focusing on responses to five key course design characteristics set by the teaching staff as important: how interdisciplinary and challenge-based (or linked to real-life problems) the courses are,

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how entrepreneurial and hands-on they are, and how much they contributed to students' personal development, as well as their team development. The results show that what attracts students to these CBL courses matches closely these five characteristics, and we discuss why this might be the case. Interestingly, some of the more hands-on aspects of the courses do not seem to have been affected by the COVID-19 disruption in the 2019-2020 academic year.

1 INTRODUCTION

Challenge-based learning (CBL) is a relatively new educational concept [1], which focuses on enabling learners to solve complex challenges in an increasingly volatile, uncertain, complex and ambiguous (VUCA) world. This way of learning prepares students for the future of interdisciplinarity and complex decision-making in the workplace, with emphasis on teamwork, self-awareness and entrepreneurial mindset [2]. Eindhoven University of Technology (TU/e) has placed CBL at the core of its educational vision for 2030 and aims to make CBL a substantial part of all programs at the Bachelor and Masters level. With that in mind, TU/e innovation Space was formed in 2015 (and started operating in a physical space from 2018) by a group of innovative academics who already applied various aspects of CBL in their courses. Today, TU/e innovation Space is the center of expertise for Challenge-Based Learning and student entrepreneurship. It is a learning hub for fostering connections between motivated staff, students, industry, and societal organizations to collaborate on real-life challenges. The hub facilitates courses and experiments on (interdisciplinary) CBL and student entrepreneurship; offers services and inspirational workshops for implementing CBL; and coordinates students' extra-curricular activities related to entrepreneurship. To this extent, TU/e innovation Space collaborates with and supports interested lecturers from other departments whose course objectives match the hub's objectives in terms of CBL characteristics and require hub's comprehensive facilities (including technical and other support). TU/e innovation Space monitors all the CBL experiments undertaken in the hub through educational research, in order to ultimately arrive at evidence-based teaching and learning CBL approaches.

In this paper, we present a case review of student experiences in CBL courses that were facilitated by TU/e innovation Space over the two first academic years of the hub's operation (2018-2019, 2019-2020). There were 31 courses from 7 different departments that used the hub over that time, 21 at the Bachelor level and 10 at the Master level. We are interested in investigating to what level have students perceived the key CBL characteristics attained in their courses, and provide an overview of their initial experience with CBL education. Innovation and creativity, real world challenges, collaboration across stakeholders and disciplines are at the core of CBL education worldwide [1]. Our work aims to contribute to the overall body of knowledge and support further research related to identifying best practices for implementing and facilitating CBL learning.

2 METHODOLOGY

2.2 Case review

We use a case review of CBL courses run at TU/e innovation Space during eight quartiles (four semesters) over the two academic years. A mixed-method approach was used, with a qualitative and quantitative component derived from the same instrument. Specifically, we use a course evaluation survey designed by the TU/e innovation Space Education team to monitor to what level the key CBL characteristics were met for the courses that were hosted in the learning hub. This survey, together with other forms of feedback, is collected for quality assurance, to ascertain in which form CBL is a scalable educational concept for TU/e, and what is an added value of CBL approach for all the stakeholders. Ethics approval was obtained for use of this data (ERB2021ESOE8).

Participants. The participants were the students enrolled in the 31 courses which run over the two academic years in TU/e innovation Space. There were more than 1100 students per year, of which only around 20% filled out the survey. Therefore, these results are not fully representative of the whole cohort. However, it is likely that students with the most desire to share the feedback are willing to take the time to fill out surveys such as these, and thus this information is still highly valuable as an insight in students' perception of their experience with CBL education.

Instrument. The survey was distributed electronically to the students as a part of their overall end-of-the-course evaluation. That means that the questions pertinent to the CBL characteristics would sometimes come at the end of a long string of questions, if the lecturer has agreed for the survey to be included. The survey consists of seven closed questions (Likert scales) and three open questions to gather detailed insights into the students' perceptions and experiences (see Table 1 for details).

2.2 Data analysis procedure

Quantitative data. The anonymised student responses have been provided to TU/e innovation Space as a report, one for each course, collated by the Department of Education and Student Affairs. As mentioned before, the main purpose for these reports was monitoring of quality insurance, and we performed further (secondary) analysis of these existing data. We transferred all the responses from the individual reports to an Excel spreadsheet for in-depth analysis. The seven closed questions have a 5-point ordinal scale (to rate the degree to which students agree or disagree with a statement), which is commonly used in course evaluations. In the reports that were available to us, these data have been expressed as a median value with standard deviation, which somewhat limits the depth of the analysis we were able to perform. Therefore, rather than being able to report the frequency of responses for each category, we are only able to report the median value.

Initially, we compared all the median values for all the courses across the two academic years, in order to investigate if data showed any interesting patterns across different types of courses. The result was that most of the courses ended up sitting within a wide band of median values, with no significant pattern or outliers emerging. However, this analysis was also limited by a low number of responses per course – some courses had only 20-30 students, with 3-4 responses per course on average. We therefore decided to combine all the responses per question for each year, in order to focus analysis on each of the CBL characteristics. We present the analysis of our results via boxplots in Figure 1.

Table 1. The survey questions used in this study, and how they relate to the five key CBL characteristics (KCs).

Survey questions	**The scale**
Q1. Why did you choose this course?	Open-ended
Q2. Would you recommend this course to a fellow student? Q2a. Please explain:	No, definitely not – Yes, definitely Open-ended
Q3. To what extent do you think this course: (KC1) was interdisciplinary? (cooperating with students from different study programs, applying/integrating knowledge from different disciplines for the end result) (KC2) was challenge based? (challenging question at the start of the project, real-life problem) (KC3) was hands-on? (learning by doing; developing a prototype or minimal viable product) (KC4) had an entrepreneurial mindset? (have to deal with uncertainty, take entrepreneurial aspects into account) (KC5) contributed to personal and team development? (in terms of professional skills, like collaborating, presenting, coaching, creativity)	No, definitely not – Yes, definitely
Q4. I see the added value of the open learning spaces and prototyping facilities in innovation Space. Q4a. What is in your opinion the added value of courses in TU/e innovation Space?	Strongly Disagree – Strongly Agree Open-ended

Qualitative data. Answers to the open-ended questions were analysed to collect more detailed information on how students experienced CBL learning in the early implementation (the first two academic years). The responses were coded through exploratory thematic analysis to identify any interesting patterns and insights, based on the participants' own words. We performed inductive coding, using semantic analysis and participants' own words as "meta-themes", which were then combined into the main themes. Only the responses to the first questions provided answers that resulted in coherent codes, and we present the results in Table 2.

3 RESULTS AND DISCUSSION

3.1 Overal results

Figure 1 shows aggregated results from data analysis of the quantitative data used in this paper. Students' answers to the seven closed survey items are visualised here with the boxplots, which allow us to present the median values for each question, the interquartile range (where the middle 50% of the scores are), as well as to show the minimum and maximum score given for each item.

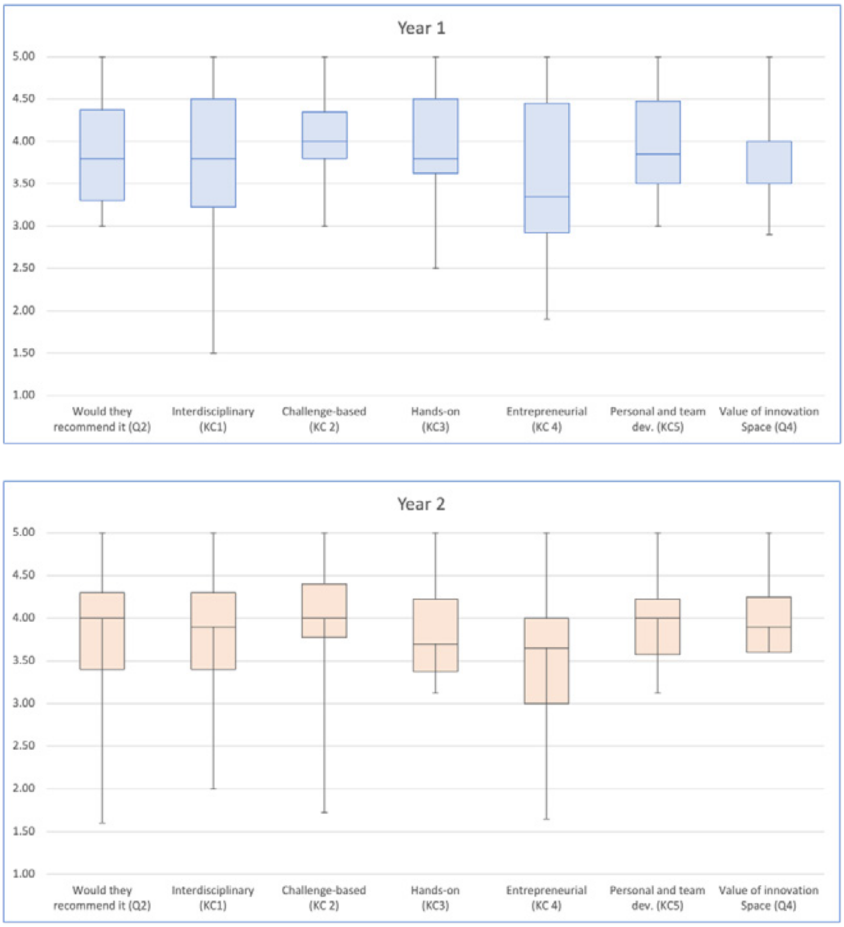

Figure 1. The two boxplots visualise each of the closed survey items (see Table 1) from the first (2018-2019) and second (2019-2020) academic year that the courses have run at the TU/e innovation Space.

In the first year, we see that most aspects of the courses have been received well by the students, with only one aspect of the course (related to how entrepreneurial the courses were) sitting under median of 3.5. In the second year, we see some improvements, despite the fact that this academic year was disrupted by COVID-19 pandemic. The range of scores decreased for most of the items, especially for the item about how interdisciplinary and entrepreneurial the courses were. All the medians improved, except for how hands-on the courses were, which is likely to do with moving some aspects of the course online in the third and fourth quartile of the year.

The answers to open-ended questions allow us to explore in more depth what students' experiences in these CBL courses were. Table 2 shows the most-frequently mentioned reasons for enrolling in the CBL courses (Q1). Besides the obvious reason that some of the courses were mandatory (which have been omitted from the table), the most frequent answer was interest in the subject matter (T1), followed by general interests (T2), and wanting to expand core knowledge and skills (T3). Wanting an interdisciplinary course has been mentioned by a relatively small number of students (T4). However, interdisciplinarity is commonly used interchangeably with similar expressions, and it's possible that some of the reasons categorized in T3 category could belong to T4.

Table 2. Frequency of themes from coding of the open-ended question Q1. There are 184 responses in year 1 to this question, and 234 responses in year 2. The main themes are listed in the first column and mapped to the five key CBL characteristics (KCs, see Table 1) where appropriate, and meta-themes are listed in the second column. Third and fourth columns list the frequency of the main themes for each academic year.

Main themes (T)	**Meta-themes**	**Year 1**	**Year 2**
T1: Subject-related	subject interest, fits my interests	15%	21%
T2: General interest	interesting, fun, curious about, seems challenging	9%	12%
T3: Breath of knowledge & skills	something different, not research, other than major, wanted breath of knowledge & skills, more interesting than their major	7%	5%
T4: Interdisciplinary (KC1)	interdisciplinary (multidisciplinary)	5%	3%
T5: Real-life, challenge-based (KC2)	work with companies, real life, business oriented, responsible innovation	7%	17%
T6: Hands-on (KC3)	applying knowledge, prototyping, project-based, hands on	3%	6%
T7: Entrepreneurship (KC4)	entrepreneurship, want coaching, start ups	5%	9%
T8: Team work (KC5)	group work, learn from other students, create community, like minded people	4%	4%

Reasons related to real-life experiences and work with companies (T5) have also been mentioned often, in particular in the second year. It's possible that the students became more aware of this aspect after the first run of the courses, and after the first generation of students started recommending the CBL courses (as mentioned by a small number of students). This might be also linked to the next two identified themes – wanting to do something hands-on (T6) and entrepreneurial (T7) – which have doubled in the second year. And finally, wanting to do something with like-minded people or in a team (T8) was equally frequent across the two years.

The second question (Q2a) resulted in substantial amounts of responses (124 in the first year, and 233 in the second year), but they largely coincide with the answers to the first questions (Q1). Most frequent general reasons for recommending a CBL course to other students were that it provides a different way of learning or work on projects, and that it was interesting or fun. On the negative side of things, the students also mention that there are some teething issues when establishing these kinds of courses that could be improved, mainly to do with the way assessment was structured [3]. There were not many answers to the third open-ended question (Q4a), but there were some interesting highlights, which we discuss below.

3.2 Students perception of the key CBL characteristics

Based on the answers of the participants to the open-ended question about the reasons for enrolling in one of the CBL courses, it can be inferred that the students clearly see the characteristics defined as important by TU/e innovation Space Education team – exploratory coding of their answers, grouped in themes T4 to T8 in Table 2, can be mapped directly to the five CBL characteristics (Table 1).

Interdisciplinary aspect of the courses. Interdisciplinarity refers to integration of knowledge and skills between disciplines [4]. While the students in this study are mainly from disciplines such as design, engineering and science, they are encountering diversity of approaches between different majors, and identifying benefits of interdisciplinary approach to problem solving, such as working on a project with aspects other than the major, working together with a team in order to come up with better solutions. Not surprisingly, the students see the learning hub as a conduit for such learning, as working in interdisciplinary teams isn't common or possible in faculties. The issues around interdisciplinarity were also mentioned as a negative aspect, mainly to do with students having to navigate assessment requirements between different faculties, which has been explored by Valencia et al [3]. Indeed, there is much work to be done in bridging collaborative teaching between disciplines, starting with appropriate training for lecturers to facilitate students' learning in interdisciplinary settings [2].

Challenge-based aspect of the courses. There are different approaches to setting challenges in CBL courses [1] and at TU/e innovation Space, it is preferred for challenges to be open-ended and defined by students. They need to have societal relevance and, therefore, students get to collaborate with challenge owners (companies, organisations, researchers, student start-ups). Working with companies and on real-life (rather than theoretical) problems was a significant reason for some of the students to join CBL courses. A few students commented on liking the freedom of choices within a project available in their courses. Some students found extra motivation to succeed in their study when working with companies, because it gave them a better idea what is possible with their degrees. Interacting with companies and working on real-life problems contextualises for students how what they are learning is relevant for their future. Context-based learning can take many shapes, but all have been found to have a positive effect on student learning [5]. The main negative comments regarding the challenges were that the projects are somewhat vague. Indeed, some students would have preferred to work on predefined questions, usually provided in more traditional courses where project questions have been offered by a lecturer. The main difference in the two approaches is that in traditional project-based learning the outcome of the research tends to be the final goal to be assessed. In open-ended CBL projects at TU/e innovation Space, the emphasis is on the process of learning through the projects. Learning through discovery and self-development of a learner are the ultimate goals.

Hands-on aspect of the courses. Practical or applied side of learning was mentioned as a motivation to join CBL courses, often contrasted with “theory” learned in other courses. An opportunity to experience the commercial side of innovation is also mentioned. In the early 1990s, there was a call for a more hands-on, “learning by doing” approach to engineering education [6]. However, hands-on education has been gradually reducing rather than increasing since that time, due to many factors, one of which is massification of post-secondary education which led to increasing students-to-teacher ratios. However, in the last few years there were global changes across higher education to move to more active and hands-on approaches to learning, which have shown many times over to increase engagement and learning outcomes for the students [7]. Learning by doing is the teaching philosophy of TU/e innovation Space. The students taking courses at the learning hub have an added benefit of having teaching spaces next to prototyping facilities (as mentioned in the students’ responses to Q4a), as well as support from the technical staff at the hub, to facilitate the process of creating their own concept and product. Interestingly enough, there was almost no mention on how educational modifications introduced due to COVID-19 pandemic have affected hands-on learning, probably because the students, who were able to do so, were allowed to continue using prototyping facilities to some extent and under the strict health guidelines.

Entrepreneurial aspect of the courses. This is one of the items in the evaluation surveys with the widest range of answers. This could potentially stem from a narrow interpretation of what entrepreneurship is, focusing just on start-ups or running your own business, as expressed by the students. Entrepreneurship is not a necessary part of CBL education, but it forms a strong focus at TU/e innovation Space, which also hosts and facilitates related entrepreneurial extra-curricular events. The students expressed significant curiosity about wanting to learn more about the entrepreneurial side of things, often in the context of working with other students. Developing wider enterprising abilities in university graduates has been encouraged since the 1980s, but has not progressed as hoped [8]. However, recent reports indicate that there are significant benefits in embedding entrepreneurship education at undergraduate level across all disciplines, which impact on both students’ learning outcomes, as well as provide benefits for the society and economy [9].

Personal and team development aspects of the courses. This is one of the strongest aspects of the courses, as rated by the students. As a motivation to join the CBL course, or reason why they would recommend the CBL course, the students list wanting to learn *from* other students or *with* other students, and wanting to work in groups. This links to known benefits of collaborative learning approaches, which are found to improve students' knowledge and skills through the co-creation process [10]. Some students mention that this is the most fun part of the courses. However, a small number of comments refer to increased responsibility for such learning, especially if some of the team members are perceived not to contribute equally or are not "developed enough" to persist in courses such as these. As a benefit of the learning hub (Q4a), the open learning spaces that enable group work are welcomed by the students, providing opportunities to mingle and exchange ideas, as well as create a "motivating atmosphere". The fact that these spaces can be noisy is sometimes mentioned as one of the negative aspects. From the third quartile of the 2019-2020 academic year, a large fraction of collaborative learning was moved to an online setting due to COVID-19 pandemic, but that warranted only a very small number of comments from the participants.

4 SUMMARY

This paper presented a case review of student experiences in a variety of CBL courses delivered at TU/e innovation Space during the first two years of implementation. The overall experiences are very positive, and interestingly enough, the students highlighted the course design characteristics that closely match those set by the Education team as important. Our future work will focus on conducting more in-depth focus groups and interviews with both the students and the staff to examine how these particular CBL characteristics can be used as design principles to support CBL learning in a variety of courses and settings.

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DEVELOPING UNIVERSITY WORK-BASED LEARNING FOR ENGINEERING INDUSTRIES IN SUB-SAHARAN AFRICA: A CASE STUDY OF THE KINGDOM OF ESWATINI

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ABSTRACT

The 2021 UNESCO report ‘Engineering for Sustainable Development’ indicates the need for engineering education to shift its approach towards developing competencies capable of solving complex interdisciplinary problems. Moreover, the report highlights the role for a quality system to support lifelong learning of engineers and technologists. Additionally, the UK Royal Academy of Engineering (2020) recognised that there is a global shortage of engineering skills (in both quantity and potentially quality). Work-based learning, that sees co-creation and co-delivery of engineering programmes between university and industry, has the potential to address these challenges.

Whilst University accredited work-based learning (WBL) programmes are found in many countries, WBL is not currently a common approach in Sub-Saharan African engineering education. This paper will present results from an ongoing Royal Academy of Engineering funded project developing a work-based learning programme in engineering in the Kingdom of Eswatini– adopting a Log-Frame approach. The WBL programme is being co-designed by The University of Eswatini and local engineering industries with the aim of improving the quality and quantity of currently employed engineering practitioners. Specifically, the paper will highlight some of the emergent national and university policy dimensions supporting the development of WBL – such as a National Qualifications Framework and Recognition of Prior Learning – as well as questionnaire results indicating the

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original awareness of WBL amongst industry and the subsequent need to raise awareness of WBL and its benefits. Finally, the adaptation of the curriculum development approaches that support co-creation of a WBL programme under Covid-19 restrictions will be shared.

1 INTRODUCTION

The UN Sustainable Development Goals (SDGs) provide a global framework and call for action to improve the lives of all people over the coming decade. Engineers must be at the heart of achieving this and updated competences will be required for all Engineering Practitioners – from Technician to Engineer [1]. The development of such competences will require changes to engineering education to be able to tackle the acute problems of the next decade and beyond [2] and are likely to incorporate active and experiential learning and development of transversal skills to underpin lifelong learning and employability [3]. Whilst problem-based or practice-based learning (fusing academic and professional considerations) may be possible approaches [4], work-based learning (WBL) is an engaging and authentic approach that has been recognised as suitable in engineering education and for lifelong learning in the 21st Century [5].

Gibbs and Garnett [6] define work-based learning as a learning process that focuses university-level thinking upon work in an effort to facilitate the recognition, acquisition and application of knowledge learnt, skills and abilities acquired in the process [6]. Its purpose is to achieve specific learning outcomes that are of value to the learner, the workplace and the university, through a structured curriculum encompassing theory and practice; this partnership between students, employers and university is critical for design and sustainability of WBL programmes. Different types of work-based learning exist: at-work (company training); for-work (placement; internship) and through-work (linked to part-time study and accredited professional development in an organisational context) [7], indicating different WBL models. Such models allow for flexible access to Higher Education for a wider group of candidates. Unfortunately, the uptake of work-based learning shows geographic disparity that can be attributed to socio-economic and cultural factors, and has been more successfully adopted in countries like the UK, Australia and Germany. In Sub-Saharan Africa (SSA) the adoption of WBL has been mainly in the Technical and Vocational Education and Training (TVET) sector, with encouragement for a wider adoption of WBL to support skills development outcomes [8], including at university-level (where it is much less common).

Employers across the Sub-Saharan African region have already identified inadequately skilled workforces as a major constraint to their businesses [10]. Specifically, in the Kingdom of Eswatini, a skills gap analysis revealed that more than 80% of the sampled companies were not satisfied with the skill levels of the graduates produced by the TVET colleges in the Kingdom of Eswatini. The TVET throughputs are directly absorbed into industry, with the insufficient skill levels that calls for re-skilling/up-skilling of these candidates. Evidently, there is a need to adapt engineering education and find new pathways to develop more programmes and align them to the needs of society and industry as well as encouraging entrepreneurship in the Kingdom of Eswatini. Additionally, the lack of engagement in advising and researching future skill needs, and the lack of dynamic industry informed curricula has been identified as a major barrier on the higher education system in the Kingdom of Eswatini [11]. This situation is compounded by the scarcity of Engineers in Sub-Saharan African countries per head of population and the vital role qualified engineers play in contributing to GDP [9].

The opportunity for WBL, as an engineering education approach, to build the required engineering competences in Sub-Saharan Africa, particularly in the Kingdom of Eswatini, has been introduced above. A Royal Academy of Engineering (RAE) funded project has a stated aim of developing one through-work, work-based learning programme in Engineering with the long-term goal of encouraging its adoption throughout Sub-Saharan Africa. This workstream partnered The University of Eswatini (UNESWA) with Glasgow Caledonian University (GCU). In the rest of this paper, the methodological approach will be outlined, followed by the developments and insights so far in this project, before summarising and outlining the next steps.

2 METHODOLOGY

The WBL workstream aim requires a transformative approach that engages relevant stakeholders (in university, in industry and in government) in a sustainable change to a new engineering education approach, one that will deliver engineers with the desired competences to address the long-term needs of society.

The complexity of the transformational process necessitated a structured approach to plan and evaluate the project and its success. A Logical Framework (Log-Frame) approach was adopted [12], as it provided a hierarchical and logic-driven approach to planning that engages stakeholders, and has been used in a wide-range of different interventions, and was supported by RAE (funders). As an intervention tool, Log-Frames help to identify activities (work-streams), and detail how the success of the project intervention will be evaluated and verified, as well as offering flexibility in how the activities need to be managed to achieve the outcomes.

The project-specific Log-Frame was developed through a series of workshops in January and February 2020 (pre-COVID) by university staff – at UNESWA and GCU (Table 1) that took a strategic view of the potential for WBL (so beyond the needs of the RAE project) to lay sustainable foundations for WBL in the Kingdom of Eswatini. It is noted as a limitation of this research that the envisaged engagements with other stakeholders were not possible at that time due to the onset of COVID-19 and lockdowns – implications of this are discussed below. This paper will evaluate the key activities undertaken to-date using the Log-Frame as a basis, as well as the value of Log-Frame for such developments. At this stage of the project, and as a result of delays from COVID-19, progress has been made in work streams (i) andragogical model and (ii) communication and engagement plan and form the focus of the detailed research presented in this paper. In particular, results will focus on a) policy ecosystem gap analysis and implications and potential opportunity identification; b) engagement with industry around opportunity for understanding of

WBL to-date; and c) development of UNESWA staff through knowledge exchange and training. Specific data collection and analysis methods are presented with the activities below in the results section.

Table 1.Abridged Log-Frame document for this project

	Area of intervention	**Indicators of achievement**	**Means of verification**	**Risks & assumptions**
Overall objectives	Contribute to the economic and social growth of the Kingdom of Eswatini through the development of a co-created work-based approach to engineering education	Industry improvements; Uptake to new learning pathways for engineering practitioners	Company results Country socio-economic indicators	Strategic buy in; Funding
Project purpose	To co-create with industry sustainable workforce with relevant and applied competences through WBL programme pilot	Successful pilot programme WBL Graduates	Surveys of stakeholders Number of WBL Graduates Case studies	Capacity and capability in stakeholders to develop WBL programme Support & demand from industry
Expected results	1. Andragogical model for WBL	Gap analysis HE ecosystem; WBL Blueprint at UNESWA	Gap-analysis report Knowledge exchange visits;	Ecosystem supportive of project Staffing and CPD engagement around WBL Existing positive relationships with stakeholders (industry and ministries)
	2. Sustainable business model	Industries signed-up; Agreed business model	MOUs and contracts	
	3. Successful communications & engagement plan	Engagement events; Website	Attendance lists; Website engagement	
	4. Pilot programme developed and approved	Sufficiently trained staff in WBL; Programme approved	Training evaluation & materials; Programme approved	
Activities	Workstreams below managed via project plan: 1. WBL workstream project management; 2. Andragogic model; 3. Business model; 4. Comms & engagement; 5.UNESWA WBL project team development; 6. Pilot programme development			

3 RESULTS

3.1 National and University Policy gap analysis

The development of any new educational approach needs to be possible within the national and institutional policy landscape. As such, a key question posed was "Is the policy landscape supportive of pursuing a through-work, work-based learning approach in the Kingdom of Eswatini and at UNESWA?" This question was addressed through a comparative document-based gap-analysis, looking at the national Higher Education policy landscape, as well as at university-level policy. As identified in section 1 above, through-work WBL has potential for widening participation and offering flexible pathways. This is only possible if there is a National Credit and Qualifications Framework in place that supports progression through the levels by different learning pathways [13], as well as an outcome-based approach to learning. As such, policies included related to National Qualifications and Credit Framework, Recognition of Prior (informal) Learning, and Teaching and Learning Policies. As can be seen, whilst some gaps were initially identified, actions are now in place to address any gaps.

T*able 2: Gap Analysis of UNESWA policies against enabling policies for WBL*

Policy	Eswatini/UNESWA status	Comment
National Qualifications and Credit Framework	Framework launched officially April 2021; In transition as UNESWA needs to adopt the framework, including credit definition.	Timing supportive of WBL programme development.
Learning outcome based curriculum design approach	In transition: UNESWA Teaching. Learning and Assessment Policy Framework proposes all programmes to be learning outcome based by 2022	Policy direction supportive of WBL programme development
Recognition of Prior (informal) Learning	Policy not in place yet. Policy to go to Senate before end of 2021	Policy direction supportive of WBL programme development
Teaching ,Learning and Assessment Policy Framework	Policy in place, including policy on Blended Learning (envisaged as possible strategy for delivery)	Policies in place. Recent pivot to on-line due to COVID-19 supportive of possible WBL delivery models.

Another national consideration is around the Professional and Regulatory Body for the profession, and their requirements and support for university-level WBL. Within the Southern African Development Countries of Sub-Saharan Africa region, engineering programmes may also refer and benchmark against the Engineering Council of South Africa (ECSA). Whilst ECSA requires WBL (placements) for Diploma qualifications, it is not as clear as to their position around university-level

WBL and a through-work WBL approach (that embraces authentic learning and assessment). At this stage, this is an area for further analysis and discussions.

This gap analysis activity highlighted also that currently it was difficult for vertical progression within the Qualifications Framework, for example someone with a Diploma qualification to proceed to study to degree level at University and get recognition for their prior learning. Consequently, such engineering practitioners have been identified as a potential group for whom a university-level WBL programme would be attractive and beneficial, and would be supported by ongoing evolution in National and university policies.

3.2 Industry and stakeholder understanding of WBL

A key assumption made in the Log-Frame above was that industry was receptive to and would engage with a through-work WBL programme. An online-survey was used to evaluate the perspective of a purposive sample of engineering industries in the Kingdom of Eswatini around their use and experiences of different forms of WBL to test that assumption. Purposive sampling was chosen to reflect the need to include industries of different sizes and within related technical fields that form important parts of the country's economy (with a mind to the goal of designing one WBL programme). A sample of seventeen (17) companies were invited to participate in a questionnaire with a mixture of closed, rating and open responses, of which nine (9) responded to the questionnaire. This showed a response rate of 53%; such a positive response-rate was likely obtained as the companies were asked to voluntarily participate through an invitation letter from UNESWA's Vice Chancellor. A suitably diverse range of companies participated (Fig. 1).

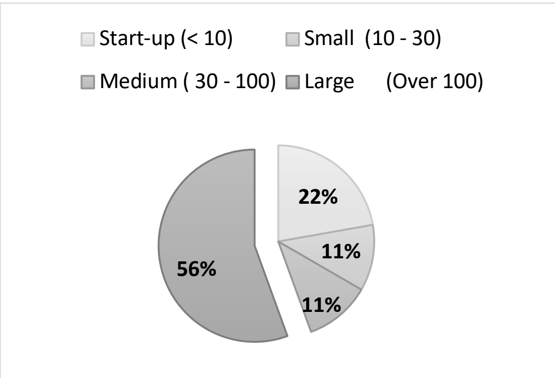

Fig. 1 Categories of participating companies

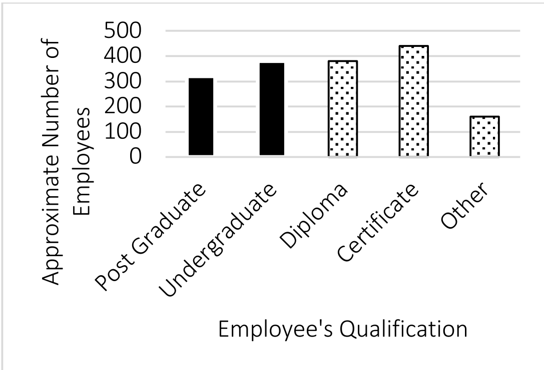

Fig. 2 Potential Candidates for the propose WBL Model (distinguishing between those wi degree and above (solid shading), with thos with sub-degree qualifications (shaded)

Fig.2 indicates more employees with Diploma and Certificate qualifications (as compared to Bachelor or postgraduate qualifications), and confirms that the proposed target for the pilot WBL programme (offering pathway from existing qualification to degree) would have approximately 1000 candidates (based just on sampled companies). Additionally, there is the potential for developing a postgraduate qualification also, based on the data above.

Fig. 3 indicates the current awareness of the different forms of WBL in the Kingdom of Eswatini, and shows existing engagement with internships and apprenticeships, similarly to a previous study [11]. This previous study highlights low levels of cooperation between industry and academia, as well as companies holding the view that apprenticeships and internships are expensive, that industries are not-well developed to provide internships/apprenticeships, and lack the time and resources to train TVET trainees on practical industry skills. Consequently, this paper proposes a cooperative education (through-work WBL) programme that will help in upskilling engineering practitioners while they remain at work in employment. However, the results in Fig. 3 revealed that few companies (11% of respondents) were familiar with the cooperative education model proposed. This result shows the need for future workshops with stakeholders (industry, employers, regulatory bodies and government) to enable successful collaboration– an adaptation that was made to the project plan (reflecting that a Log-Frame is a live and adaptable document). The first of several ongoing engagement events with these key stakeholders has already taken place and more are planned.

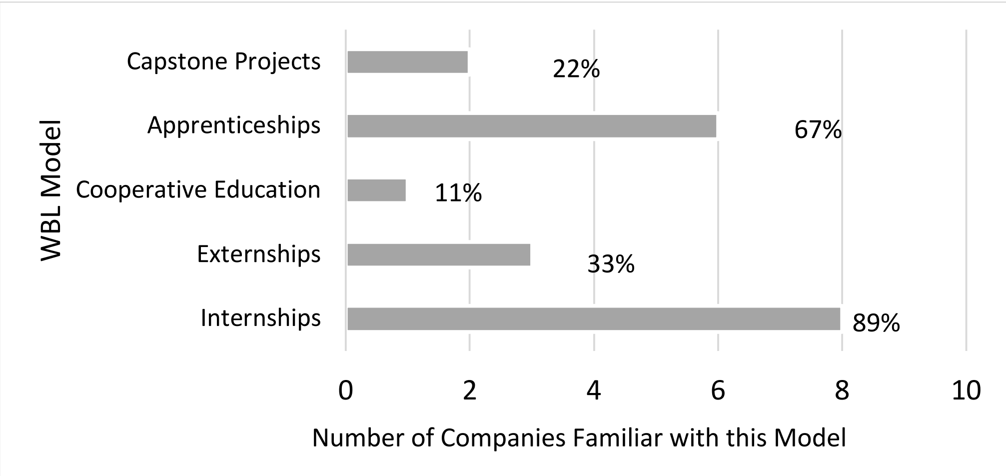

Fig. 3 Company respondents Familiarity with various WBL Models

All respondents indicated a need to upskill and reskill their Engineering and Technical Practitioners with a particular desire for the focus to be in the discipline and technical areas of Electrical, Electronics and Software Engineering.

The survey (as an initial step in engaging a key stakeholder group) has indicated that there is need for closer and ongoing collaboration between industry and academia (and other stakeholders) to support development of Engineering Practitioners, with the above discipline areas having been identified as the initial potential focus areas for the development of the WBL pilot programme.

3.3 Staff development through knowledge exchange and training

University-level WBL was new to the Kingdom of Eswatini so a key consideration for this project was “how best to enable UNESWA to adopt a curriculum development approach suitable for a through-work WBL programme?” The original project plan envisaged knowledge-exchange staff placements (from UNESWA to GCU and vice-versa), where workshop activities (aligned to stakeholder approach embodied in Log-Frame) would have helped achieve these outcomes. The outcome-focused approach of the Log-Frame encouraged the project team to adapt to COVID-19 circumstances (again reflecting the live nature of the Log-Frame document). A series of knowledge-exchange webinars (using Zoom) led by GCU took place. The webinar series aimed for participants to have a clear appreciation of what WBL in Engineering is, and to be able to plan the next steps in designing a WBL Engineering programme. An evaluation of the objectives through a paper-based questionnaire was undertaken after the series. The results indicated that the objectives were achieved; respondents appreciated the importance of the tripartite nature (university-employer-student partnership) in WBL in "both crafting and running the WBL programme".

In terms of supporting the UNESWA WBL team to develop the work-based engineering programme, an on-line method of programme development that focused on a learning-outcome, graduate-focussed approach was required. At the current stage of the project, the plan is to use a Signature Pedagogy approach, enabled by an online whiteboard approach to develop this work-based learning programme. These design activities are planned to take place later in 2021, after further stakeholder engagement to build further consensus and support to university through-work WBL in the Kingdom of Eswatini, as identified in section 3.2 above.

4 SUMMARY AND ACKNOWLEDGMENTS

A Log-Frame approach is being used to support the co-design of a work-based learning (WBL) programme in Engineering. The approach outlined above has highlighted the importance of policies enabling a through-work WBL programme, the current lack of understanding of through-work WBL (co-operative education) amongst Engineering Industries in the Kingdom of Eswatini, and a current demand for WBL, particularly in Electronics, Electrical and Software Engineering fields. Further ongoing engagement with key stakeholders is embedded within the operational plans to achieve the deliverables and to truly develop a WBL Engineering programme appropriate to the Kingdom of Eswatini. The flexibility of the Log-Frame – as a living document - has allowed the project to continue to make consistent progress. Whilst there are ongoing limitations, due to COVID-19 pandemic, of not being able to involve wider stakeholders in development of Log-Frame and as comprehensive an evaluation of deliverables as desired, it is evident that the Log-Frame is still a valid approach (even if the more granular plans have had to adapt). Such a Log-Frame approach could be adopted by other institutions and countries interested in adopting through-work WBL or making significant changes to engineering education. The authors acknowledge the support of the UK Royal Academy of Engineering funding for this project under the Higher Education Partnerships in Sub-Saharan Africa fund.

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LAB-IN-A-BOX: PRELIMINARY FINDINGS OF A PROFESSIONAL LEARNING EXPERIENCE FOR TEACHERS

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ABSTRACT

In the USA, the National Science Foundation (NSF) funds Research Experience for Teachers (RET) programs where teachers have the opportunity to contribute to ongoing research projects in the setting of institutions of higher education. RET programs are usually held in person during summer over several weeks. In this paper, we describe a virtual RET program, called Portable Lab RET, piloted by NSF Nanosystems Engineering Research Center (ERC) for Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies (NASCENT) at the University of Texas, Austin during the summer 2020, in response to the COVID-19 pandemic.

During the two-week long Portable Lab RET program, teachers performed two real-world scientific experiments using pre-made lab kits deployed to their homes. For each lab kit, teachers discussed and shared ideas with NASCENT faculty and staff and other RET participants about different ways to implement and adapt them to their classrooms.

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The 2020 RET program was attended by 5 participants, math, science and engineering teachers from local school districts. Data were collected through Zoom interviews a few weeks after the end of the program. Overall, participants enjoyed the experience and offered meaningful suggestions on how to improve it. Teachers developed ideas to adapt the lab kits to one or more of their curricular units and to engage their students in directly interacting with the kits. We believe that the collaboration between university researchers and K-12 teachers afforded by the lab kits could bridge the gap between these two worlds.

1 INTRODUCTION

1.1 Context Background

In the United States, the Next Generation Science Standards push for a redesigned K-12 science education where students are actively engaged in real world scientific problems. Professional Learning Experiences (PLEs) that encourage the development and understanding of scientific and engineering practices aim to support teachers in the implementation of these new standards. However, it is important to distinguish the key components of quality PLE among the vast array of opportunities available. According to Wilson [1] key factors for successful science PLE are: engaging teachers in active learning, alignment with standard reforms, providing activities that are close to practice and immersing teachers in inquiry experiences. PLEs need to provide numerous opportunities for educators to experience activities in a fashion similar to how they will present them to their students [2, 3] and focus on inquiry experiences [4, 5]. Indeed, Garet et al. [6] reported that it is important for PLE to focus on duration, collective participation and content with opportunities for hands-on work to have an impact on teaching practices.

Among the many PLEs available, the U.S. National Science Foundation (NSF) funds Research Experience for Teachers (RET) programs [7] where teachers have the opportunity to experience scientific research and learn “how to do science” in the setting of institutions of higher education. RET programs are usually held in the summer, lasting several weeks, when local teachers participate to ongoing research projects under the supervision of graduate students and faculty members through daily laboratory work. Several studies have shown that the collaboration between scientists and educators leads to gains in teachers' understanding of scientific inquiry and increased use of inquiry-based lessons [8-10] and hands-on classroom activities [11]. Other benefits connected to the RET format include the use of real-world interdisciplinary applications, increased exposure to engineering processes [12] and the opportunity to build a community of like-minded teachers, scientists and engineering professionals [13, 14].

In this paper, we describe a new kind of RET program developed by the NSF Nanosystems Engineering Research Center (ERC) for Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies (NASCENT) at the University of Texas, Austin, during the summer 2020, called the Portable Lab RET program. NASCENT is a research center funded by the NSF that, parallel to its research, organizes a variety of educational outreach programs for undergraduates, graduates and elementary, middle and high school teachers. The Portable Lab program was piloted during the summer 2020 in response to the COVID-19 pandemic that forced a drastic change in how the RET program could be delivered. NASCENT took this challenge has an opportunity to reimagine the RET program to be completely online with the goal to possibly expand it to teachers across the country. Drawing from the in-person RET, it was important to include a research component to afford teachers the opportunity to experience and take back to the classroom first-hand knowledge of scientific research and engineering practices.

The Portable Lab RET program employs pre-made lab kits that are deployed to teachers' homes and support is provided through an online platform. Teachers perform scientific experiments following detailed instructions, while reviewing scientific concepts through seminars and reading materials. Each week, together with NASCENT faculty and staff and other RET participants, teachers have the opportunity to discuss possible applications of the lab kits to fit them into their curriculum. Current research that examines PLEs and their impact on teachers' learning indicates that enabling teachers to be active learners and co-designers of a PLE supports the growth of interdisciplinary, active classroom teaching [15]. During the Portable Lab RET program, each teacher contributes to the discussion by bringing their preexisting subject-matter and pedagogical content knowledge and background and by applying the new concepts and pedagogy learned during the program. Teachers become essential contributors and leaders of the PLE and, leveraging their expertise, they are able to build on each other's ideas to propose multiple ways to adapt the lab kits to a curricular unit and to engage their students in interacting activities.

This preliminary study aims to investigate how teachers respond and interact with these new tools and their plans to incorporate the lab kits in their classroom activities. In this paper, we will first describe the portable labs and the theoretical framework used to design this study and the research questions. In the methods section, we will provide a brief description of the program, report on the methods used for data collection and results; we will then conclude with a discussion of findings, highlighting implications and plans for future research on this topic.

1.2 Portable Labs

The lab kits used in this project were originally developed as part of university-level coursework and later adapted for use with teachers. The efforts to expand the use of lab kits into the school system involves planning experiments that would enhance the already-taught school curriculum. Choosing and designing the lab involved the following aspects:

- The labs have to be part of a coherent curriculum.
- The simplified hardware should allow students to acquire practical knowledge in a short term and grasp the basic theory, incentivizing them to seek deeper information at their own discretion.
- The experiments should contain quantitative components where the students have to measure values and report them. This aspect elevates the experience from a general demonstration.
- The experiments have to be robust and the hardware should be reliable. When designing the experimental procedure, we try to mitigate possibilities of incorrect assembly. For example, we make sure the quantities of materials applied are within comfortable range so a few drops more, or less, of added

material will not affect the experiment. We set the results to be well within the detecting and measuring ranges of our devices.
- Safety in a residential setting should be a priority. Participants conduct the experiments in their homes rather than in a lab or chemical hood. For example, participants should not be expected to handle toxic materials or dispose of toxic waste.

Within these considerations in mind, we designed the lab modules as self-standing; manuals include concise and clear instructions and some theoretical background to execute the experiment. To keep safety in the forefront, each manual includes safety instructions and a quiz for the user to test knowledge of safety protocols prior to conducting the experiment. Lastly, in order to mass produce the lab kits, their cost cannot exceed US$100 (approximately 84€) each.

The two lab kits employed during the 2020 Portable RET included the following experiments:
- Spin coating lab kit: participants built a spin coater and deposit a thin organic film on a silicon wafer. Then they deduced the thickness of the film according to the color caused by interference.
- Particle contamination lab kit: participants learned about scattering of light by nanoparticle suspensions. They let various lasers run through gold and silica nanoparticle suspensions and determined the sizes of the nanoparticles.

For each lab kit, the manual includes detailed photos and step-by-step instructions.

1.3 Theoretical Framework

This study is grounded in a cognitive perspective on teaching and teacher learning [16, 17]. This perspective explains teaching as a way of relying on different categories of knowledge in sensemaking while interacting with a new tool or assimilating a new idea. *Knowledge* is the broad term referring to mental structures, consisting of mental representations and processes that act on them [18].

This theoretical framework has an important implication for the study of teachers' approach and experience with the lab kits and for the way they adapt them in their classroom. With the assumption that teachers come from a wide range of backgrounds, they approached the lab kits in different ways depending on their subject matter knowledge, the discipline that they teach and the related pedagogical content knowledge, and their experience with the grade level of their students. In particular, it is worthwhile to analyze whether the teachers' preexisting knowledge and the support materials provided during the program were sufficient for the teachers' development of the related content knowledge. Also, while proceeding through the experiment, teachers reflected and elaborated on plans to incorporate the lab kit in their classroom. Since science and engineering teachers may have more experience with lab and hands-on activities compared to math teachers who may have a more traditional approach to teaching (teaching spectrum), the plan to use the lab kits in the classroom may vary from a live-experiment to a demo.

The intent of this study is to analyze the interaction of teachers with the lab kits, understand the impactful factors that shape this interaction and document the different ways teachers envision the use of the lab kits in their classrooms and their students engaging with them.

1.4 Research Questions

The research questions investigated in this paper are:

- What was the overall teachers' experience with the lab kits and the RET online format?
- How do teachers plan to adapt the lab kits to their curricular needs?

2 METHODOLOGY

2.1 Program description

The Portable Lab RET program is a two week-long online program. Teachers independently performed the experiments in the two lab kits supported by NASCENT faculty and staff through an online platform. Together with the two labs, participants received a safety guide and instructional manuals.

Each week, teachers attended three days of lectures and seminars and two days of curriculum mapping and ideas sharing in the morning and worked on the experiments in the afternoon with the online support of NASCENT graduate students. The schedule of the two weeks is reported in Table 1. For each lab, participants reviewed the manual and instruction material with the graduate students supervising the experiment and took a pre-lab safety quiz which was a prerequisite before moving forward with the experiment. At the end of each experiment, the teachers took an assessment quiz (multiple choice questions).

Table 1: RET 2020 Schedule

	Lectures (10am-12pm)	**Labs (1:30 - 4:00 pm)**
1st week		
Day 1	History of miniaturization, micro- and nano-technologies, electronics, healthcare, etc.	
Day 2	Coating and lithography	Spin-coating lab: go over lab manual, pre-lab quiz
Day 3	Nanodevices overview	Participants work on the spin-coating lab
Day 4	Discuss mapping to curriculum	Participants complete spin-coating lab
Day 5	Discuss mapping to curriculum	Participants complete post-lab quiz
2nd Week		
Day 1	Nanoparticle fabrication and properties	Nanoparticle lab: go over lab manual, pre-lab quiz
Day 2	Nanobiotechnology	Participants work and complete nanoparticle lab
Day 3	Nanotech and big data	RETs complete post-lab quiz
Day 4	Discuss mapping to curriculum	Example of student lab activity
Day 5	Discuss Future labs	

The 2020 Portable Lab RET program was attended by five participants, four of whom agreed to participate in this research study: one middle school math teacher, one middle school science teachers, one high school math teacher and one middle school engineering teacher. Among the four participants in this study, two attended the in-person RET at NASCENT in prior years. It is typical for teachers to participate multiple years.

2.2 Data Collection and Analysis

The Portable Lab RET program ran from July 6-17, 2020. Teachers participating in this program were employees of two neighboring school districts in the Austin (Texas, USA) area. At the end of August, RET participants were contacted via email to check their availability for an interview. Four participants out of five agreed to the interview.

The semi-structured interviews were held online through Zoom and lasted approximately 45 min. Each participant was interviewed individually, following the same semi-structured protocol, and a consent form was signed by each interviewee. The protocol included three broad areas of questions:

1. experience with the kit and with the program: teachers were asked questions concerning the use of the kit, the clarity of the manual and instructions received and their satisfaction with program format;
2. classroom application: teachers were asked to describe their vision concerning the use the lab kit in the classroom and the possible impact of this experience on their students;
3. suggestions about expanding the program in the future.

Interviews were recorded and transcribed. Inductive coding by the first author under the supervision of another author was used to address the research questions posed in this paper. An Institutional Research Board (i.e., ethics) approved protocol (Federal Wide Assurance of Compliance # 00002030) governs data analysis and publication.

3 RESULTS

3.1 RQ 1: What was the overall teachers' experience with the lab kits and the RET online format?

Overall, all the teachers enjoyed the experience of working with the lab kits.

One teacher, who previously experienced the in-person format and loved it, felt that the online format needed some adjustments. Another teacher who previously attended the in-person format felt that the online format was equally successful, and they would highly recommend it. This latter teacher felt that expanding the program to teachers from other areas will bring new ideas, allowing collaboration across multiple geographic areas and different disciplines.

Teachers reported that instruction manuals were clear, but some grammar edits are needed to improve readability and some photos need to be replaced to match the experiment as closely as possible; this is seen of particular importance for students' use of the lab kits. Seminars and lectures were very useful, but teachers suggested breaking down lectures into mini lectures or slowing the pace to allow time to absorb the material. For example, one teacher suggested changing the schedule to mini lectures and embed discussion into them. Another expressed preference towards a PLE delivered in a fashion similar to the kind of structure that will be used for students, for example synchronous/whole class session of approximately 40-45min with the addition of asynchronous/independent work time to allow for breaks from the computer. Teachers were very pleased with the guidance received and they felt that the afternoon format when teacher performed the experiment guided by NASCENT graduate students was successful. However, due to the different backgrounds, some teachers expressed the need for additional guidance and supporting material.

During the interviews, all the teachers reported how finding themselves in the role of the learner impacted them. The teachers expressed a renewed empathy and understanding towards their students and the frustration they experience while challenged with new concepts. One teacher suggested adding a "pep-talk" in the schedule to help maintain a positive attitude and to support teachers in coping with the possible frustration of the challenges of "being the student".

3.2 RQ 2: How do teachers plan to adapt the lab kits to their curricular needs?

Teachers reported that the main appeal of the kits is engaging their students in the experiments. They planned creative ways to use the lab kits in their classroom, adapting them to the subject they teach and the specific curricular constraints they face, with some teachers having more curricular flexibility than others due to state government requirements and testing.

Moreover, each teacher presented a different perspective based on their area of expertise and interests. For example, one of the math teachers planned to challenge students to find patterns and perform statistical analysis of the data; this math teacher seemed enthusiastic to show their students that "mathematics isn't just in a textbook" and to bring "real world mathematics in the classroom". The engineering teacher examined ways to include the kit in an engineering design project; they are planning to incorporate the spin coating lab in the building of a solar cell and the particle contamination project in the creation of a water filtration system for the local creek.

At the time of the interviews, it was still unclear when schools in the area were going to reopen in-person, the number of students attending in-person and what constraints were going to be imposed to the in-person teaching. When discussing possible options to use the lab kits with their students, teachers weighted the possibilities of working in-person or online. If schools resume in-person, their goal is to have students directly interact with the kits; teachers discussed sharing two-three lab kits per class and creating rotation stations giving each student the opportunity to manipulate the kits. According to the teachers, the benefit of the lab kits in the classroom is more than the specific science concepts; students will experience real science and be inspired by the sense of discovery. One teacher felt that the biggest takeaway was "the idea that a project doesn't have to be focused on math or on the content for it to be beneficial; if it adds to students' interests and students' engagement then it's adding to the course". In the case of online school, some teachers were planning video demonstrations; according to teachers, demonstrations are not ideal since they take away from the tactile and interactive experience, but they would still be interesting for students.

When asked in what ways this program changed their teaching practices, only one teacher replied that it didn't because they felt that their teaching approach is already hands-on. One teacher replied that it helped in bringing 21st century technology in the classroom; another hoped to better relate with the students having experienced the discomfort of being in the learner seat, and another teacher replied that they feel more inclined to use lab kits to bring the real world in the classroom while teaching mathematics.

An interesting observation came from a teacher who attended the in-person program twice in previous years. The teacher felt that the two prior in-person RET experiences were very powerful because the teacher worked with researchers and observe and learn from them and was given the opportunity to create their own lab. According to this teacher, the online format took away "the creative outlet" because it consisted in learning to follow tasks instead of creating a lab to use in class. "It felt that something at the university level was forced in the curriculum" while the goal is to learn "what scientists do at the university level and teach it to my kids. Teachers have the expertise to bridge university research with school curriculum."

4 SUMMARY AND CONCLUSION

Overall, all the teachers enjoyed the experience of working with the lab kits, in particular because of the subsequent opportunity to engage their students with them in the classroom.

To answer research question 1, about the overall teachers' experience with the lab kits during the program, teachers were asked questions concerning the material and support received and the clarity of the tasks assigned. Participants made the suggestion of administering a PLE that is similar to what they will present to their students with short lectures and time for breaks; this finding is in line with literature studies on the characteristics of effective PLEs [2, 3]. Additional attention should be given to the teachers' existing content knowledge in order to provide adequate support and material and allow completion of the tasks and deep understanding of the science behind the experiment. Finding the middle ground between a rigorous scientific experiment and the need to accommodate a variety of science backgrounds is an important goal for NASCENT. Additionally, teachers reported an increased ability to better relate to their students, having experienced the frustration and discomfort of learning new and challenging concepts.

To answer research question 2, about teachers' plans to adapt the lab kits to their curricular needs, participants were asked questions concerning ways to include the lab kits in one or more curricular units and how they envision their students engaging with the lab kits. Participants discussed creative plans to incorporate the lab kits in their classrooms, including teachers of subjects "usually not hands-on". One teacher lamented the limitations to the creativity due to the use of the pre-made lab kit while others have welcomed the opportunity to bring real world applications into the classroom. Reflecting of these observations, we believe that although the online format uses premade lab kits, taking away the creativity to make a personal research project, they afford teachers and students the opportunity to manipulate equipment as in an actual lab (in a similar fashion as scientists do). Indeed, participants reported that they believe their students will engage with the lab kits and will be inspired and excited by the sense of discovery and the ability to do "real science". Moreover, due to the vital involvement of the teachers in adapting the lab kits to their curricular units, these projects intend to leverage on teachers' expertise to bridge the gap between university research and K-12 teaching. The lab kits have the potential to give teachers the flexibility to adjust them to their curricular needs.

All the participants except one – whose teaching style is already “hands-on” - felt that the program had an impact on their teaching practices, from bringing 21st century technology in the classroom to real world scientific applications to ability to better relate with students’ frustration when dealing with difficult concepts. Future investigation of classroom implementation of lab kits related materials will help determine the impact of this program on teaching practices.

5 LIMITATIONS AND FUTURE WORK

This study presents preliminary findings related to the evaluation of a pilot RET virtual program developed in response to the challenges presented by the COVID-19 pandemic. The results from this first session are encouraging in terms of participants’ satisfaction and impact that the lab kits could have on teachers and students across the country. The multi-disciplinary application of the lab is, in our opinion, the strength of the lab kits together with the collaboration that they create between the research world and the K-12world.

However, the small sample size doesn’t allow for generalization and, although classroom plans to use the lab kits have been discussed in detail during the interviews, investigation of classroom implementation is needed. Future research will focus on students’ interaction with the kits and teachers’ interaction with the kit and with their students in the classroom.

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STRUCTURES AND ADAPTATIONS TO FOSTER STUDENT SUCCESS IN THE COVID-19 PANDEMIC LEARNING ENVIRONMENT

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Conference Key Areas: *Methods, formats and essential elements for online/blended learning, Lab courses and projects in online/blended learning*
Keywords: *online learning, active learning, pandemic learning environment*

ABSTRACT

Due to the coronavirus pandemic, all engineering courses at University of the Pacific were offered in an online modality during the Fall 2020 semester. The learning environment for students in social isolation is a challenging one; studies show that social isolation can cause negative psychological effects which can adversely affect academic performance. The online medium also offers challenges related to keeping students engaged while delivering content and administering examinations in the absence of proctoring resources. Synchronous class meetings to give students a structured schedule, use of breakout rooms to help students connect with each another, use of a tablet PC with ink annotation of skeleton notes to keep students engaged during class meetings, and changes in the design of exams (to help assess student knowledge without the bias caused by access to text and online resources) are some of the structures and adaptations employed to foster student success in this challenging environment.

A comparison of student performance between the Fall 2019 in-person offering and the Fall 2020 online offering of an introductory Digital Signal Processing course was done to evaluate whether the adaptations helped to combat the negative effects of social isolation on academic performance, and the availability of resources during exams that might artificially boost exam scores. Hypothesis testing showed that the adaptations helped accomplish both objectives: an independent samples t test performed to compare the mean composite student scores of the two groups showed no statistically significant differences ($p = 0.77$) between the population means.

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1 INTRODUCTION

1.1 The effect of the Covid-19 pandemic on the learning environment

The COVID-19 pandemic forced all classes at University of the Pacific during Fall 2020 to be conducted online. Student learning environments were altered: students could not network, socialize, or engage in group study as they previously had while on campus. They had to retreat to their individual homes and take classes remotely, in some cases being hampered by lack of suitable study spaces, easy access to software, and poor network connectivity. The pandemic has subjected students to increased levels of stress, anxiety, and depression due to factors such as loss of family income, housing instability, worry about getting infected, and anxiety about academic performance [1,2]. Studies have also indicated that learning online in the pandemic environment has had a negative effect on academic performance of students [3,4].

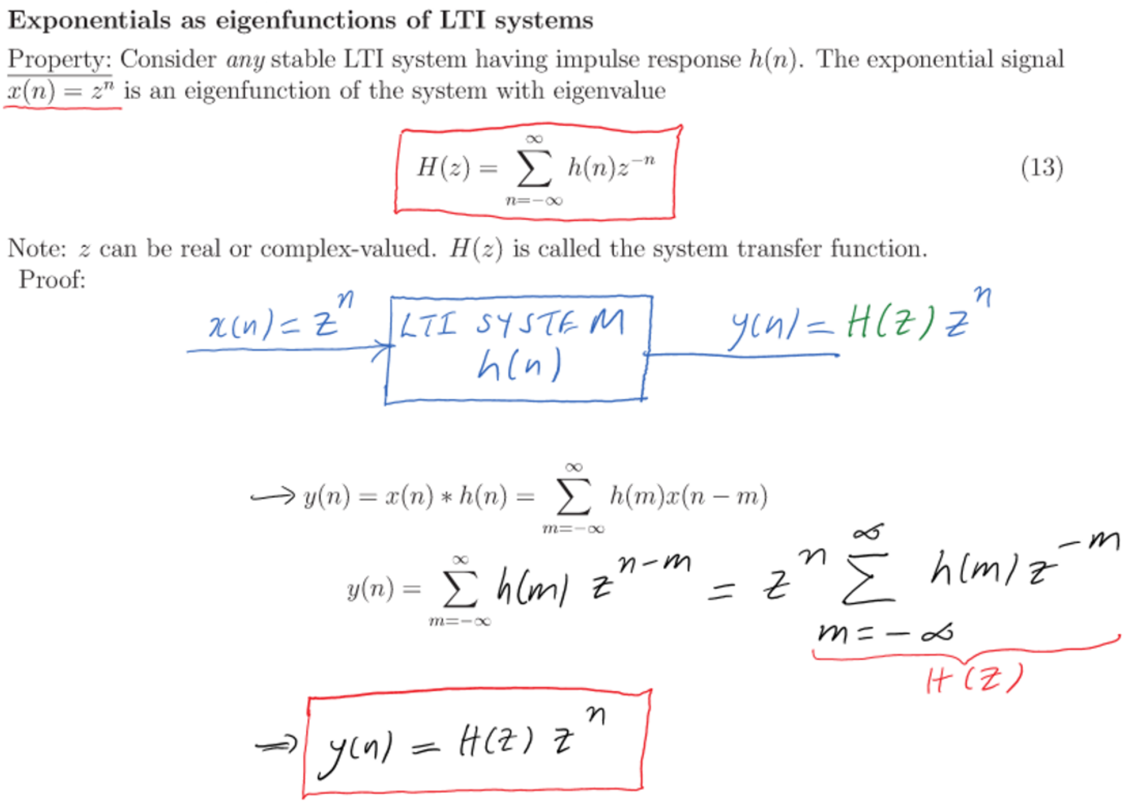
University of the Pacific is a private institution that prides itself on excellence in undergraduate education and meeting the needs of students. To help maintain a sense of community, foster interaction between faculty and students, lessen feelings of social isolation, and provide a structured schedule for students, the university recommended the synchronous online teaching method; classes would meet regularly online (via Zoom or Webex) at scheduled days and times. Class sessions were recorded to give students the flexibility to miss class meetings in case of emergencies. Synchronous class meetings represent the foundational structure employed to minimize the negative social effects of the pandemic. The author employed additional structures and adaptations to keep students engaged in the online learning environment and to minimize the pandemic's negative effects on academic performance: these structures and adaptations are described in the following subsections.

A study was conducted to compare the academic performance of students in the Fall 2019 offering (pre-pandemic, in-person class meetings) and the Fall 2020 offering (during pandemic, online class meetings) of a Digital Signal Processing course. The aim of the study was to evaluate whether the structures and interventions employed to minimize the negative effects of the pandemic on academic performance were successful. An independent samples t test comparing the mean composite scores of the two groups showed that there was no statistically significant differences between them: the interventions have proved to be effective at stemming loss in student academic performance in the pandemic learning environment.

1.2 Structures that helped facilitate student interaction and engagement

The backbone of the transition to online learning in response to the pandemic was the use of synchronous learning: faculty and students interacted in the virtual classroom via Zoom thrice a week at scheduled times. Asynchronous learning during a period of social isolation is difficult on students – they must have the intrinsic drive to watch video lectures, do homework, and keep in step with all their classes. The structure provided by synchronous class meetings can help students during a period of social isolation (they can interact with their teacher and classmates) and make progress with course material just by attending class on a predictable schedule. Synchronous learning also facilitates collaboration between students.

Another structure that helped facilitate online teaching and learning was the use of skeleton notes for instruction. As can be seen in Fig. 1, the skeleton note is a file (provided ahead of time to students) containing printed text and background material with gaps in it; the gaps are filled in by the instructor during class using digital ink. The background material, problem statements and figures in the skeleton notes obviate the need for students to stay busy copying down everything that is done during class. Students instead engage with the material in class while filling in the gaps or solving problems whose statements are available in the note packet. This contrasts with one-sided PowerPoint style lectures where the all the material is in the handout and students just listen as the instructor talks through the material. Skeleton notes help keep the students engaged during class and free up time that can be used for active problem solving. Time available for active learning (which can be instructor led while the class works on solving a problem, or in breakout rooms where students feel free to come on camera and interact with each other) is the key benefit that the skeleton notes provide. Active learning and peer interaction have been shown to improve student outcomes in an online learning environment [4].



Exponentials as eigenfunctions of LTI systems

Property: Consider *any* stable LTI system having impulse response $h(n)$. The exponential signal $x(n) = z^n$ is an eigenfunction of the system with eigenvalue

$$\boxed{H(z) = \sum_{n=-\infty}^{\infty} h(n) z^{-n}} \qquad (13)$$

Note: z can be real or complex-valued. $H(z)$ is called the system transfer function.

Proof:

$$\longrightarrow y(n) = x(n) * h(n) = \sum_{m=-\infty}^{\infty} h(m) x(n-m)$$

$$y(n) = \sum_{m=-\infty}^{\infty} h(m) z^{n-m} = z^n \underbrace{\sum_{m=-\infty}^{\infty} h(m) z^{-m}}_{H(z)}$$

$$\Rightarrow \boxed{y(n) = H(z) z^n}$$

Fig. 1. A sample skeleton note

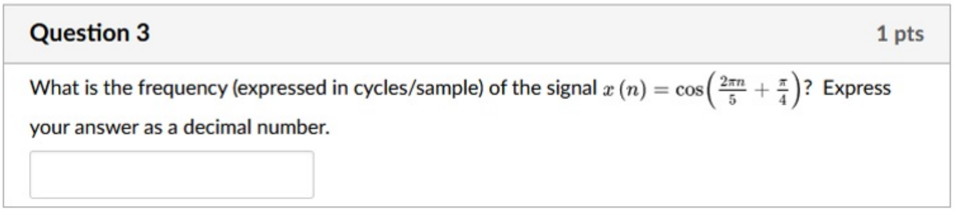
The final structure that helped foster communication between students and provide access to teaching assistants was the channel-based messaging platform Slack.

The Electrical and Computer Engineering department set up Slack channels for each individual class, allowing students in the class to communicate and collaborate with each other without having to exchange email addresses. All the teaching assistants in the department had a common Slack channel through which students could ask questions or join the office hours of any teaching assistant.

1.3 Adaptations employed in the pandemic environment

In the pre-pandemic environment (Fall 2019), the digital signal processing course had eight exams on theoretical concepts and one practical examination pertaining to the use of Matlab for signal processing. Having eight exams over a fifteen-week semester helps keep students abreast of the material; they cannot afford to delay engaging seriously with the course material as might be possible in a course with three examinations.

The first adaptation made in the pandemic environment (Fall 2020) was the addition of eight pre-quizzes. The quizzes were concept-based multiple choice questions that students could work on outside of class that were automatically graded by the Canvas online learning platform. Fig. 2 depicts a sample quiz question: a typical quiz had three short questions. The pre-quizzes fell roughly in the weeks where there were no scheduled exams and thus provided even more structured engagement with the course material for students. They also served to help students come to class comprehending recently presented material and prepared for the new material that was to be introduced.



Question 3 1 pts

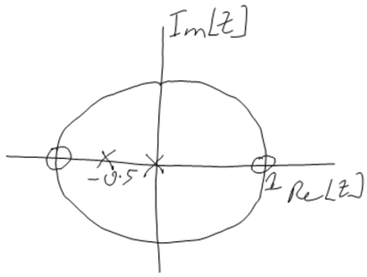
What is the frequency (expressed in cycles/sample) of the signal $x(n) = \cos\left(\frac{2\pi n}{5} + \frac{\pi}{4}\right)$? Express your answer as a decimal number.

Fig. 2. A sample quiz question

The second adaptation pertained to modification of the exam structure for the course given that our department chose to avoid the costs needed to use proctored exam services. The exams (which students took in their homes) essentially became open-book exams and therefore had to be restructured. Six out of the eight course exams were split into two parts, part A involving theory, and part B involving the use of Matlab to solve problems. The theory-based part A exams were to be completed in a short time frame, thus denying students the luxury of searching out materials from their class notes. Students had to be well prepared for the exams to be able to complete and upload them in the available time. The Matlab-based part B exams replaced the single practical exam that was employed pre-pandemic. The new model gave students many more opportunities for testing in Matlab (and thus to gain experience with this tool) than in the pre-pandemic environment. There was no time pressure for the part B exams; students had close to 12 hours to complete them. Fig. 3 depicts a sample part A exam, which students had to complete and upload in a short time frame of 16 minutes. Fig. 4 depicts the corresponding part B exam which involves the use of Matlab for filter design and analysis.

Mini Exam 6A (12 pts total)

1. (4pts) The pole-zero plot of a digital filter is depicted below. Use a geometric approach to determine the magnitude response (gain) of the filter at the frequency $\theta = \pi/2$ rad/sample. Show all your work.



2. (4 pts) The transfer function of a stable, causal digital filter is $H(z) = \frac{z^2-2z}{z^2-1.4z+0.49}$. Obtain the difference equation that can be used to implement the filter.
3. (4 pts) A DSP system operates at a sampling rate of 10000 samples/sec. A digital filter is desired that will reject the $F = 2kHz$ component in the input signal. Specify the desired filter zeros needed to accomplish this; express your answer in polar form.

Fig. 3. A sample 'part A' exam with short time-constraints

Exam 6B (13 points)

Use Matlab/sptool to help design a stable, causal, bandpass filter for use in a system operating at a sampling rate of 16,000 samples/sec. The filter must have a **maximum gain of 1 at $F = 6$kHz** and must have **zero gain at both $F = 0$ and $F = 8$kHz**.

1. Sketch the pole-zero plot of the filter.
2. Determine the transfer function of your filter. Provide details on how you get the transfer function.
3. Use Matlab to obtain the magnitude response plot of the filter you designed. The frequency axis in the plot must be in units of kHz. Place a marker at the point on the plot where the filter gain is maximum. Include a screenshot of the filter gain in your submission.

Fig. 4. A sample 'part B' exam involving use of Matlab

2 METHODOLOGY

The purpose of the study is to examine whether the interventions made in the Fall 2020 offering of the Digital Signal Processing course in the pandemic environment (F20P class) helped to prevent decline in student performance when compared with the Fall 2019 offering in a pre-pandemic environment (F19 class). All undergraduate students in the Electrical and Computer Engineering Department take the Digital Signal Processing (DSP) course, normally in their fifth semester or later. The population of students in the class thus reflects the average student population entering the department, and can be assumed to be randomized from semester to semester.

The F19 class had 23 students with an average class grade-point-average (GPA) of 3.21 at the time of entering the DSP class. Two students were excluded from consideration in the F20P class; a student who received an F grade due to cheating, and a graduate student taking the class to fulfill prerequisites requirements. The F20P class had 18 undergraduate students after the exclusions, with an incoming average class GPA of 3.15. The incoming GPAs of 3.21 and 3.15 for the F19 and F20P student groups are very similar, supporting the premise that the population of students in the DSP class each year is a random sample of the incoming student population.

The dependent variable in the study is the final weighted student score for the class. The final weighted score is a weighted sum of scores from all assessment categories such as homework, laboratory work, and exams. In the absence of any interventions, the literature would suggest that the pandemic learning environment would cause a decline in performance of the F20P class relative to the F19P class. The study uses hypothesis testing to examine whether the interventions employed during the pandemic in the F20P class arrested any decline in performance with respect to the F19 class.

The study also examined student ratings of the DSP course and instructor in the F19 and F20P classes to see if the pandemic caused significant changes in student perceptions regarding the course and the effectiveness of the instructor.

3 RESULTS

Table 1 contains statistics pertaining to the final weighted student score for the F19 (pre-pandemic, in-person) class and the F20P (pandemic, online modality) class. A first look at the data shows that the mean student scores for the F19 and F20P are very similar; the mean for the F20P class is 0.8 points higher than the F19 class, but this difference is partly due to the deletion of a poorly performing student for cheating. The standard deviation, median, and range of the two groups are quite similar as well. The fact that the statistics of the two student groups are very similar indicates that the structures and adaptations employed during the pandemic helped prevent any decline in student performance.

Table 1. Statistics of the final weighted student score for F19 and F20P classes

	Number of students	Mean	Standard Deviation	Median	Range
Fall 19 class	23	81.2	8.4	81.9	31.7
Fall 20 class	18	82.0	9.0	81.4	31.4

A Shapiro-Wilk test supported the hypothesis that the student scores in the F19 and F20P classes were normally distributed (for F19, $W(23) = 0.93, p = 0.09$, and for

F20P, $W(18) = 0.97, p = 0.74$.) An independent-samples t-test performed to compare the mean composite student scores of the F19 and F20P classes showed no statistically significant difference ($p = 0.77$) between the groups. Results from Bartlett's test support the null hypothesis that the variances of the F19 and F20P classes are the same: $B(1) = 0.08, p = 0.77, B = 0.08 < \chi^2(3.84)$. Hypothesis testing lets us conclude that there is no statistically significant difference in the performance (mean and variance) of students in the F20P pandemic-section and the pre-pandemic F19 section, thus validating the effectiveness of the instructional structures and interventions at preventing decline in student performance due to the pressures of the pandemic. The results also show that the strategy of administering exams with short time constraints during the pandemic helped prevent increases in student grades due to availability of reference materials and unauthorized student collaboration (since the tests were unproctored.)

A study of student course evaluations was also performed to analyze student perceptions of the F19 and F20P DSP classes (students can provide anonymous feedback on the course and the performance of the instructor at the end of each semester.) The evaluation instrument has 11 categories in which students can provide feedback on the course, and 15 categories in which students can provide feedback on the performance of the instructor. Students provide responses to each category using a 5-point Likert scale, with a 1 corresponding to a poor rating, and a 5 corresponding to an outstanding rating. Example categories for course ratings include course organization, and effectiveness of class time, while example categories for instructor performance include preparedness, and availability outside of class hours. The percentages of students completing the evaluation instrument were 52.2% and 78.9% for the F19 and F20P classes, respectively. Due to the difference in response rate, student rating medians were examined rather than the means, as the median inherently filters out extreme responses.

Table 2 contains data on categories for which the median ratings for the F19 and F20P classes were different. The drop in student ratings in the course category were in areas where course changes were made in the F20P class, namely the addition of extra quizzes, and the reduction in time available for part A exams. The results of this study show that the exam changes helped prevent score increases that could be associated with unauthorized student collaboration during exams. Gaining this outcome at the expense of a small drop in student rating is an acceptable tradeoff.

The drop in median student rating from 5 to 4 in the instructor category were in areas related to level of enthusiasm for the subject, and ability to keep students interested / motivated. This drop in rating is not surprising given the transition from in-person to online learning: it is a lot more difficult to convey enthusiasm and keep students interested and motivated in an online modality.

Table 2. Categories in which median rating changed between F19 and F20P classes

Rating category	Median student rating	
	F19 class	F20P class
Course: Quality of tests and quizzes as measures of achievement	5	4
Course: Appropriateness of number of tests, quizzes	5	4
Instructor: Level of enthusiasm for subject	5	4
Instructor: Ability to keep students interested / motivated; conveys relevance of course	5	4

Out of 26 categories in which students could rate the course and the instructor, the median ratings between the F19 and F20P classes were different only in four categories. In these categories the median rating dropped from 5 (Outstanding) to Very Good (4). This leads to the conclusion that student satisfaction with the course and the instructor was substantially the same in the F19 and F20P semesters. This is remarkable given that the F19 class was offered in person while the F20P class was online with social isolation. The teaching structures and adaptations employed in the pandemic environment have kept student perceptions on the quality of the course and the instructor relatively unchanged between the pre-pandemic and pandemic environments. This conclusion is also supported by written student comments in the course evaluations. There were comments indicating that the DSP class was well suited for online delivery and that the remote version went very well. Two students made positive comments regarding synchronous class meetings. The F20P course had more written comments commending the instructor's teaching style and course organization than the F19 course.

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TOWARDS ONLINE INTERNSHIP

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Conference Key Areas: *Methods, formats and essential elements for online/blended learning, Lab courses and projects in online/blended learning*
Keywords: *Internship, Online, Remote, Virtual, Telework*

ABSTRACT

The PracDis research project was started to develop new online internship methods to address the lack of information and communication technology (ICT) experts in the industry. The PracDis project was planned and started at a time when there was no foresight of an emergency caused by the COVID-19 pandemic. The transition to distance work during the pandemic was a necessity for office-based companies, for example, ICT companies, that wanted to maintain operations. According to the latest research, the majority of companies want to continue with some form of remote work post-pandemic. As a result of the pandemic, the value, importance, and effectiveness of the project increased significantly. Remote work became, in a way, the new normal for health reasons.

This paper presents the expectations and needs of companies and students for distance internships and what kind of model takes these into account. Data were collected during spring 2020 through surveys of students (N = 61) and national ICT companies (N = 21).

The results showed that both students and companies think positively about distance internships. Initial orientation, progress reviews, and the existence of a support

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network were considered important. To take into account the above-mentioned factors, the PracDis distance internship concept was developed. The PracDis concept can be adapted globally to the internship ecosystem of any higher education, business, or industry.

1 INTRODUCTION

1.1 The Need for Online Internships

The situation of the COVID-19 pandemic at the time of writing, in spring 2021, was very serious around the world. Various restrictive measures are forcing a reduction in business travel. The amount of teleworking has increased significantly in those jobs where it is possible. Preliminary studies on the transition to teleworking have been published, such as a survey conducted in the spring of 2020 in the United States. The study found that the regional incidence of a pandemic causes a shift from work to telework, and young knowledge workers, in particular, are shifting to telework [1].

Distance/virtual/e-internship has been researched and developed according to various sources for about 10 years [2]. According to Jeske [2], in the early years, the topic was not often considered and remained marginal despite the many benefits it offers. According to the Board of European Technology Students (BEST), since 2009, virtual internships have been actively developed in Europe, as exemplified by the research in Table 1, which summarizes the advantages and disadvantages of online internships [3].

Table 1. Advantages and disadvantages of online internships

Advantages	Disadvantages
Mobility	Self-organization
Flexibility	Lack of physical access (intranet, equipment)
Different countries and economies	Lack of social interaction
Access to university resources	Different time zones
No extra costs for the intern	Limited subjects
Autonomy	Communication problems and misunderstandings
Companies save resources	Limited resources
Enhanced creativity by choosing a workspace	Slow process
Empowered diversity for companies	Information breach
More places are available, and more students can apply	Low attachment
Language (English)	Difficult knowledge transfer
Learning opportunity	
Building the professional network of interns	

The PracDis research project has been launched to address the lack of ICT experts by identifying the needs and expectations of ICT companies and students for online internships. Figure 1 shows the goals of the parties behind the concept. For students, the goals established by the curriculum and personal goals determine the content of the internship. The student's goal is to develop his or her competence in a way that would lead to employment, preferably in the target organization that provided the internship. From a business and industry perspective, business perspectives guide the provision of internships to promote production and support recruitment. The PracDis concept was developed for the virtual internship, based on which the pilot will be launched.

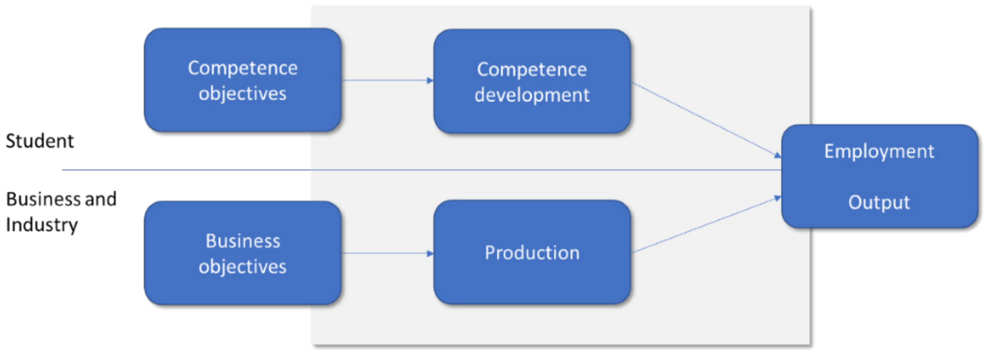

Fig. 1. Objectives of the PracDis concept from the perspective of the student and the business and industry

From the perspective of students and working life, three types of needs can be seen for the concept. Business and industry offer continuous internships in the field that students must be able to take as individuals and complete the 30 credits included in the internship. In terms of study, work, identification of competence, and flexibility, the number of credits reserved for internships in the curriculum may prove to be insufficient, in which case the opportunity to complete the study studies included in the curriculum should be sought. However, the needs of companies can be applied to broader entities, providing a learning environment for an entire group of student projects.

1.2 Research Questions

ICT is a common factor for distance internships in the examples mentioned. Jobs where employees are not necessarily working in the same facilities. The work was mainly used for fixed-term and/or part-time work contracts.

This article answers the following research questions: 1) What are the expectations and needs of companies and students for online internships and 2) What kind of model takes these into account.

2 METHODOLOGY

2.1 A survey

Students' views, attitudes, and willingness to do online internships were asked through a Webropol survey. The questionnaire was sent to all groups of students in the Bachelor of Science in Computer Science and the Engineering Education of Information and Communication Technology of Lapland University of Applied Sciences (Lapland UAS) in mid-April 2020, just after the beginning of a COVID-19 pandemic. There were a total of 355 students in the groups. The name of the respondent was asked because of their willingness to participate in the project pilots at the same time. The students were informed about the project and the purpose of the responses and had the opportunity to refuse to respond.

The responses to the questionnaire were received from 61 students, of whom 72% (N = 44) were engineering students and 28% (N = 17) were computer science students. There were 23% of first-year students, 26% of second-year students, 36% of third-year students, and 15% of fourth-year students.

The survey included general questions such as how and when the student would prefer the internship, what would be the student’s preferred internship period, how familiar the student is with the listed digital team communication tools, and the student’s willingness to do an internship at an international exchange destination. The results section in this paper includes the results of an open-ended survey on the questions of what kind of guidance the student would like from an educational institution and what kind of guidance from the industry, as well as other thoughts. None of the questions were mandatory.

3 RESULTS

3.1 Design Principles

The results of the survey provided the design principles for the creation of the PracDis concept. The key expectations of the students and the elements included in the model based on them are described in Table 2.

Table 2. Student expectations for university together with the solutions in PracDis Concept

Expectation	Actions/elements in PracDis concept
Initial orientation (N = 7) Guidance on the use and deployment of teleworking software (N = 3)	**Initial orientation** included in the process of the starting phase
Adequate guidance and support as needed (N = 12) Own support person in the educational institution (N = 1) Guidance on the choice of working methods (N = 2) Networking skills training (N = 1) Guided practice in online communication (N = 1)	**"My technical support person"** included in the concept throughout the whole process **Digital operating environment** MS Teams, Cloud-based development environment
Regular reviews to monitor progress (N = 2)	**Reviews** included in processes
Clarity of tasks / project / assignment (N = 2) Mapping, evaluating, and managing security aspects (N = 1)	A joint **kick-off meeting** will be included in the starting phase. **The project plan** is produced at the beginning of the project. The plan also agrees on the employer's responsibilities for guidance and support.
Support to obtain an internship (N = 1)	Included in the original internship support model
Information on internships (N = 2)	The possibility of supporting this through a **concept website** under construction is being considered.
Providing tools (N = 1)	The institution has a wide range of licenses and equipment.

3.2 PracDis Concept

The PracDis concept is based on the criteria described above, the prevailing practices, and methods in the field of ICT. In Figure 2, the previous objectives have been broken down into three core processes: starting, implementation, and closing phases. Based on the required assessment of the analysis phase of this study, the concept can be assigned quality improving factors, such as cooperation, communication, support network, goal orientation and continuous monitoring.

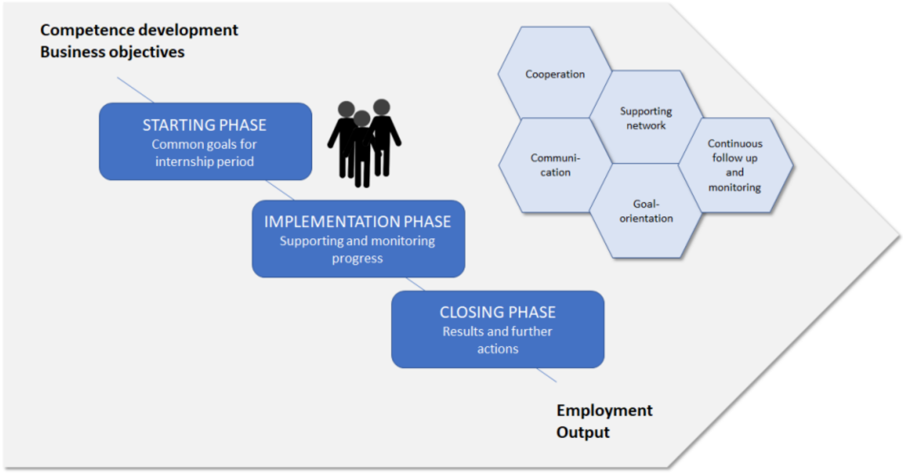

Figure 2. The PracDis Concept

In the starting phase presented in Figure 3, the common goals for the internship are agreed on together. Setting up a supporting network for the concept is natural to implement through existing expert resources. The research laboratories of the Lapland UAS provide professional-level support for potential problem solving by students. The concept is planned for an individual student or a team/project.

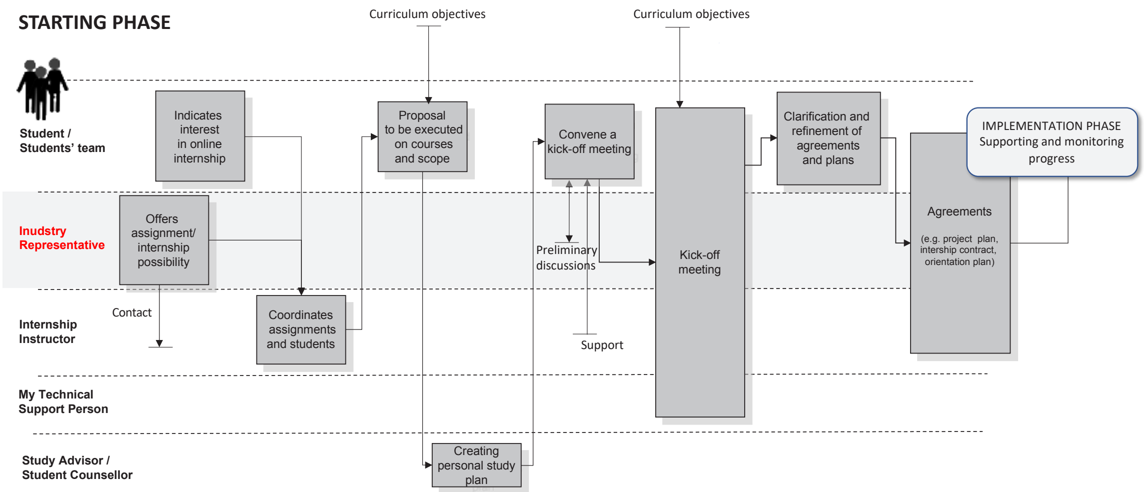

Figure 3. The process model of the starting phase

During the implementation phase, as described in Figure 4, progress is monitored and supported. Teleworking requires a digital operating environment. The model will be implemented in the default infrastructure, which includes MS Teams and MS Azure DevOps with GitLab/Hub for collaboration, communication, and development. The default environment can naturally deviate, as required by the employer. Agile methods are applied. All parties, including the employer and support staff, are in constant interaction with each other. Regular reviews of the process ensure the progress of the work. In the implementation of the project, reviews follow the sprint review methodology of the SCRUM method.

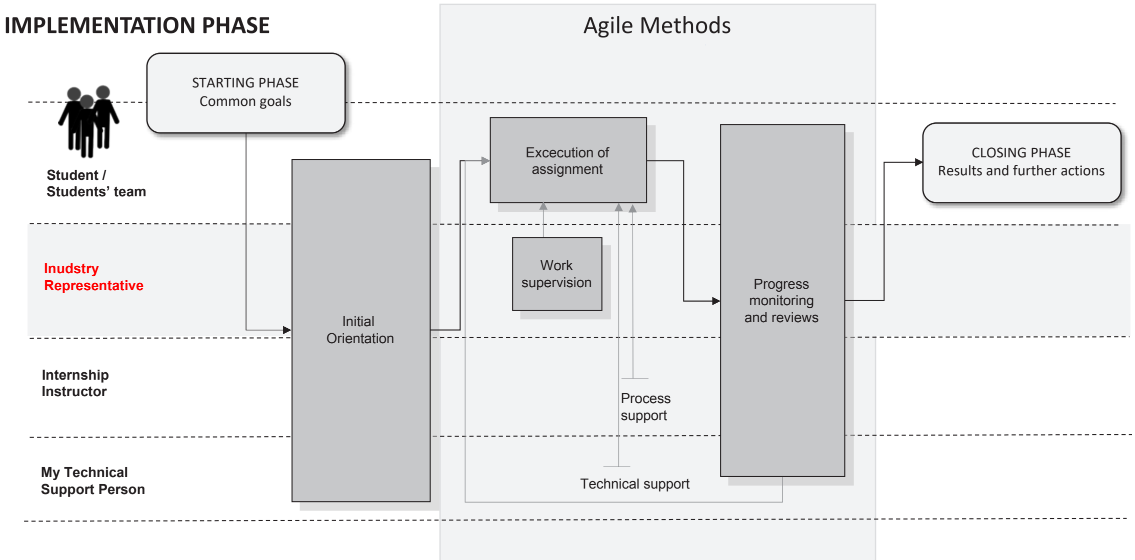

Figure 4. The process model of the implementation phase

In the final phase presented in Figure 5, the results are presented and possible actions for further development are planned.

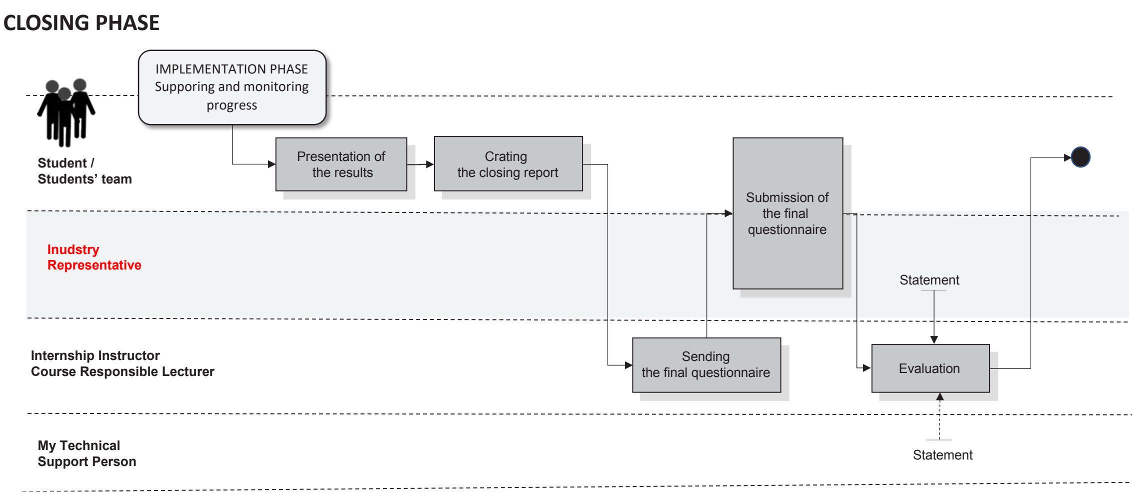

Figure 5. The process model of the closing phase

Previously, the training was an agreement between the student and the company, and in the end, the student has written a report on the training period. The PracDis concept changes the role of the university to operate more actively and makes communication more open. The aim is that the university is involved in the student's internship throughout the process.

Goal orientation motivates the student and gives meaning to the internship. Continuous monitoring ensures the achievement of the target. It ensures the quality of both the internship process and the results.

4 SUMMARY AND ACKNOWLEDGMENTS

The expectations are almost identical for both the educational institution and the employers. On the basis of the results, it has been possible to develop a concept that meets the expectations of the students. There are some similarities in the ideology of the concept described in this document with the TOGAF model, which provides a framework for an intelligent community internship application [4]. A functioning community requires a functioning communication platform and an operating model that supports cooperation, enabling synchronous and asynchronous communication between parties, such as MS Teams [5], [6]. Mentoring, e-mentoring, and support persons are widely reported in internship support [7]. Technical mentoring has been considered a critical factor in student productivity [8-10], and in their study it is stated that mentors and colleagues need to be perceived as available to consider them relevant. The existence of a support network creates security in challenging situations, and mere awareness of its existence can strengthen a student’s confidence.

The concept presented in this study is suitable for use in engineering education to combine higher education and industry. The concept of a distance internship prepares students for the common way of working remotely in the future. The methods supported by the concept correspond to the practices already used in the industry, such as reviews and agile product development.

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Incorporating microlearning videos, online exercises and assessments into introductory physics

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Keywords: physics, microlearning videos, online exercises, electronic assessments, changes beyond Covid-19

ABSTRACT

We report on the evolution of the largest physics course at the Technical University Berlin during the COVID-19 pandemic, which boosted the development of online learning content, electronic assessments, and, not at least, the reconceptualization of our teaching methods. By shifting to distance education, we created features that can be easily implemented and combined with any physics-type course at a university level. Thereby, we incidentally made introductory physics sustainably accessible to students having difficulties visiting the university. Besides our experiences gained on blended learning methods, we provide a guide to online exercises, microlearning videos, and e-assessments, including exams realized in a virtual setting via the university's Moodle. Since the course is attended annually by more than 800 students enrolled in at least twelve bachelor degree engineering and all STEM (science, technology, engineering, and mathematics) fields, our reformations greatly impact the student's learning style. The teaching concepts presented here are supported by results from the Force Concept Inventory, student feedback, and exam results. The Force Concept Inventory shows that our online teaching did not negatively affect the student's learning process compared with a traditional face-to-face lecture. Student's feedback shows that the new format and material being available online are received very well. Finally, the exam results show that virtual exams conducted in a remote setting can be designed to minimize cheating possibilities. In addition, the test was able to yield a similar distribution of points as in the previous traditional ones.

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1 INTRODUCTION

Due to the COVID-19 pandemic, from the summer semester 2020 on, we were forced to transform our introductory physics course "Physics for Engineers" into a distance learning format. We did not have the time to plan and prepare our online teaching methods carefully, but fortunately, we could use the suddenly freed human resources tied up in face-to-face on-site teaching methods. Therefore, our team was vigorously supported by ten student assistants, many of whom worked overtime to get involved and create online content. Another advantage was that we started reforms in 2017 and implemented interactive teaching methods such as peer instruction [1] and new exercises, including concept tests, so we did not start from scratch; cf. Ref. [2].
This paper aims to provide guidance and act as a motivator to implement microlearning videos, online exercises, and virtual exams conducted in a remote setting into any physics-type course; see Sec. 2 for the methods implemented. Here we share our experiences and suggest instructor-level implications for online teaching methods that can be combined with face-to-face teaching and interactive methods making the teaching approach even more effective. In particular, we focus on creating material for online learning, laying out a foundation for building interactive formats. Also, the effort required to implement the methods and their reception will be discussed. In Secs. 3 and 4, we show our methods for evaluating our new teaching methods and discuss selected results related to the videos and the weekly exercises. We conducted a Force Concept Inventory (FCI) test [3], and the exam results show that exams taken by students at home on their own devices can produce comparable results to face-to-face on-site exams.

General structure of the course. Our physics course is aimed mainly at engineering students in the first two semesters. For some curricula, this is a compulsory elective for higher semesters also. Additionally, some students of mathematics, computer sciences, and other fields are attending our module as a part of their extracurricular studies. The course is entirely organized via the university's Moodle. It was structured into weekly units consisting of a virtual lecture, non-mandatory online exercises, and additional online material, including videos and lecture notes.
To make the course more accessible, we used the lesson activity of Moodle, guiding the students through each week's material. Here, we organized all the content related to a specific topic in small chunks connected by a golden thread guiding the students. This became available after each lecture along with the weekly material. If there was no additional material, participants were first advised to watch the microlearning videos. Then they were asked to read the corresponding chapter in the lecture notes and finally to solve algebraic and conceptual tasks to test their knowledge themselves. Also, they were reminded each week that they can use our various possibilities to contact us any time. This golden thread is particularly helpful because the course covers lots of content, beginning with classical mechanics, electromagnetism, and thermodynamics in the first semester and continues with atomic physics, quantum mechanics, nuclear, and solid-state physics during the second.
The course is usually passed with a written exam, now changed to a virtual remote setting via Moodle, including automatic grading of most of the questions. There were no requirements to participate in the exam. However, the students were highly encouraged to use all of the material we offered them, particularly the online exercises.
Since the course is mainly attended by first-year students, and because studies suggest that communication among and with students and student's ability to self-organize are essential to the perceived effectiveness of a teaching method [4, 5], we tried various social media. Social media are critical to the sustainable success of digital teaching methods, but our experience is discussed elsewhere due to the article's brevity. After two semesters, the Moodle forum and

virtual seminars proved to be successful. Offerings such as chats were hardly used; however, students primarily use messenger channels with peers to communicate with each other.

2 IMPLEMENTED DISTANCE LEARNING METHODS

2.1 Videos

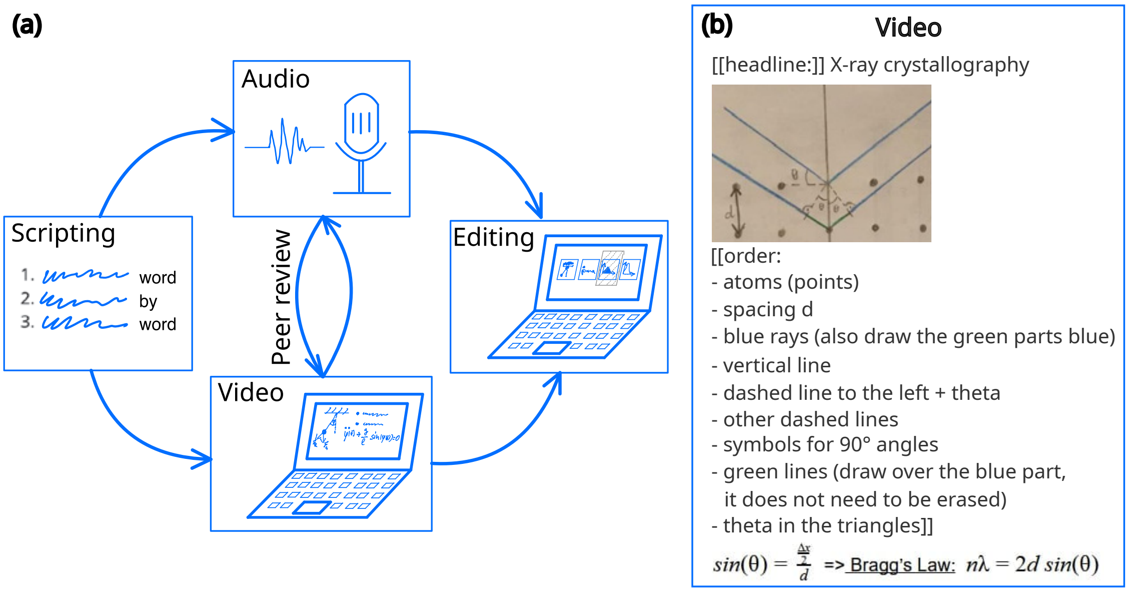

Figure 1: (a) Flowchart of the process we used to create the videos. (b) An example of instructions included in the video recording script.

While the lecture was not recorded due to the privacy guidelines, we provided short videos covering the essential aspects in just a few minutes. The creation of the videos was divided into three major steps, visualized in Fig. 1(a):

1. *Scripting.* Carefully deciding on the text to be spoken and written and the sketches to be drawn was the major accomplishment in improving the videos compared to recordings of a free talk. We had the chance not only to avoid filler words and choose efficient and instructive phrases but also to think about possible misunderstandings or inaccuracies that go unnoticed by the speaker when speaking freely, even in a well-planned presentation.
   We prepared separate scripts for audio and video, such that one can focus on recording the respective part without being distracted by speaking and writing simultaneously. Figure 1(b) shows an example for the video scripts. Here a sketch is to be drawn with instructions on the order of its elements, making sure that each new element is added in the identical sequence as in the audio recording. There is no need to take the time to work out elaborated sketches or formatting in the scripts as long as the recorder understands how to translate the instructions into the video correctly. We also point out the following: In the example from Fig. 1(b), the script continues with an interlude on wave interference, written on a new sheet. In the final edit of the video, this interlude is shown after the sketch is finished. Afterward, the video switches back to the screen with the sketch and continues with deriving the formula seen in the example. However, this is irrelevant to the process of recording, which in turn shows the flexibility of our video creation process.
2. *Audio and video recording.* After recording these separately, we double-checked for mistakes and removed the noise from the audio file. Another advantage of this way of

video production compared with a direct recording of a talk is the possibility to repeat the last sentence if there occurs some mistake in speaking or writing.

3. *Editing.* Not only are mistakes cut out, but also the pacing can be adjusted when putting audio and video together. In particular, the person writing can focus on readable handwriting and carefully draw the sketches without talking while rushing to finish a sketch quickly. Of course, the drawing speed of sketches was kept slow enough in cases where a faster pace would be confusing.

We worked in a team of five people by creating the videos, though each could switch with someone for another video. In the following, we outline the workload of creating the videos:
The *scripting* is done by (at least) two people. This is necessary to discuss the wording and the arrangement of sketches, for example. Thorough preparation for one video of about 15 minutes can take up to one day of scripting, making this the most time-consuming part of the production.
We also assigned two people to record *video and audio*, one for each of these tasks. Afterward, they both cross-check the recording of the other. We found that recording five minutes of final audio, already removing noise and cutting out mistakes, took us about one hour of work.
Since no discussion or cross-checking is needed to *edit* the videos, one person is sufficient for this task. However, we cannot provide a typical amount of time for this, as this highly depends on the contents of the video. For example, some sketches include many changes in color or the use of several tools where a menu bar shows up, which was to be cut out of the video. See also the note and video at [6].

2.2 Exercises

In anticipation of the online format of the exam, the exercises were also integrated into Moodle, thus being solved completely online and graded automatically. Most of our exercises can be sorted into two categories:

- *Algebraic exercises with random numbers*. Here, the students had to write down a numerical result, including a unit if necessary. For example, given the wavelength of a laser pointer and the distance between minima of diffraction caused by a hair in a given distance to the screen, the students had to estimate the hair's breadth, motivating them to try this with their's at home.
  While in classical worksheets, points can also be assigned for correct formulas or intermediate steps in miscalculations, Moodle only grades the final result. However, this did not turn out to be a problem when the exercise was short enough. Also, as the students were allowed and expected to use a cheat sheet and tools such as WolframAlpha [7], there is no need to grade achievements like "knowing the correct formula" or "computing correctly." Instead, the grading of the final result is considered as grading their derived formula by testing it for the given random values.

- *Exercises with fixed options*, e. g., multiple-choice (MC) questions or drag and drop exercises. This type is well suited for conceptual questions and also suitable for algebraic ones with more complicated computations. By giving a few answers to select from, computational errors are readily noticed instead of being graded with zero points. If there is an expected typical mistake that should not be given away by this and would not give points in a traditional exercise, it can be included as one of the possible answer options.
  We also used this type when the correct answer is somewhat surprising and offered answer options in a more expected range. By this, the multiple-choice character does not give away the correct answer, but students are encouraged to select their correct result if found in the options even if they would doubt it at first. For example, the time

it would take in theory to fall through a hole straight through the earth onto its other side was to be computed as less than an hour while it would take more than half a day to travel around the earth with the speed of sound.
Also, Moodle's "random short-answer matching" allows for non-algebraic randomized questions. For example, the students had to select the number of translational and rotational degrees of freedom of several gas molecules randomly chosen out of a given list.

When using algebraic MC questions with random numbers, the following shortcoming is pointed out: These exercises can be designed in a way that the correct option is either in a fixed position in terms of its numerical value (e. g., it is always the third-highest number) or at a random position (e. g., using a sine of the random numbers for generating wrong answers). In the first case, the correct answer is easily communicated when used in an exam, diminishing the effect of using random numbers. However, in the second case, one of the randomly generated incorrect answers could approximately match the correct one while still being graded as a wrong answer. To avoid this confusion, one would need to manually check all the rows of numbers generated by Moodle and change them if necessary.
An advantage of the online format is that animated GIFs can be used. For example, students have to identify different types of damped oscillators from given animations of springs. Also, animations are helpful to illustrate the scenario in exercises about moving objects. For example, the rotation of a wire loop relative to a magnetic field is easily represented.
The creation of the exercises took about one to two days per week, strongly depending on the exercises. The most time-consuming factors are the following:

- *Developing new questions suitable for the online format*. For instance, questions that ask students to explain or draw something or derive a formula need to be adapted accordingly. Instead of giving explanations, they had to select the correct reasoning in an MC format, and instead of drawing, they have to select or label the correct diagram. Formulas to be derived were checked by plugging in numbers.
- *Creating sketches and animations*. For instance, diagrams are needed when the task was to label them, such as the phase diagram of a Van der Waals gas. In other cases, we deemed a sketch of the given scenario helpful rather than explaining geometric details in words.

2.3 Exam

Since the exam was taken in a virtual setting via Moodle, with each student using their own device at home, two major questions arose:

- How to choose appropriate questions for an open-book online exam?
- How to avoid cheating in a remote exam?

As a general discussion on creating assessment tasks via Moodle is given in Sec. 2.2, we focus on the kind of tasks suitable for a virtual exam. In selecting questions for the exam, we considered the following concept:

- *Structure*. 30 to 40% of the exam questions consist of the weekly exercises, which we announced at the beginning of the semester as motivation to complete the exercises. The remaining 60 to 70% of the exam consists of moderately tricky as well as challenging tasks, allowing for efficient differentiation between grades. We weigh the easier of these tasks and the tasks from the weekly exercises with enough points to pass the exam, making it easier to pass the exam by solving the exercises during the semester.
- *Concept tasks*. We take care to include only those questions whose answers cannot be

easily found on the internet. Solutions to some of the conceptual problems are easy to find, but a simple transfer to another situation is often enough to hide the keywords. For example, in a paradox of special relativity, a train traveling through a tunnel is replaced by an arrow shot through a pipe.
In the MC-type tasks, we combine possible answers (such as "yes" or "no") with different explanations that include some keywords also used in explanations found on the internet. Thus, students who find explanations during the exam must understand them well enough to exclude the wrong answers. We also included tasks of the essay question type from Moodle. Here we make sure to include at least one easy question where everyone should answer and at least one difficult one where the exact wording should not be the same in any of the answers. Copied answers could then be easily found by comparing the student's respective texts.

- *Algebraic tasks*. For algebraic tasks where students derive a formula, plug in numbers from the text, and get a numerical result, it is easy to construct examples that avoid finding the answers quickly on the internet. To avoid cheating, we use random numbers.

Other options avoiding cheating, which we did not use due to time constraints, are: Preparing several equivalent questions of a similar type and have one of them randomly drawn. The order of the questions and the options within the MC questions could also be randomized, making communication between students a bit more complicated, but not very much either.
Instead, we used a more effective method by including more complex questions than usual. Thus, we put some pressure on the students to finish the exam in time, not giving them enough time to communicate. Of course, this strategy alone could also result in a lack of time for solving the question independently. To ensure that the overall difficulty of the exam is not affected, we specified that the best grade is 85% of the total points instead of 95%, and that the exam is passed with 40% instead of 50%. This way, students are busy answering all the questions without being very disadvantaged if they did not manage to complete all the questions in time.

3 EVALUATION METHODS

To evaluate the success of our teaching methods and how the students received them, we used the following two methods:
First, we evaluated the learning process during the semester. In addition to the weekly exercises, we included the FCI, which is easily adapted into Moodle's MC-type questions. The FCI is a test instrument that gives a measure for understanding classical Newtonian mechanics, particularly Newton's axioms and the concept of a force. The test was offered at the beginning of the semester and after Newtonian mechanics was covered in the lecture.
Second, we asked the students for feedback with a mid-term evaluation via Moodle's feedback activity. In order to obtain a sufficient amount of answers, we made this activity obligatory for the remaining weekly exercises. The number of responses we obtained matched the number of participants in the exam quite well, so we consider the results very representative for our audience, despite the student answered anonymously.

4 RESULTS AND DISCUSSION

In this section, we analyze the results obtained from the FCI test, the mid-term evaluation, as well as the exam results and discuss our experiences.
Figure 2(a) shows the results for the students participating in both *FCI* tests. In a meta-analysis by Korff et al. [8] using data from 450 classes, the "normalized gain" is used to measure student's improvement. This is defined as the absolute gain in points divided by the number of wrong answers in the first test. The meta-analysis found an average normalized gain

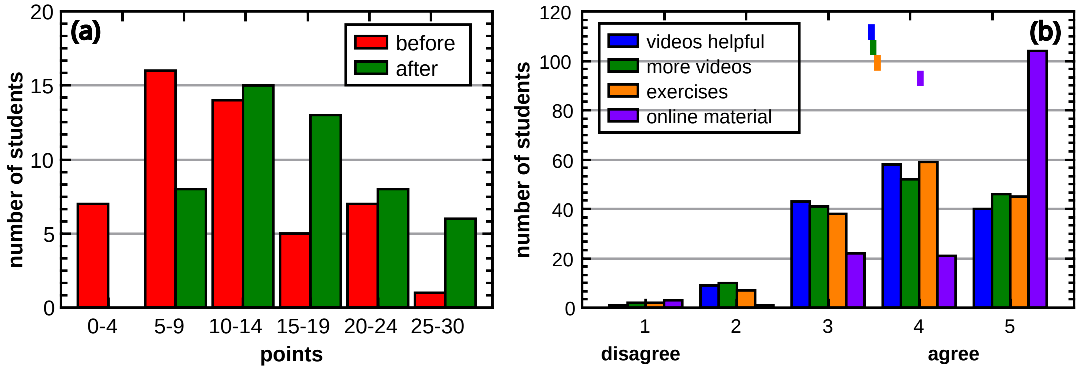

Figure 2: (a) Results of the FCI at the beginning of the semester ("before", average 11.2) and after the Newtonian mechanics were discussed in the course ("after", average 15.7). A total number of $N = 50$ participated in both tests. (b) Answers of students to "The videos were helpful for my understanding" (blue), "There should be more videos in the future" (green), "The format of Moodle exercises works well" (orange), and "It is helpful that material (exercises, videos, slides, and lecture notes) are available online" (purple), from 1 for "absolutely disagree" to 5 for "absolutely agree". Mean values are 3.84 (blue), 3.86 (green), 3.91 (orange), and 4.47 (purple). A total number of $N = 151$ students participated in the evaluation.

of 0.22 for traditional lectures and an average of 0.39 for courses with interactive engagement. In our case, the normalized gain was 0.23. As seen from our course outline, we mostly offered material for self-learning, making the course more comparable to a traditional lecture. Thus, we conclude that the online format did not affect the learning progress in any negative way.
In the following, we relate the e-learning content discussed above – videos, exercises, and the exam – to their respective benefits and evaluate student feedback as much as possible.
We start with the *videos*, for which we built a team of five persons as mentioned above, each of them working about one day each week. Despite this great effort of careful video production, we want to emphasize that the videos will be used in the following years of teaching, which is expected to relieve us from much work in the long term. This effort was also well received by the students. In the comments, they complimented on the videos, and in the evaluation, they wished for us to continue producing them; see the green bars in Fig. 2(b). Similarly, most of them said the videos were helpful for their learning process; see the blue bars in Fig. 2(b).
As for the videos, the *exercises* will and can be easily reused in upcoming years. Also, the online exercises are graded automatically, which saved us much time. We solely needed to hand out a few exercises of the essay question type, which required to be graded manually, as this type was also included in the exam. Additionally, the automatic grading allowed the students to try the exercises at any time and as many times as they preferred. We could see that this possibility was frequently used from the timestamps in the attempts. Also, the students answered in our evaluation that they are happy with the way the exercises are available; see the orange bars in Fig. 2(b).
As the course ended with the *exam*, we did not obtain feedback via an evaluation from the students. Instead, we evaluate the grading. The grades were distributed in a way we wished for and did not deviate significantly from preceding semesters. Figure 3 shows the percentage of students obtaining a relative number of points for the online exam and those three years before. The exam was neither showing a massive amount of best grades, which would be a possible indicator that many students cheated, nor a lot of failed exams, indicating that the online teaching itself failed. The only notable deviation from previous distributions is the lower percentage of students with 80–90 points, which an unexpectedly tricky question might cause. However, the statistical significance is not clear as there were some outliers on the traditional

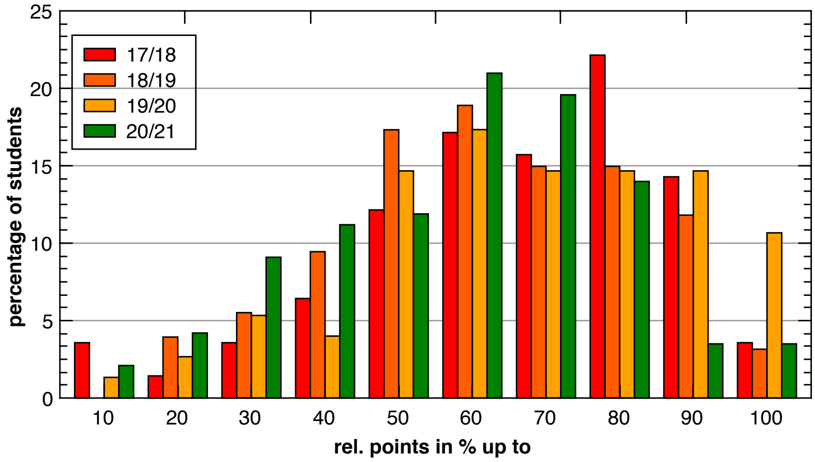

Figure 3: The relative share of students versus relative points obtained in the final online exam at the end of the winter term 2020/21 (green) and the preceding three winter terms (red, orange, yellow). The relative points of the online exam were slightly changed for this graphic to account for the best grade being obtained at a lower number of points.

exams as well, as seen in the 100-point bars. From these results, we feel well prepared for another online exam. Although there might have been some students who cheated, it seems that this did not affect the overall grade distribution.

5 CONCLUSION

We provide a guide to implementing distance learning formats based on our experiences in the last two semesters. Here we address the production of microlearning videos, online exercises, and the implementation of virtual exam formats. Our experience shows that online teaching content has been well received by students and evaluated positively. Examinations that are conducted in a virtual and remote setting can be designed in a way that the results are comparable to assessments that are conducted on-site face-to-face. As shown by the FCI, at least the teaching in Newtonian mechanics did not suffer from the online format than a traditional face-to-face lecture. The available resources will help and support us with online and face-to-face teaching in the years to come. Having made some efforts in the first two distance semesters, we have thus laid the foundation for further online teaching while maintaining the quality of our teaching. As we have focused on creating materials and exercises, we hope to continue to improve our teaching by incorporating them into more interactive formats.

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WHY IS THIS COURSE PUSHING FUNCTIONAL PROGRAMMING? – EDUCATING WELL-ROUNDED WEB DEVELOPERS WITH FUNCTIONAL JAVASCRIPT

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ABSTRACT

Imperative, object-oriented, and multi-paradigm programming languages are dominant in higher education. However, the use of functional languages is emerging. In parallel, features supporting functional paradigm (FP) have been added to languages traditionally categorized to other paradigms. Students benefit from fluency with several paradigms. In the studied primary Web Development course, JavaScript was used to familiarize students with selected features of the FP. The grading of the FP exercises was automatic. The automatic graders guaranteed the uniformity of feedback, treating each student's submissions equally. Exercise graders accepted multiple submissions, and their feedback suggested code improvements to students. After each of the ten exercise modules, students (N=257) estimated the topic difficulty and gave feedback. The post-module questionnaires emphasized FP topics in particular. The results show that students are aware of programming paradigms, but more support should be offered when learning new ones, for instance, having more concrete instructions and hands-on videos. The need for more instructions was apparent as, after the course's FP introduction, some students were still easily confused about such abstract FP concepts

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as ‘functions as first-class citizens’. However, exercise results showed that students learned to use the taught FP features. They found them difficult, but for example, the JavaScript concurrency model was found to be more difficult.

1 INTRODUCTION

Paradigmatic classification of programming languages does not fully capture their multi-paradigm nature if a multi-paradigm language is classified under one paradigm. Yet paradigmatic classification provides a means to structure a vastly heterogeneous space of software design and implementation methodologies and their associated programming languages [1, 2]. General-purpose programming languages have adopted concepts that were first introduced in functional programming languages: for example lambda functions and new immutable data structures have been introduced to C++ and Java [3–6]. In addition, Python and JavaScript (ECMAScript version 6) support functions as arguments, and currying. These modern multi-paradigm languages can be used to introduce FP features to students. As programming languages are becoming multi-paradigm in increasing quantities, students should be taught about applying these paradigms.

JavaScript is used in the industry for implementing Web applications. Learning this language which is appreciated by potential employers adds to many students’ motivation. As a side dish for the main course of learning JavaScript, its functional features can be used to teach functional programming, too.

The context for this work is a basic Web Development course. The course’s intended learning outcomes would see students be able to design and implement basic Web server and client applications, and be able to describe and use FP feature presented during the course. Based on its use in the industry, and its FP features JavaScript was chosen as the programming language for the course. The course’s JavaScript exercises included FP tasks. In these FP tasks students designed and implemented code, approaching the task using the FP paradigm.

At the start of the course students’ understanding of functional programming concepts was collected with a questionnaire in order to come up with a suitable curriculum along with fitting learning activities. While the transfer of FP concepts was measured with the exercises, their retention was captured by a questionnaire aimed at checking the knowledge they have gained during the course.

Vast majority of the course’s online programming exercises were automatically graded, a couple used peer-reviews to introduce students to other students’ code and giving useful feedback. Students worked on their code in their own Git repositories. Upon student submission automatic grader programs wfould clone the students code, run it against the grader’s test code. After the tests were run, the grader would give students the points for the exercises, and importantly feedback on how a student could improve the code they had submitted. For each of the exercises, students had a change to submit their code multiple times, typically 20 submissions per exercise. This number of submissions could enable students to use the grader to iteratively improve their code, as they reflected on the features discussed in the exercise.

2 RELATED WORK

In the functional programming paradigm, functions are pure: pure functions depend only on their input values, their parameters. Whenever a pure function would receive the same inputs, its output would consistently remain the same. Pure functions cause no side effects, such as state changes, where the state is defined as a Cartesian product of the values of all the variables of the program.

In mathematics, functions are also pure. Algebra is the domain of mathematics that is the most concerned with functions and variables. The transfer between algebraic constructs and computer science has been found to have favorable effects on learning in both directions [7, 8]. In their seminal work, 'How to design programs?' Felleisen et al. set guidelines for implementing a program in a reusable and secure manner, the key feature being purity [9]. Moreover, Design Recipe systematizes problem solving: a problem is divided into smaller solvable steps, i.e., functions, with a test-driven approach [9]. The use of Design Recipe has proven to foster the right order of operations and the composition of nested functions. Thus, Felleisen and Krishnamurthi state that functional programming provides the strongest evidence for the favorable effects on math skills [10].

Felleisen and Krishnamurthi list FP's advantages, i.e., more disciplined approach to problem solving, no side-effects, and data immutability. These features provide chances for applying mathematical structures to computer science, which is likely to appeal to academics and educators in CS field. A stricter FP approach would also foster code-level testability, security, an increased support for distributed and parallel computing, and large-scale development. The value of this approach is understood in the industry, too.

When looking at the popularity of functional programming languages in the TIOBE index[11], currently (Mar/2021) the first functional programming language is R in the 13th position, while and MATLAB and functional-flavoured Swift place 18th and 19th, respectively. However, some useful features of FP have been adopted by languages traditionally seen as representatives of other paradigms. These features include lambdas and some monadic structures. Lambdas have been introduced in mainstream languages such as C# (C# v2.0, 2006), PHP (PHP 5.3.0, 2009), C++ (version 11, 2011), and Java (version 8, 2014), whereas in JavaScript lambdas are inherently built-in to the structure of the language, thereby existent from the very beginning.

JavaScript has borrowed such FP features from functional Scheme, Scheme being one of the primary influencers. Thus, JavaScript enables demonstrating ideas from FP. Students are partly motivated by desire to optimize their skill set for transition to working life. For the teaching of FP to bear more fruit, we should seek ways to align teaching with the intentional motivation of students to be easily employable [12] and ways for lowering the threshold of learning [13].

2.1 JavaScript and functional programming

JavaScript has several features which enable functional programming. One of them is functions as first-class citizens: functions are accepted as variables, and as parameters of other functions. Moreover, JavaScript has a single-threaded, event-driven concurrency model. This enables concurrently executing for example user-initiated events, network requests, UI rendering, and animations. When developing Web applications with JavaScript asynchronous processing is a key feature, as there will be delays in the communication between clients and servers. The concurrency model relies on asynchronous callbacks and functions as parameters, i.e., the affordances of functional programming.

Higher-order functions can be used in JavaScript with, for example, Array's methods *map()*, *filter()*, and *reduce()*. ECMAScript version 6 and a great deal of libraries in JavaScript ecosystem are to some extent based on the ideas of FP.

However, for the majority of students, the move towards FP has proven to be quite a challenge [14]. This study then aims at improving the comprehension of these difficulties, and, ultimately, lowering the learning threshold. Thus, this study asks:

- RQ1: Which programming paradigms were students aware of before WebDev1 course?
- RQ2: Which JavaScript topics, and in particular which FP concepts, were students struggling with?
- RQ3: What could the course personnel do to make those FP concepts easier to grasp?

3 RESEARCH CONTEXT

The studied WebDev1 course is a comprehensive introduction to both front-end and back-end web technologies. Front-end technologies comprise of HTML5, CSS, and JavaScript, whereas back-end introduces Node.js. Unlike previous years, the utilization of Node.js frameworks, such as Express and Handlebars, was omitted. Instead, vanilla JavaScript approach was used primarily for pedagogical reasons: frameworks come and go, but HTTP and generic client-server architecture will stay. The course is targeted to third- and fourth-year students. The prerequisites for this course include three basic programming courses, and a basic database course. Prerequisites imply that course participants should have a considerable amount of programming routine, including a basic understanding of project work, e.g., from using Agile project management.

The study was conducted during the global COVID restrictions, where moving to remote teaching was a general recommendation. Thus, WebDev1 course replaced previous lectures with video recordings, and on-premises tutoring with online tutoring sessions. Students struggling with the exercises or the coursework assignment could get help during these so-called Kooditorio sessions, which were held in Teams. Kooditorio is a tutoring practice a-kin to primetime [15], except voluntary, where teachers and assistants answer questions, debug and co-implement students' code and scaffold them finalizing their exercises. Outside the set session times, the same Teams channels functioned as a Q&A discussion board. The students were encouraged to help each other and respond to these questions, cooperation between students was encouraged in course messages. During exercises and coursework assignment, the discussion was lively and the channel was extensively used. The assignment was done in pairs that, preferably, would also foster learning from each other. The earlier study has shown that earlier social connections primarily guide group formation, while help seeking within the groups is geared towards students with the most domain knowledge [16]. In this implementation, the groups were formed by course personnel with the help of an algorithm, which was designed to allocate pairs from students with the same target grades and performance level, also the responses to a group formation quiz were influential in the match making.

3.1 Grading

To complete the course, students had to pass weekly exercises, a coursework assignment, and an exam. The rounds overlapped so that the next exercise round opened before the current one closed. The topics consisted of, e.g., HTTP, Client-Server architecture, DOM, Web security, authentication, data persistence, and MVC architecture. In parallel, a transferral thread of FP was run.

The grading of exercises and the coursework assignment was automated where possible. Without automation, the amount of work would have been enormous, the theoretical maximum total number of submissions was 205.600. Course personnel of three could not have assessed this number of submissions manually.

3.2 FP topics in the course content

The imperative paradigm is dominant in the curricula of CS students. This basic Web Development 1 course (hereafter: WebDev1) might be the first time they are exposed to FP. For learning functional programming, WebDev1 course sought to act as an easy starting point: during the course the following aspects of FP were discussed:

- the emphasis on "no side effects" and immutability (*const* rather than *let* or *var*, *map()* rather than in-place changes with *for* loop)
- functions as first-class citizens
- higher-order functions (*Array* methods: *map()*, *filter()*, and *reduce()*)
- arrow functions.

Listed topics were covered more deeply in materials and exercises. They were complemented by a cursory introduction of the following in materials and questionnaires: recursion and higher-order functions in general, continuation-passing style, currying, functors / monads, and finally railway-oriented programming. Fifth exercise round had exercises on the central functional programming practice of avoiding side effects from function calls and the associated immutable data, as well as higher-order Array functions map,() filter(), and reduce(). The tenth exercise round included discussion in the materials on topics related to functional programming: higher-order functions, recursion, functors/monads, continuation-passing style, and railway-oriented programming.

In JavaScript, the prominence of functions manifests itself also in handling asynchronicity with callbacks; this in contrast to other imperative languages, where functions as parameters are not so common. The syntax for using asynchronicity in JavaScript has evolved in steps from callbacks to promises, and finally to async/await. Promises provide two-fold handling options: promise can either resolve or reject. Here again, functions play the main role, whereas async/await returns to a more conventional control flow. In the scale of one function, async/await behavior is sync-like: the magic happens in the background, where actions do not block the execution of each other. Asynchronous callbacks and high-order functions force students to practice coding in a function-oriented manner.

Many software developers start their careers in Web development. The JavaScript code that runs in the context of a web browser with the help of a library such as React, provides a learning laboratory for CS students and prepares them for future multi-paradigm challenges. A functional programming library such as Ramda can add a great deal of functional look and feel to showcase algorithm design in a more declarative and functional way. Ramda is suitable for demonstrating side-effect free algorithm design with pure and curried functions.

JavaScript can be a good tool for learning and teaching the ideas of functional programming. Once the teaching of the language constructs is combined with teaching practices that are not only motivating, but also conceptually rewarding, we may be able to hit the sweet spot of designing learning solutions.

If JavaScript were taught along with libraries, such as React and Ramda, this might help the students to grasp the skills required by employers and make the learning curve for functional programming easier. The React library is considered moderately easy and therefore may be suitable for teaching [17]. Both libraries promote side-effect free style for writing software.

3.3 Method and research instruments

The WebDev1 course will be developed in iteration cycles twice a year. The development started in 2019 [18]; in 2020, it was continued by the introduction of new autograders mainly for static code analysis. Cyclic development with reflective redesign phases is characteristic of design-based research (DBR) [19] [20] [21]. DBR mandates a guiding background theory, and this study leans of the previous findings of flipped learning in the course arrangements [22–24]. On FP, we looked back to research reporting on courses that applied FP principles.

In DBR, educational solutions are combined with the empirical interventions and proof: DBR systematizes course development cycle of *design, development, enactment, and analysis* [25–27]. Here the *cycle* represents a course term. The retrospective analysis inserts requirements into the design of the next implementation [28–30]. The redesign implies *'reflective conversation with the situation'* [31], whereby course personnel observes the effects of new arrangements and refines them if necessary.

At the start of the course, the prior knowledge of students was captured using a pre-questionnaire. The questionnaire consisted of 20 Likert-scale questions followed by three open-ended questions about programming experience and knowledge. The Likert-scale questions corresponded with the topics of each exercise round, complemented with some additional transversal skills in functional programming. The three open-ended questions were:

- My programming experience in years.
- Programming languages that I know.
- Programming paradigms I am aware of.

Each exercise round was completed with a similar questionnaire collecting students' open questions, and difficulties with the taught topics.

4 RESULTS AND DISCUSSION

4.1 Students' awareness of programming paradigms

The data for RQ1 'Which programming paradigms were students aware of before the FP intervention of WebDev1 course?' was collected as a part of the pre-questionnaire. The mentioned programming paradigms are presented in Table 1. Students could list any number of paradigms they were aware of. 'Being aware' may have been too vague an expression. Some students listed as much as nine paradigms, it can be assumed that at least a few of them interpreted the purpose to be to list all the paradigms they had even some familiarity with. On the other end of the spectrum, 36 students left the question empty, and additional 12 students answered with a variant of ‘I do not know any paradigms’. Some students mixed programming languages with programming paradigms. When looking at this data, it should be kept in mind that the number of programming paradigms that exist is not a universally-agreed upon quantity. For example, procedural programming is a form of imperative programming, and there is an overlap between logical programming and declarative programming.

Paradigm	Mentions (n)	Paradigm	Mentions (n)
Object-oriented	162	Functional	114
Procedural	47	Imperative	34
Declarative	22	Event-based	10
Logical	8	Structured	6
Data-driven	2	Reactive	1

Table 1: Mentioned programming paradigms

As expected, the object-oriented paradigm was the most well-known, being mentioned by 162 students: first programming courses in Tampere University use object-oriented programming languages. In contrast, the imperative programming paradigm got only 34 mentions, even if the object-oriented paradigm can be categorized as an imperative paradigm.

Surprisingly, the functional paradigm got second-most mentions, with 114 students stating they are aware of it. This was unexpected, as there had not been any functional programming courses in their curriculum. Functional languages multi-paradigm languages popularity both in- and outside academia could be one valid explanation, with possible contribution by JavaScript. Functional paradigm may be grouped under declarative paradigms, which itself got 22 mentions.

4.2 Experienced difficulty levels of exercise topics

Students’ answers to questionnaires in each exercise round about the experienced difficulty of the topics discussed used a range from difficult(1) to easy(5). The number of respondents dropped towards the end. The first topic in the first exercise round questionnaire (Git) received submissions from 227 students, while the last topic in the last questionnaire (Error handling) received 110. There is a noticeable drop in the number of students filling questionnaires when exercise rounds moved from ninth data persistence exercise round to the tenth which handled MVC and code quality.

Among topics that students felt were the easiest are Git version control (154 viewing the topic as easy or somewhat easy [67.8%, n=227]), JavaScript’s events (125 [61%, n=205]), JSON file and data format (105 [57%, n=184]) and LocalStorage API used for data persistence in the browser(87 [55%, n=157]). These topics come from different exercise rounds, so the relative ease students felt with the subject matter is not explained by the one or two exercise rounds having a familiar subject matter. While many of the students studied will have encountered Git and JSON in their earlier courses, JavaScript events or LocalStorage API were not taught in any earlier course in Tampere University.

The most difficult general topics included the REST architecture (76 students regarded the topic difficult/somewhat difficult [36%, n=209]), spread operator (72 [39%n=186]), CORS (63 [36%, n=174]), sessions and streams (91 [52%, n=175]). Among asynchronous JavaScript topics especially difficult were Promises (83 [47%, n=177]) and async/await (88 [49%, n=178]). These two asynchronous topics are so fundamental, that they can be seen as threshold concepts.

Looking at students' difficulties with FP topics relatively most difficult topics were perceived to be: the requirement for function calls to have no side effects (86 students reporting the topic was difficult or somewhat difficult [36%, n=180]) and the closely related immutability of the object's state data (73 [40%, n=183]). Other difficult FP topics were functors/monads (48 [43%, n=112]), railway oriented-programming (46 [41%, n=111]), and higher-order functions (40 [36%, n=112]).

These terms are part of the knowledge students will require to understand and apply functional programming in problem solving in the future. That these topics were harder to grasp comes as no surprise, if we keep in mind that the curriculum is such that they will take functional programming courses during the next years of their studies.

These answers can be viewed in the context of students' answers to the pre-questionnaire where 114 students reported being aware of FP. In the same questionnaire the reportedly difficult FP topics are at the same time central to the paradigm. This can be interpreted to mean that students aware of FP, but were not introduced to FP in the previous courses. The gentle FP primer offered as part of this course was then well placed to find an audience that was already aware of the paradigm.

4.3 Peer tutoring and scaffolding

Help seeking during the course was enabled using Teams channels where students could ask and answer questions. 240 students participated in the discussions, 15 received extra points ranging from 2 to 5 for being active on the channels. Overall, the activity points correlated with higher course grades, as all but one of the 15 students received grade 3 or higher. As these students had answered questions in the channels, the channels provided peer-tutoring from more knowledgeable others [32] in complement to scaffold by the course personnel.

The opportunity for earning the extra activity points was made known to students at the start of the course. Pursuing those extra points might have been a part of what motivated the active students, but still their efforts enabled other students receive competent and timely help. If this would have happened without the extra activity points, is up to debate.

5 CONCLUSIONS

RQ1: Which programming paradigms were students aware of before the FP intervention of WebDev1 course? Several paradigms were mentioned, most frequently object-oriented and functional paradigms. Students' answers, however, revealed that many did not fully understand what a programming paradigm is. This can be seen as a product of the code-first approach in the earlier courses. Students can design and implement code without identifying the underlying paradigms and their pros and cons. The introduction of prominent paradigms would give them a basic structure for understanding and classifying programming languages.

RQ2: Which JavaScript topics, and in particular which FP concepts, were students struggling with? Asynchronous features of JavaScript, using Promises and async/await, were the most difficult topics, and encountering JavaScript concurrency model for the first time during this course added to the difficulty. Asynchronous features are extensively used in modern web development, thus their perception is of pivotal importance. Compared with async, FP was considered easier: FP topics were reported being difficult or only somewhat difficult. The difficult topics included, among others, no side-effects, and immutability.

RQ3: What could the course personnel do to make those FP concepts easier to grasp? The student feedback suggested that the course personnel should create more concrete examples covering both lecture slides and hands-on videos. Videos should be short and to-the-point, and material and attached exercises should flow in sync. From students' feedback we could also read that very abstract concepts, such as the ones borrowed from mathematics, should be properly primed and explained. These concepts comprise, e.g., higher-order functions and functions as first-class citizens. Using JavaScript libraries such as Underscore.js, Ramda and Lodash could be used for making understanding these concepts easier to see and implement at code level while using functional programming.

6 FURTHER STUDIES

The results direct the improvements of the course in the next DBR cycle, the main result being a call for a more concrete FP approach: examples and hands-on videos could be elevated with visualizations to demonstrate FP and async principles that were ranked the most challenging topic. The right rhythm of videos and exercises may be found with the help of flipped learning research.

Data collected by Learning management system XYZ and GitLab is massive and would provide material for learning analytics; the results should be accessible for both teachers and students. Students could be keen on performance comparisons, though this might induce unnecessary competition. Comparing students' performance with their own earlier performance is safer. Current Learning management system XYZ graders check code quality and conventions. In addition, a grader visualizing the learning process would be handy in improving students' consciousness of their strengths and weaknesses, preferably with suggestions of exercises to fill the gaps. The anticipated grader is called a self-reflection grader.

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CHALLENGE EPISODES AND COPING STRATEGIES IN UNDERGRADUATE ENGINEERING RESEARCH

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ABSTRACT

Higher education institutions are increasingly placing importance on engaging undergraduate students in genuine research, known as undergraduate research experiences (UREs). While the professional and personal benefits that result from UREs have been theorized and researched, the potential challenges students experience when engaging in genuine research remain relatively underexplored. Drawing on a sociocultural understanding of learning, this paper details challenge episodes and coping strategies that engineering students at master level reported while carrying out a research project in biomedical engineering. Data consisted of reflective writing collected at the beginning, middle, and end of the research project.

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A thematic analysis of the data led to the identification of three overarching areas of challenges: (1) organizing, planning, and executing tasks; (2) managing the group and its members; and (3) receiving support from the teachers. We find that while groups often experienced similar challenges, the coping strategies they employed differed and were influenced by the groups' disciplinary composition and the students' previous project experiences. We nuance the discourse around the role of challenges in UREs by making the distinction between "desirable challenges" and "undesirable challenges", and we draw out implications for teachers wishing to involve students in realistic research.

1 INTRODUCTION

Across the globe, higher education institutions are increasingly experimenting with approaches for involving undergraduate students in realistic research, known as undergraduate research experiences (UREs). This surge of interest in UREs is also reflected in the rapidly growing body of research on UREs. The bulk of that research has relied on quantitative methodologies and focused on the professional and personal benefits of UREs [1]. While such studies can provide important insights, they tell us little to nothing about how students navigate their way through UREs, or how students experience being involved in realistic research [1]. Additionally, a quick perusal of three recent systematic reviews of research on UREs [2,3,4] reveals that there is a conspicuous lack of studies attending to the potential *challenges* that students experience while navigating their way through UREs — even though it is widely recognized that cognitive, affective, and social challenges have a significant impact on learning [5].

To redress this knowledge gap in the literature on UREs, this paper reports on a qualitative case study [6] driven by two research questions:

- What challenges do students experience during UREs?
- What coping strategies do students use in response to those challenges?

In examining these questions, we take our theoretical cue from the concept of "situated learning" in "communities of practice" [7], which emphasizes the importance of context — both social and material — for understanding how people learn to become members of a community of practice. Using this theoretical lens to study UREs means attending to how students engage in genuine scientific practices in a real laboratory environment, while interacting with experienced scientists as mentors and other students.

2 STUDY SETTING AND DESIGN

2.1 Empirical setting

The program this study is based on was designed to give undergraduate students an opportunity to participate in genuine research, for which they received payment. There were 14 participants, all of whom were about to begin their fourth year of a five-year master's program. Of the 14 participants, ten were female and four were male, and they came from a variety of different engineering disciplines. They were divided into four groups, with each group containing one male student. While only some groups were interdisciplinary, each project was designed to be interdisciplinary. The students were expected to work an average of 40 hours per week and each group had one to two scheduled weekly contact hours with their teachers. Each group were assigned their own project, all of which were actual research projects rather than projects with a course-based design. To give an example, one project was on the development of a gel to be used in the testing of medical applications of microwaves for cancer treatment. The students were given a list of criteria that the gel needed to fulfil. The project combined two disciplines: electrical engineering and chemistry.

To ensure the groups had a basic toolbox of skills to allow them to begin the project, one of two approaches was taken for each group. For some their project was based on their group bachelor's project, but at a higher level that took it further in a theoretical sense. The other groups were brought into the labs, trained on the relevant tools and theory, and worked on the same or similar research questions that they would work on in the project.

2.2 Data collection and analysis

As we sought to contextualize the groups' experiences, a qualitative case study design was deemed to be appropriate [6]. The project ran over eight weeks, each participant completed between four and five weeks, and not all participants worked full time on the project. This set up saw the participants finish at different times, which affected the data collection as some had finished before the final wave of collections. Said data was collected in the form or reflective writing, and the collections waves were in the initial stage (one or two weeks in), the middle stage (four to six weeks in), and the final stage (on the last week). Each wave consisted of between one and three questions addressing the participants' experiences and perceptions of the URE during the different phases. Eleven participants responded with their reflective writings in the first wave, three in the second wave, and seven responded in the final wave.

The data was analysed through inductive coding [8] identifying salient challenge episodes and their corresponding coping strategies. In a second step, the identified challenge episodes were grouped into larger themes based on their proximity.

3 FINDINGS

Three overarching themes of challenges were identified: (1) organizing, planning, and executing tasks; (2) managing the group and its members; and (3) receiving support from the teachers. This section describes challenge episodes within each theme and their corresponding coping strategies.

3.1 Organizing, planning, and executing tasks

The project required the students to plan and organise their own work, which raised several challenges. In the initial stages, *the project's unstructured nature* was a common challenge expressed by the groups. Some of those — but not all — felt that their issues stemmed from a lack of instruction. The coping strategies to face the lack of structure varied, from those that did not begin any work until they received what they felt were better instructions, to those that decided to work in the same vein as they had for their Bachelors project. Other solution strategies consisted of attempting to gain knowledge from examining previous data that was available to them, and simply making decisions under uncertainty on what tasks to perform, despite the lack of the scaffolding or structure they were used to.

Another challenge, *planning project work,* means having to decide which tasks to prioritize and which direction to take. A common strategy utilised by the groups for this was trial and error: they would try something, analyse the results, apply changes they think would lead to improvements and try again, or if needed they would change direction entirely. For one group this challenge led to the emergence of a de-facto leader who appeared to have naturally fit the role and who added structure. This same group would also allow for members to take on the role of an expert when tasks were in their area of study. In these instances, we were told that despite their expert status, the whole group would have to agree before making decisions. It is not known if this joint decision making also applied to the de facto leader.

The length of the project was also listed as a challenge as it was longer than any of the students' previous projects. However, no specific coping strategy for it was mentioned; they simply continued to work and seemed to adapt or became accustomed to it.

Further, the groups faced the challenge of *processing results*. Results needed to be analysed, conclusions drawn, and the reasons for wrong or unexpected results identified. Results could cause a change in strategy or the direction of a group's work. The groups predominantly used cooperative activities as a coping strategy for this challenge, working together to analyse results and try to identify potential improvements. The sharing of results among all group members was recognised as important, especially when obtained by a single individual or a sub-group working on a task. Group discussions were another cooperative activity used as a coping strategy for this challenge. The discussion of and sharing of results was not limited to individual groups as at least one group reported that they shared and discussed results with their teacher. Another strategy employed was the application of previous knowledge and knowledge gained from relevant research papers when analysing results to identify what would have a positive effect in future tasks.

Performing new or unfamiliar tasks was another listed challenge. One group's coping strategy was to seek out and read relevant literature on the topic. They remarked that the knowledge they gained from this coping strategy also proved useful later in the project. Some groups assigned tasks to individual participants and interdisciplinary groups would try to ensure said tasks fell within a participant's knowledge or discipline. This was not always possible, particularly in more homogeneous groups. For these participants, the only solution was for them to learn how to perform the task with the group providing support and help if needed.

An individual *becoming mired in a task*, which includes obtaining unexpected or unexplainable results, was a challenge some faced, regardless of whether it was in their discipline or not. The strategies employed were similar to those for previous challenges: the individual would present the issue to the group, and together they would try to provide help.

Further, *conducting academic tasks* — such as forming hypothesis, developing ideas, and being innovative — was reported as a challenge. Once again, the coping strategies were cooperative in nature as groups would hold brainstorming sessions and group discussions, where they would try to form hypothesis, ideas, plans, perform analyses and share ideas and thoughts.

The final challenge that was mentioned in this theme was when groups received *late task descriptions, goals, or last-minute project changes*. No specific coping strategies were provided; it appears that the groups simply worked to complete said goals and tasks.

3.2 Managing the group and its members

As mentioned previously, the groups had to organise and plan their own work, which led to the challenge of *assigning work within groups*. Groups would employ one of two coping strategies. The first strategy was to work on tasks together when physically possible, and if a group member had expertise or experience in the subject area then they would lead the group. The second strategy was to assign tasks to individuals or sub-groups. Groups tried to ensure that participants would be assigned tasks within their area of expertise or experience when possible. Interdisciplinary groups appeared to have an advantage over more homogeneous groups for both coping strategies.

Dealing with task dependencies, where groups were unable to proceed as planned due to unforeseen circumstances, was another challenge. Examples include delays in receiving vital data or being unable to begin a task until another was completed. These events were beyond students' control as they could not influence the person or task they were waiting on. Thus, they had no way of applying coping strategies directly to ease these bottlenecks. Instead, they often ensured the time spent waiting was not wasted by reading relevant articles about their task or identifying and performing other tasks.

While participants in interdisciplinary groups were positive of their experiences, such groups would sometimes experience knowledge gaps which arose when reviewing literature, or performing a task, or analyse results that were outside of some members' discipline. The challenge then was *addressing knowledge gaps within the group*. One coping strategy was knowledge sharing, where one member would take on the role of an expert and explain concepts or material to the rest of the group. Another strategy was the use of cooperative activities, such as discussions, and the sharing of ideas or experiences. These coping strategies allowed group members to contribute with their own unique knowledge and skills, an experience they found fulfilling.

While most groups reported positive interactions and good social cohesion, one group reported negative interactions which led to *poor cohesion within the group*. These issues were due to the actions and attitude of one group member that worked independently off campus, did not coordinate with the others on task allocation, and communication was either negative or non-existent. As a result, the rest of the group did not know what work that member was doing or how the work was progressing. Ultimately this member left the project before its conclusion and failed to provide work or documentation of his/her work to the other members. Thus, *dealing with a negative member* was a challenge unique to this group. The group did not list any coping strategies employed to remedy the situation. Instead, they worked closely together as a separate group on campus, and after the troublesome member left the project, they worked to complete the outstanding tasks that remained.

3.3 Receiving support from the teachers

While participants generally praised the support provided by the teachers as the project progressed, several felt dissatisfied with the level of support and instruction provided to them at the beginning of the project. The perceived challenge then was *dealing with instructions that were unclear, few, non-existent, or late*. Various coping strategies were employed by different groups. One strategy was to learn more by questioning the teachers, with one group reporting that they did not begin any work until they received instructions that they considered adequate. Other groups were less specific about their strategies, with one group reporting that they did not start working until things became clearer, and another group simply reported that they "figured out" what they needed to do. Some groups did not provide any specific coping strategy that they employed for this challenge.

The project was run over the summer period, which resulted in limited access to teachers due to summer vacation. This, coupled with changes in the campus environment due to the Covid-19 pandemic, meant that groups were often unable to physically meet with their teachers. Adapting to this *lack of physical contact with teachers* was a challenge for the groups. A common coping strategy employed by the groups was to email their teachers. One group did mention having meaningful conversations with their teacher but did not specify if these conversations were in person or digitally, for example a phone call or Zoom. *Limited communication* between groups and teachers brought other issues to the fore; for example, when a group had more than one teacher for their project, who should they direct task specific questions to? Sometimes teachers would respond late or would reply that the group had asked the wrong person. One group employed the following coping strategy for these challenges: they would email as many people as possible that they think may know the correct answer to ensure a quicker reply. If possible, they would attempt to call teachers for an even faster response.

Another issue that arose was when a group received *conflicting facts or answers from different teachers* on the same topic or question. No coping strategy was provided for this issue, but the group reported that teachers tried to answer questions quickly, so we can speculate that their strategy may have been to send more emails to clarify previous answers. A particular issue highlighted by one student was knowing what questions to ask to ensure they received the information needed. As time progressed the student learned how to pose questions using previous experiences.

4 DISCUSSION AND CONCLUSIONS

This study set out to identify challenges students experience during UREs and the coping strategies they mobilise in the face of those challenges. In the remainder of this paper, we will discuss some of our most significant findings against the backdrop of prior work in the area and their implications for instructional design of UREs.

The first theme of challenges revolves around organizing, planning, and executing tasks. As suggested here and by others [9], students partaking in UREs tend to expect scientific research to be like their previous lab work and projects, with clear guidance and predictable outcomes. These expectations are inconsistent with the messy and iterative nature of doing research, resulting in the expressed challenges. Even though those challenges caused considerable frustration for some of the students, most students were able to develop effective collaborative coping strategies, leading to progress and learning.

The challenges allocated to the second theme relate to internal group interactions, project management, as well as knowledge gaps within the group. This theme is significant since the ability to work in groups has been signposted as a critical aspect of successful UREs [10]. Our findings reveal that coping strategies are largely based on students' previous project experiences, as well as groups' disciplinary make up. Members of interdisciplinary groups could in many cases contribute with their specific content knowledge, either in the role of an expert to share their specialised knowledge, group leader on a task, or specialist completing the task as an individual. This appears to have given interdisciplinary groups an advantage over more homogeneous groups that had to compensate for the lack of expert knowledge by reading articles and taking part in cooperative activities such as group discussions. Consequently, interdisciplinary groups were better equipped to develop coping strategies, which might be connected to the interdisciplinary nature of the projects. These findings suggest that (1) students partaking in UREs can benefit from relevant training in group work or project management prior to or as part of the UREs [10], and that (2) it is important to pay close attention to group composition.

Challenges allocated to the final theme relates to interactions between groups and teachers, including scaffolding, support, instructions, and communication. Students partaking in the URE viewed the teachers as a valuable source of information and guidance. This finding is consistent with prior research on UREs, stressing the importance of teachers as mentors, discussions between students and teachers, and scaffolding if needed [2,10]. The challenges in this theme were caused or exasperated by three factors: (1) the unstructured and open-ended nature of UREs, (2) the fact that the project ran during the summer when there was limited access to teachers due to summer vacation, and (3) that the project coincided with the pandemic, resulting in restricted campus access for both staff and students. Despite some contextual factors beyond the teachers' control, a lack of presence and interaction between teachers and students seemed to create significant challenges, such as late instructions, lack of physical contact with teachers in the labs, and difficulties to establish communication with teachers when needed. At the same time, we also find that students developed valuable coping strategies in dealing with those challenges, such as learning how to correctly formulate a question, finding out who to ask said question, and working with what they might consider few or unclear initial instructions. These findings suggest that teachers in UREs should ensure that there is an adequate support structure available, and that instructions are clear, adequate, and delivered in a timely manner. Teachers also need to ensure that their students have access to expert performances to build a research identity as part of a community of practice [7,11].

Taken together, our findings point towards an understanding of challenges as a *double-edged sword*. That is, challenges are not inherently good or inherently bad in terms of learning. To nuance the discourse around the role of challenges in UREs, and engineering education more generally, we find it useful to borrow from the concept of "desirable difficulties" [12] and make the distinction between "desirable challenges" and "undesirable challenges". In terms of implications for teachers, we argue that teachers should strive to find the right amount and type of "desirable challenges" — together with support for appropriate coping strategies — while avoiding "undesirable challenges" resulting in a lack of progress, a loss of motivation, or inefficient use of resources (e.g. time). To be able to find this balance, future research on UREs would do well to suggest ways to better connect the research experiences to the students' prior experiences and beliefs, an argument that was brought forward in similar form by Linn et al. [2]. In the presented study, the overwhelming majority of students were overall very positive and enthusiastic about their experience of participating in the URE, despite - or because of - being confronted with the challenges of doing "real" research. Thus, we strongly encourage teachers and universities to offer UREs as part of their portfolio.

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PEER ASSESSMENT TO IMPROVE REPRODUCIBILITY OF COMPUTATIONAL PROJECT WORK

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ABSTRACT

Computational research requires increased reproducibility for open science practices yet is not widely taught in the geosciences. Teaching reproducibility and establishing it as learning qualification and objective is an important step towards improving scientific practice and will also improve student learning by facilitating peer-review and reuse of earlier work in later courses. It will also improve the formal (summative and formative) assessment of student project work within a course, and the quality of reusable open educational resources. There is evidence in the literature that teaching reproducibility should combine practice (tutorials) trying to reproduce someone else's work, and iterations of teacher and peer feedback on the reproducibility of one's own work.

In this contribution, reproducibility was introduced as a new topic in a 15 EC MSc course, which follows a challenge-based learning approach to tackle the wicked problem of different stakeholders facing human-induced earthquakes due to gas extraction. Students work in groups for different stakeholders. Self-regulated feedback is encouraged to include other stakeholders' views. After a tutorial at the end of the first half of the course, student groups submitted a reproducibility plan for their project work, which was then peer-reviewed by the other groups, so that any feedback could still be incorporated. The quality and depth of the peer feedback itself provided information on how well the topic has been understood. The outcomes show that the approach delivered encouraging results with respect to the previous year.

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1 INTRODUCTION

1.1 Motivation and objectives

This work is motivated by (1) the growth of study programs that address data science and computational science which require more algorithmic thinking and coding skills from students [1] and (2) the specific challenges and requirements of open and reproducible research which ask for new assessment approaches.

Reproducibility is commonly defined as the potential for a given study to be reproduced by an independent team of researchers. For example, a paper that uses a proprietary data set and only describes methods without details on parameters is not reproducible. In contrast, a study that uses open data, open-source software, and provides the full source code of the analysis workflow is highly reproducible.

Although reproducibility has always been an criterion for scientific research, several disciplines have seen a veritable reproducibility crisis: published studies and results were not reproducible with the provided information [2]. To improve the situation, we need to initiate a culture change already when teaching new scientists, and practice reproducibility as integral part of educational [3], including student assignments and project work. To be taught effectively, teaching materials need to be reproducible, reproducibility needs to be a learning objective that is assessed, and assessment itself needs to be reproducible and transparent. Since reproducibility depends on someone trying to reproduce someone else’s work, it promises to be well suited to peer assessment, i.e., students attempting to reproduce other student’s work and providing feedback on what worked and what did not. Peer assessment as part of peer learning has been shown to be effective for academic teaching [4], [5].

This paper describes an intervention in the context of a Senior University Teaching Qualification [6] during the MSc program Spatial Engineering (M-SE) at the University of Twente. M-SE follows principles of challenge-based learning (CBL) during three case studies of 15 EC each, which are scheduled during the first three academic quarters of the first year. They address so-called wicked problems [7], which have no clear ideal solution, but instead either several sub-optimal solutions, or even none. Since the case studies also require interdisciplinary group work, concern real-word cases, and involve multiple stakeholders, they qualify as CBL.

The intervention took place during the third case study with a cohort of 23 MSc students. For the third case study course, reproducibility is especially important for two reasons: First, M-SE assessment is focused on the process instead of outcomes, because for wicked problems no single best solution exists. To assess the process, an examiner needs to be able to reproduce it. Second, the course’s main theme is legitimacy, because the case study setting is the gas extraction and resulting earthquakes in the Groningen province of the Netherlands, where years of mismanagement have dramatically reduced the trust of the various stakeholders in solutions proposed by the government or any other official authority. To re-establish trust and legitimacy, the analysis process leading to proposed policy interventions needs transparency. Thus, the first reason is linked with the teaching and learning process and the second to course content and final qualifications.

The reproducibility of students' final reports of previous years was very low, meaning that anyone reading the reports cannot reproduce the analysis they conducted, because insufficient code or data was provided. This is not surprising for two reasons: M-SE students have diverse backgrounds and often only limited code literacy at the beginning of the course; and academic skills teaching focuses on preventing plagiarism, creating a tension with reproducible code reuse and sharing.

The goal of this work was to increase (1) the students' awareness of reproducibility, (2) their knowledge about different aspects of reproducibility (e.g., data, methods, results), and (3) skills to make their own work more reproducible. This should be reflected in increased (compared with previous years) reproducibility of the students' final reports. Further, this work provides valuable information on how and when to include reproducibility in a curriculum by answering the following questions:

1. Was the designed method, and in particular peer- and self-assessment, effective in increasing reproducibility of outcomes?

2. How do the students experience and evaluate the activities, especially the peer- and self-assessment?

3. In what way can the designed method be improved?

The first two questions will be addressed mainly in the results section, while the last question will be addressed in the discussion and reflection section.

1.2 Reproducibility in education

Although technical tools to document and assess student progress on code and project materials exist, their use within an electronic learning environment faces several challenges [8]. Early attempts included protocols for data management and analysis [9], but even more recent approaches in geoscience education [10] do not explicitly address reproducibility within the classroom, but rather that of scientific studies themselves [11], [12].There is evidence in the literature that reproducibility is best taught by letting students take both perspectives: that of a researcher who has to design and implement his or her work reproducibly, and that of a researcher or practitioner who wants to use or validate someone else's work and reproduce it. Teaching reproducibility therefore should rely on a combination of practice (tutorials) trying to reproduce someone else's work, and iterations of teacher and peer feedback on the reproducibility of one's own work [13], [14].

A research group on reproducibility in the geosciences has developed a rubric to assess the reproducibility of research [2] as part of on-going efforts to increase reproducibility, which have led to a funded initiative to create improved author guidelines and article peer reviews for a major geoscience conference series [15]. The outcomes have provided valuable input to the presented work.

2 METHODOLOGY

2.1 Intervention design and data

The target course runs for 10 weeks full-time (15 ECTS). It focuses on human-induced earthquakes and starts with an introductory week during which students form groups and choose a stakeholder (e.g., citizens, municipality, mining company) to represent. Week 10 is reserved for examination, leaving weeks 2-9 for student groups to design an intervention (planning, policy) that addresses the needs of their stakeholder, while acknowledging the interests of the other stakeholders. The intervention needs support from quantitative data and analysis, but also includes document studies and qualitative (interview) data and is presented by each group in a scientific report and supplementary materials, which make up 25% of the course assessment.

As mentioned, reproducibility issues can be experienced from two viewpoints: The creator of a study who needs to invest efforts to make it reproducible, and the reader who attempts the re-production. Further, literature supports the assumption that practical exercises and peer-assessment are suitable for teaching reproducibility. The intervention design takes this into account and follows four stages with new elements to the course (see Figure 1 below for the entire workflow and theory of action components):

1. Introductory information on the role of reproducibility for learning and assessment.

2. A face-to-face tutorial, consisting of four parts. First, a short lecture providing basic information, followed by two hands-on exercises to experience different viewpoints on reproducibility: assessing the reproducibility of paper, and attempting to reproduce a short mock paper with given code and data. The tutorial concluded with information about simple strategies and tools from the perspective of authors to make the scientific reports more reproducible. Further material was available on the electronic learning environment for additional self-study.

3. The self- and peer-assessment consisted of designing and assessing a reproducibility plan (RP) using a predefined template (see supplementary materials). For peer-feedback to be meaningful, students need to be able to act on it [4], which precluded peer-assessment of the final reports. Instead, all student groups had to submit the RP two days after the tutorial. In the RP, they self-assessed the current reproducibility of their project (data sources, computational workflow, outputs), then described and justified the target reproducibility, and explained the necessary measures to achieve this improvement. The RP was then peer-assessed by the other groups and reviewed by the teacher. The quality and depth of the peer feedback itself provided information on how well the topic has been understood. The feedback was formative instead of summative because the latter can lead to negative side effects and perceived disadvantages [16]–[18].

4. For the remainder of the course, the groups implemented their plans and the given feedback. They were encouraged to stay in contact with the other groups

and exchange experiences and feedback, because they all had different stakeholders to represent, yet needed to consider the viewpoints of other stakeholders as well.

The intervention used three primary data sources: First, the main data source was the scientific reports from the 2018/19 and 2019/20 academic years, with the former serving as control group. I have read and evaluated every report (in total four from 2018/19 and five from 2019/20) using the reproducibility scale developed by [2]. The reproducibility plans and the peer-feedback provided by students were the second data source, together with the final reports' reproducibility assessment addressing the first research question. The third data source was the course evaluation during and after the course, which included specific questions on reproducibility and thus provides valuable feedback to address research questions 2 and 3.

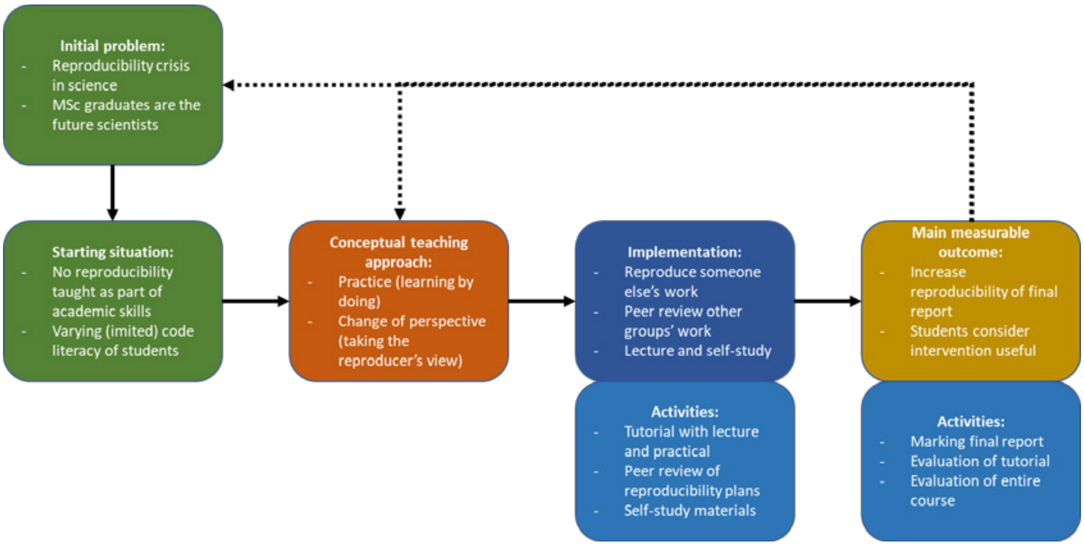

Figure 1: Conceptual workflow developing and designing the intervention; the dotted arrow indicates a feedback loop for the current (2020/21) course

2.2 Implementation

The first introduction to the intervention was part of the general course introduction (including assignments) on the first day of the course. A reminder and more detail was given during a tutoring session in the second week.

The main face-to-face activity was a tutorial at the beginning of week 6. While this was relatively late in the process, the students have to face many organizational challenges in the start-up phase, and if taught too early, a 'minor' issue like reproducibility might "go under".

The execution of the tutorial was heavily impacted by the Covid-19-related short-notice closure of the university buildings, and the decision of the university management to halt all teaching activities during that week. Since no information was provided what this imposed educational lockdown meant for the remainder of the academic calendar nor for the assessments, this was a very difficult situation. The tutorial was declared as "experimental teaching", preparing students for future online education, and several adjustments had to be made for online teaching. Overall attendance was very high (18 out of 23 enrolled students), with participants from every group present.

Four of the five groups submitted the RP and its peer-assessment and received further feedback from the teacher. Once the groups reports were submitted, I graded those, with feedback on reproducibility being part of the overall feedback.

The first evaluation of the implementation process took place right after the tutorial (please see supplementary materials), which 10 out of the 18 students completed. After the completion of the entire course, students could provide individual detailed feedback during a second evaluation, during which 13 students answered (see Results section).

3 RESULTS

3.1 Reproducibility of the scientific reports

To address the first question on the measurable effect within the course, the reproducibility of the final deliverables (one scientific report per student group) from 2020 was compared to that of the previous year 2019.

To briefly summarize the approach to scoring reproducibility (for details see [2]): Reproducibility of research can be measured along three main dimensions: Input data, processing/analysis, and output. Each of these three dimensions can achieve one of four levels:

Unavailable (a score of 0 in the following tables) indicates that there was no information on where to retrieve the input, how the computations ran, and how the outputs were created. Normally, no peer-reviewed publication should receive such a score in any dimension.

Documented (a score of 1) indicates that there is no direct access to datasets, that executable code is unavailable or proprietary software was used, and results may be incomplete. In contrast to *Unavailable*, the descriptions and metadata are likely sufficient to recreate the study given enough time and resources.

Available (a score of 2) was assigned if direct access to the materials (data, code, full results) is provided (e.g., through a link to a personal or institutional website or in supplementary materials), but not in the form of an open and permanent identifier, such as a digital object identifier (DOI). The students were encouraged to submit all materials in a supplementary archive, with an online repository being an option.

The gold standard of *Open* access (score of 3) requires open and permanent access to all materials (e.g., through public online repositories with a DOI) and open licenses to allow use and extension. This level was not expected from student submissions.

The following Table 1 provides the reproducibility scores for data/processing/results and short teacher feedback to justify those scores.

Table 1. Reproducibility of scientific reports in 2019 (pre-intervention) and 2020 (post-intervention)

Student group	**2019**		**2020**	
	scores	**teacher assessment**	**scores**	**teacher assessment**
1	1/1/1	links to important input data provided (not clear if to all required), but otherwise not enough information to under-stand details of the analysis	0/0/1	No reproducibility plan handed in; report is practically irreproducible, too much information is missing
2	0/1/1	very little concrete information on data or computational environment	1/2/2	reproducibility plan is short and vague, but addresses all main items, showing some thought; final report has very little information on the input data, but extensive information on the analysis in several appendices
3	1/0/0	many links to data sources (again unclear if all), but very little information on processing and results	1/1/1	reproducibility plan is quite good, and even has more information that the final report, very little information on any aspect of the analysis
4	1/1/1	Overall reproducibility low, but group analysed in detail the reproducibility of other sources, so there is at least an understanding of the problem	2/1/2	good reproducibility plan with clear, achievable targets; final report tried to provide as much material as possible, also in appendices, data is available through links
5	NA	NA	1/1/1	detailed reproducibility plan, although the group scored existing situation too high; final report shows little concern for reproducibility

In summary, in 2019 no group scored higher than 1 (or *Documented*) on reproducibility dimensions. In (post-intervention) 2020, four of the five groups handed in a reproducibility report as requested, and although none of the scientific reports are fully reproducible (i.e., reaching a score of 2, or *Available*), there is a clear improvement over 2019. The only group that did not hand in a reproducibility report also scored the lowest on reproducibility. Of the other four groups, two groups achieved scores of 2 in some dimensions, but two groups also fell short of their ambitions and only achieved the minimum scores of 1.

One potential reason for low scores in 2020 is that groups did less quantitative or computational analysis than planned, and conceptual and qualitative work is more difficult to reproduce. The reasons for the deviation from the plans are not mentioned explicitly in the course evaluation, but there is evidence from the course evaluation that it is linked to the impact of Covid-19 (e.g., difficulties to share work and results).

3.2 Evaluation of intervention by students

To address the second research question on how the students evaluate the intervention and the different activities, the tutorial feedback right after the session provides valuable information and was mostly positive:

Table 2. Tutorial evaluation right after the course (number of responses, different totals per question are the result of not all students responding)

How useful did you find the …	Not useful	A bit useful	Quite useful	Very useful
introductory lecture on reproducibility?	0	2	5	3
first part of the exercise (reading the paper and scoring it)?	0	0	7	3
second part of the exercise (running example code)?	1	4	4	1
information on reproducibility strategies and recommendations?	0	1	4	5

Students also provided comments. The majority of those addressed the issue that they had very different backgrounds, and while some expressed the wish for more practical examples to try out, others struggled with the given examples in the time they had. More collaboration and possibly working in pairs is another suggestion. The following two example commentaries summarize most of the feedback:

"*Unfortunately, it's not easy to choose the proper exercises since we all come from different backgrounds and have different experiences related to the topic. Perhaps by guaranteeing time to work both individually and in small groups might help (where people can help each other and share knowledge). I understand that this might be much easier when sitting in the same room rather than with online sessions (but I guess it's just a matter of getting familiar with other platforms to share screens for example, etc.*)"

"*Giving a little more time to do exercise as many students have different speed and knowledge on how they work. (Applies both) Otherwise, it was a good learning experience. I learnt an entire new thing and its importance.* "

While the immediate evaluation after the tutorial points out the utility of the exercises, the later overall course evaluation rates the utility for the course a bit lower, while the utility for the entire curriculum is seen more positive. This reflects that the fact that many students did not seem to be able to reach the point in their project analysis where reproducibility would have become more important.

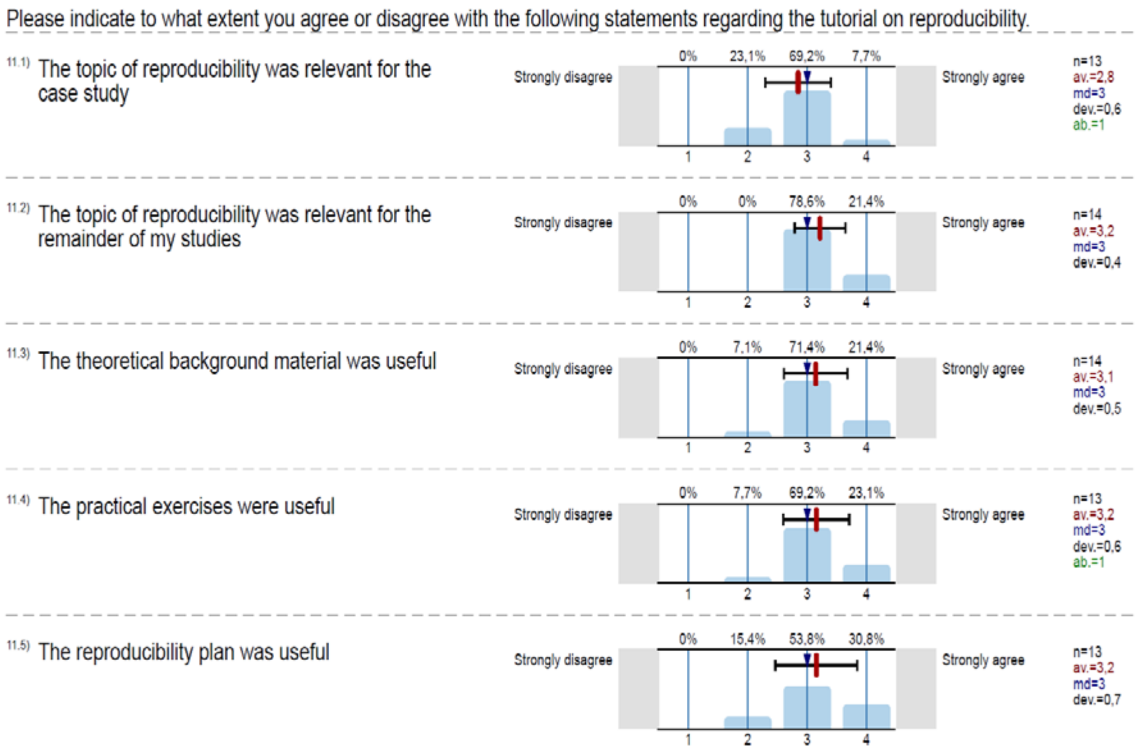

Fig. 2. Tutorial evaluation during the standard course evaluation

4 SUMMARY AND ACKNOWLEDGMENTS

The formative assessment of the reproducibility activities facilitated peer-feedback because it removed hesitations on the part of the students to criticize their peers and cause low marks for them. Most of the students had little to no experience with systematic peer-feedback and -assessment. Overall, working with student groups is easier than working with individual students (at least for larger classes). The tutorial also showed to be adaptable to full online teaching because it relied on working individually with someone else’s materials. Considering the short time frame that was available to change major parts of the intervention to full online (two working days for the tutorial), this transition went very well.

Regarding the question whether the designed method was effective in introducing reproducibility and significantly increase the students' reproducibility scores, the course evaluation and related discussion show that the impact of the Covid-19 makes it impossible to draw robust conclusions here. It affected the way of working massively in the middle of the course. Some student groups were able to deal with this more effectively than others. Most groups have better reproducible scientific reports than in the previous year, but not all, and the overall level is still not *Available*. The low level of computational spatial analysis in many of the scientific reports, for which the new materials would have been most applicable, might be a factor. Nevertheless, the results show that students found this new topic interesting. Even students with limited computational background reported raised awareness about the issue, and for them the intervention provided a lot of pointers to further information, new tools, and other learning opportunities. How many of these will be used in the long-term was outside the scope of this intervention, but I will examine the impact on the reproducibility of the students' MSc thesis reports in summer 2021.

Regarding the question how the students experienced and evaluated the activities, the clear majority found the course-based activities (i.e., the tutorial and the writing and peer-reviewing of the reproducibility plan) useful and considered it relevant for both the course and their further studies, and readily participated in the voluntary activities. This suggests sufficient reason to keep them in the course.

The last question addressed the issue in what way the designed method could be improved. Given that the topic is quite new to many students, feedback indicates that some more time for the teaching and self-assessment would be valuable. This would also mean to anchor the topic in the learning objectives and make sure to test it.

This academic year saw the repetition of the tutorial and reproducibility plan, making only very minor changes (e.g., correcting mistakes, adjusting the schedule to the different academic year) and improvements to content. The outcomes of this year will be presented at the conference and provide more evidence for robust statements about effectiveness and efficacy of the approach. Based on these insights, for the next academic year of 2021/22, plans are to expand the tutorial to two half-days, and introduce reproducibility clearly as a tested learning objective, and therefore make participation in the reproducibility plan and its peer-review mandatory. Further, I plan to coordinate and link the activities with further project proposals and activities on reproducibility in the University of Twente's open science community.

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NEED-BASED LEARNING: AN INTEGRATION OF JUST-IN-TIME-LEARNING, FLIPPED CLASSROOM AND GAMIFICATION IN A PROJECT-BASED LEARNING SETTING

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ABSTRACT

Engineering education must help learners develop analytical, communication, and teamwork skills, alongside independent learning, while meeting ever increasing content demands for solving engineering practice problems. Design problems, typically complex and lacking structure in nature, required an interdisciplinary approach, integrating multiple content domains. The currently most-favored pedagogical models for teaching design are problem-based learning (PBL) and project-based learning (PjBL), both of which are challenged when faced with multidisciplinary open problems, also known as wicked problems. To tackle wicked problems in an educational setting a combination of different pedagogical methods is necessary. This paper strives to create a pedagogical model to use while dealing with wicked problems in the specific education setting of a Master course in an Engineering programme. The behaviorism, cognitivism and situative learning

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paradigms are analyzed and related to the engineering learning peculiarities, which led to proposing Need-Based Learning (NBL). NBL is a pedagogical approach for teaching product design and development, which innovates by integrating Just-In-Time (JIT) Learning, flipped classroom and gamification in a PjBL setting. NBL includes six activities: challenge, select, acquire, apply, reflect, explain, and evaluate. A challenge is set by the lecturer, which becomes the background for all other course work. During the game phases, the students make a 'just-in-time' selection of knowledge to be acquired in the flipped classroom, applying this knowledge in the gamified project and reflecting on their choices and results. The lecturer then gives further feedback and makes the summative evaluation.

1 INTRODUCTION

Engineering education must help learners develop a complex skillset including analytic, communication, independent learning, and teamwork capabilities, while meeting ever increasing content demands for solving typical problems from the engineering practice [1]. Engineering learning and practice have three distinguishing characteristics [2]: (1) use of tools that help create representations (graphs, charts, visuals) to support the engineering work; (2) alignment with professional practices from the engineering community and to work as part of groups and teams; and (3) the emphasis on design, where design has its own unique ways of developing cognitive and situated skill requirements. Design is probably the most common kind of problem regularly solved by engineers, and is indeed widely considered to be one of the core or distinguishing engineering activites [3][4].

Design problems are typically the most complex and ill structured of all problems, and are solved through an iterative process of decision making and model building [1]. Real-world design settings are complex, multifaceted, ill-structured and interact with existing contextual elements [2]. Ill-structured and open problems, also known as wicked problems, normally require the integration of several content domains, that is, they are usually interdisciplinary in nature [1] [5].

The currently most-favored pedagogical models for teaching design are problem-based learning (PBL) and project-based learning (PjBL) [6]. Both are problem-focused, student-centered, self-directed, self-reflective, and require learning contexts that inspire the students' learning interests, encouraging them to actively participate and discuss [1] [5]. Design teaching and design project management teaching calls for PjBL that resembles the reality, and which normally relates to solving open problems and to the use of multidisciplinary approaches [5], which is a challenge for PjBL [7]. Multidisciplinary open problems require that the problem solver (in this case the students) has existing mental models related to each discipline, in addition to the mental models needed for working collaboratively and combining the disciplines [8]. So, the team members must identify and negotiate candidate approaches into a team strategy.

In this context, the identified problem is to define a pedagogical model that covers the content and thecomplex relations among its elements in a meaningful way, while resembling the engineering practice reality. Additionally, the students' knowledge level on the included and multiple disciplines cannot be assumed to be the same, which means the course must support each student in learn the disciplines starting at their level and, therefore, avoid the demotivation factor of learning material being too easy or difficult. Solving this problem is necessary to support the students creating the mental models that will help them in future design practice.

Considering this motivation, this concept paper proposes the Need-Based Learning (NBL) higher education pedagogical model for teaching product design and development (PDD), which innovates by combining JIT-Learning and gamification in a PjBL setting. The gamified project creates the scenario (set of specific tasks/problems) for the just-in-time pulling of learning content, where the students will learn as needed to perform the project.

2 THEORETICAL BACKGROUND

As mentioned before, engineering learning and working is characterized by use of supporting tools, taking part in the engineering practice community, working in groups and teams, and the emphasis on design [1] [2] [9]. When solving design problems, the future engineers must use mental models that include and integrate the content relating to: (1) the typical design and development process's phases; (2) the best practices covering the design and development process areas; (3) the different development models (i.e., waterfall, iterative and agile) that help organizing the design and development according to the specific aspects from the solution to be developed; (4) the specific techniques used by the diverse disciplines involved during a particular development; and (5) how all this content must be given relevance and meaning by being integrated during a design and development project. Therefore, defining the design and development approach to be used in a particular scenario is a multidisciplinary open problem, which can also be considered a wicked problem. These problems can have several possible solutions, and these problems' underlying uncertainty and ambiguity require critical thinking and creativity from the solvers [10].

2.1 Paradigms for learning

The three different theoretical orientations or paradigm for learning are behaviorism, cognitivism, and situative [11][2]. In a nutshell their focus is on WHAT and HOW associations among the knowledge elements exist, WHY these associations exist, and WHEN (in which situations) these associations can be used. Historically they have contributed to insights on how cognition and learning can influence educational practices [12]. While each perspective is valuable, they frame the "learning" and "transfer" of theoretical and practical issues in distinctive and complementary ways, where the former is the process by which knowledge is increased or modified, and the latter is the process of applying knowledge in new situations [12].

In behaviorism knowing is the acquisition/identification of cause-consequence associations, and learning is "conditioning", so that a response learned as an association to one stimulus generalizes/transfers more strongly to other similar stimuli [12]. The teacher gives clear and observable objectives for the student to follow; students are assessed by being able to repeat the taught procedures or repeat the content [11]. Student engagement is assumed to occur mainly in response to extrinsic motivations: rewards, punishments, and positive or negative incentives [12].

In cognitivism knowing is identifying structures of information and processes that allow recognition and construction of patterns for reasoning, problem solving, and use and understanding of languages. Understanding is an active process of construction rather than passive assimilation of information or rote memorization.

Transfer is based on acquiring an abstract mental representation/model that designates structural knowledge relations that are invariant across situations [12]. In the constructivism variant from cognitivism the learner is in control, and the mental models learned are a “construction” by the learner. As a result, each person has a slightly different model that is a combination of all of his or her past experiences and interpretations of the current situation. Problem-based learning often takes this form [11]. Student engagement is assumed to occur mainly in response to intrinsic motivations, so the emphasis is on figuring out ways to foster students’ natural tendencies to learn and understand [12].

In the situative paradigm, knowledge is distributed in the context which includes individuals, the tools, artifacts, and books that they use, and the communications and practices in which they participate. All actions and activities contribute to a larger objective, therefore learning becomes about understanding this objective and aligning collective actions with that [2]. Transfering knowledge requires that some constraints and/or affordances are invariant under the transformations that change the learning situation into the transfer situation. For transfer to occur, the learner must become aware of those invariants [12]. The teacher becomes a member in the community of practice or a stand-in for that community and is a facilitator of the learning process, while the students become increasingly skilled actors in the community of practice. Class activities and assessment include participation in authentic learning environments and solving typical/real problems from the community [11]. Motivation and engagement is based on the social engagement [12].

Some scholars advocate bridging these perspectives, particularly cognitive and situative [12][13], so it is possible to overcome the dichotomy between acquisition (learning is something we acquire, the cognitive perspective) and participation (learning is participating, the situative perspective) metaphors [2] [14]. Indeed, the choice of combining different perspectives can be supported by comparing to knowledge creation in the information theory, where a collection of data only becomes information if the relations among them is understood, and a collection of information becomes knowledge if the underlaying patterns are understood. In this sense, data acquisition resembles the behaviorism, and information and knowledge identification have a parallel to cognitive and situative, respectively. In this context, this work will combine aspects from both cognitive and situative, with emphasis in the situative.

2.2 Teaching strategies

The strategy of mixing methodologies in the classroom allows an inclusive class that embraces students diversity [15]. The situative learning paradigm advocates that different forms of knowledge emerge when different materials are involved, so learning is both impacted by the socio-material and the spatial-temporal dimensions of learning. Therefore, mediation by tools and engagement in activities (that include social interaction) are essential for learning and require understanding the interaction that has emerged over time through reciprocal roles played by actors [2].

In analyzing opportunities to learn in engineering education, learning contexts should be analyzed on how they allow participants to develop engineering-related identities and how they can support the development of positive engineering identities [2]. Consequently, in the case of multidisciplinary design it cannot be done without considering the repertoires of practice that the multiple disciplines' representatives bring to these social context.

Design has its own unique way of developing cognitive and situated skill requirements. It requires skills with materials, ability to work collaboratively, and the ability to become part of a community of practice [9]. Teaching strategies and guiding principles for situative instructional design include:

- Engage participation: students can become engaged and motivated in learning by participating in communities where learning is valued. Effective learning involves being strongly engaged in activities that captures the learner's interest because of their intrinsic qualities, as well as participating in communities [12].
- Create opportunities for active participation in the social and material practices of a target community: learning occurs when students interact with tools, people, and the physical world to develop an understanding of the affordances and constraints of culturally condoned tools and artifacts [11].
- Create a learning environment that allows learners to chart their own learning path: learning outcomes in a situated approach are not specified for each student in advance, rather the project/problem used to engage and embed the learning is rich and complex enough to support the exploration of multiple, self-determined learning pathways [11].

3 NEED-BASED PEDAGOGICAL MODEL

Pedagogical models are cognitive models or theoretical constructs derived from learning theory that enable the implementation of specific instructional and learning strategies. They are part of a broader teaching and learning model [16], where the pedagogical approach or model delivers the defined vision for learning by implementing certain teaching strategies. A visual representation of how the different elements interact is shown in figure 1.

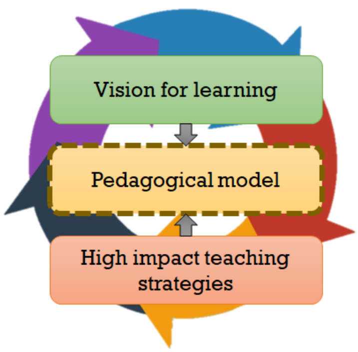

Figure 1. *Situating the pedagogical model in the teaching learning model.*

When looking at the learning paradigm and teaching strategies, as described in section 1 and 2, there are seven elements that can deducted form the literature, which should be considered when teaching engineering education, namely: (1) Ill structured/open/wicked problems; (2) multi/interdisciplinary content; (3) group/project setting; (4) different students' starting knowledge levels; (5) mental models' creation under open problems ambiguity; (6) cognitive learning aspects – patterns, intrinsic motivation; and (7) situative learning aspects – social engagement.

Taking these elements into account, the Need-Based Learning (NBL) model has been designed. As the name says, the objective is that the need for learning creted by a challenge, which pulls theother learning activities. Figure 2 shows and example of how the specific elements of the NBL model can be integrated into an engineering course for a master programme at the hosting university. The teaching strategies listed in figure 2 are a combination of teaching strategies frequenly used at the hosting university and deemed relevant to engineering education. Project-Based Learning, Just-in-time Learning and Flipped- classroom provide an opportunity for tackling all seven elements found to be important for engineering education. Gamification provides an additional opportunity to enhance student motivation, socialization and the introduction of new content in master courses of engineering education [17]. The pedagogical model includes six activities which are common to a design process, and form the backbone of the master course. The activities with blue background are led by the lecturer, and the activities with a gray background are mainly student driven and supported by gamification.

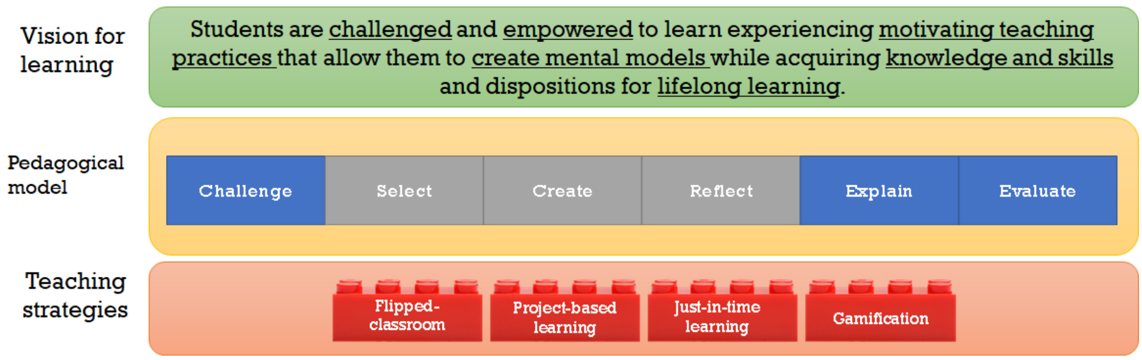

Figure2. *Need-Based Learning specific elements.*

How the **pedagogical model activities** (in bold) and the <u>teaching strategies</u> (underlined) are connected is explained as follows:

A **<u>challenge</u>** is set buy the lecturer, and which becomes the background for the game and to all other course activities. The course is based on a <u>gamified</u> <u>project</u>, where collaboration happens among project team members and competition across the teams, for the most effective design process. While going through the gamified project's phases, the students must **select** the knowledge to learn <u>'just-in-time'</u> <u>making use of</u> the <u>flipped classroom</u>. The phases are based on a typical design and development process [17] and include conceptual design, system design, detail design, final integration and production ramp-up. The teams strategize and **create** the process (by combining the selected knowledge about the diverse tools and techniques and product development best practices), which they will play in the phase. At the end of each phase, the students then **reflect** on the rationale behind the strategy they chose, the effectiveness of their choices, and what and why they would do differently in a similar future situation. The lecturer then gives feedback (**explain**) based on the reflection. The final activity is to **evaluate** the students' work. Summative assessment is based on the reflections' quality and not on the game results.

Course design under NBL requires first setting the challenge characteristics and creating a game which follows the challenge solving process. The supporting theory must be made available online using videos, articles, wiki pages, etc. This theory is the one necessary for playing the game/solving the challenge and can be accessed as needed. Technology support is only necessary for hosting the theoretical material and the game does not need to be based on software. As an example, Pereira Pessoa et al. [18] present also in this conference proceedings a card game created to be used in a NBL setting, where the compatible challenges are related to product design and development (PDD) and the game is based on the PDD process.

4 DISCUSSION

The NBL was analyzed against the previously identified relevant elements for engineering education, and their coverage by the NBL's activities are expressed in Table 1.

Table1. *Elements and Need-Based Learning' activities.*

	Challenge	Select	Create	Reflect	Explain	Evaluate
(1) Ill structured/open/wicked problems	x		x			
(2) multi/interdisciplinary content	x	x	x	x	x	
(3) group/project setting		x	x	x		
(4) different students' starting knowledge levels;		x				
(5) mental models' creation under open problems ambiguity		x	x	x	x	x
(6) cognitive learning aspects – patterns, intrinsic motivation	x	x	x	x		
(7) situative learning aspects – social engagement		x	x	x		

The pedagogical model's activities and the choice of teaching strategies were those that supported tackling the elements of NBL. By combining teaching strategies it allows attention to be paid to different types of students and their learning in the class. Since gamification is a methodology that is mixed with other pedagogical tools (project-based learning, flipped classroom, master class, problems, gamified learning, etc.), it accomodates students with diversebackgrounds [15]. The different NBL elements are addresses as following:

1) Ill structured/open/wicked problems: the problems are covered by the initial problem, and by the gamified project, which allows different valid approaches to handle the intrinsic game uncertainty.
2) multi/interdisciplinary content: the challenge poses the need of this content to be used during the game and is the base for the student's reflection and the lecturer feedback.
3) group/project setting: the gamified project is a group project.

4) different students' starting knowledge levels: the gamification setting, and the flipped classroom supports the students approaching the theoretical content according to their level and interests.
5) mental models' creation under open problems ambiguity: the gamification allows experimenting different choices, which further receive formative and summative feedback. The cycle from selecting->creating->reflecting->feedback supports the mental models' creation.
6) cognitive learning aspects – patterns, intrinsic motivation: motivation is based on the gamification setting, which brings a dynamic more in-line with the students' interests and based on bringing a reality-based challenge. Learning patterns takes place during the decision making in the gamified project phases.
   situative learning aspects – social engagement: once the challenge requires the expertise on multiple disciplines and the group project setting creates a community, the students learn from collaborating while solving one specific engineering design and development challenge.

5 SUMMARY AND ACKNOWLEDGMENTS

This concept paper shows the development of the Need-Based Learning (NBL) pedagogical model, with the motivation of overcoming the challenges for including the and making sense among the extensive multidisciplinary content required to teaching design and development in a project setting that resembles real problems. NBL integrates the cognitive and situative learning paradigms, and combines five pedagogical methods (challenge-based learning, gamification, flipped classroom, just-in-time learning and project-based learning) into six pedagogical activities. Three of these pedagogical activities (challenge, explain and evaluate) are led by the lecturer, and the other three (select, create and reflect) are student driven.

The NBL was empirically validated by cross-checking and reflecting on its coverage of the relevant elements for engineering education identified during the literature review. The results, although promising, are limited by the lack of practical NBL application. Therefore, further research is still necessary to validate the NBL concept in real courses.

This concept paper shows the development of a new pedagogical method (Need-Based Learning), starting from a literature review about the learning paradigm and teaching strategies. Then the outcome of the literature review is connected to the vision of learning of the hosting university and the important elements are related to activites typical for engineering education. The next step would be to try out the pedagogical model in a real master course for engineering education.

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INGENIOUS: AN EDUCATIONAL GAME TEACHING MULTIDISCIPLINARY PRODUCT DESIGN AND DEVELOPMENT PROJECT CHOICES

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Keywords: *Engineering education, gamification,learning game, product design and development, design tools and techniques*

ABSTRACT

While design is widely considered to be a core or distinguishing activity of engineering and probably the most common kind of problem regularly solved by engineers, teaching product design and development (PDD) is a challenge. The different engineering disciplines in a multidisciplinary PDD team use different tools and techniques (T&T) to support their work, where different T&T combinations might fit the development and new T&T are being developed every day. Choosing promising T&T during each PDD phase is therefore an important learning goal. With this motivation, this paper presents the Ingenious game. The paper explanins the theoretical background that supported developing the game, describes the game elements and mechanics, presents how its is intended to be used for gamifying a

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PDD course, and validates the game against the best practices found in the literature.

1 INTRODUCTION

Design problems are typically the most complex and ill structured of all problems, for which solutions are performed through an iterative process of decision making and model building [1]. Complex and open problems, also called wicked problems, typically require the integration of several content domains, thus taking on an interdisciplinary nature [1] [2]. As a result, teaching product design and development (PDD) can be a challenge.

The different engineering disciplines in a multidisciplinary PDD team use unique tools and techniques (T&T) to support their work, where different T&T combinations might fit the development and new T&T are being developed every day. Choosing promising T&T during each PDD phase is therefore an important learning goal. Creating their own mental model can help the students in determining promising T&T to solve the problem. The challenge, therefore, includes (1) covering the content related to the general design and development process, (2) the content from each involved discipline, and (3) also provide a meaningful relation among them, while (4) preventing that the students from one discipline lose their interest when the presented T&T are from another discipline.

Based on the author's experience it can be said that trying to fit this content into a traditional higher education PDD master course has resulted in limiting students' learning experience. The courses and related projects either deliver a broad and superficial presentation of the entire design process, or a deep and narrow analysis of one phase or discipline; both are not sufficient for teaching PDD through a course dynamic that resembles the real engineering practice.

For solving this problem, Pereira Pessoa et al. [3] proposes a gamification-based pedagogical approach, which integrates Just-in-Time-Learning (JIT-Learning) and flipped-classroom in a project-based learning (PjBL) setting. The gamified project creates the scenario (set of specific tasks/problems) for the just-in-time pulling of learning content supported by the flipped-classroom, where the students will learn as needed to perform the project. This paper presents the background for this gamification setting, describes the created game for supporting the gamification and reflects on its capabilities.

2 THEORETICAL BACKGROUND

According to Huizinga [4] "playing is older than culture and is at the very center of what makes us human". When reflecting on Huizinga's work Tekinbaş and Zimmerman [5] conclude that play creates an artificial space beyond that of ordinary life, where meaning emerges from what is "at play". Indeed, "the goal of successful game design is the creation of meaningful play" [5]. Meaning emerges from the game setting and rules, which is what differs simple play from a game.

The form of a game can vary, although an approach by Miller and Cliff [6] characterizes games in relation to several dimensions of complexity: number of players ("single-person", "two-person" and "n-person"); number of movements (moves); continuity of the strategy space (discrete or continuous); scoring structure ("zero-sum" or "non zero-sum"); information structure (perfect or imperfect); and symmetry of strategies (symmetric or asymmetric). Games can also be classified according to their application [7]; namely leisure games designed with the sole objective of entertaining, serious games with purposes other than or additional to entertainment, and learning games which are designd with specific learning goals in mind.

2.1 Conflicts of interest and games theory

The study of conflict of interest was formalized, initially, by game theory: Von Neumann and Morgenstern [8] proposed ways to study and predict the performance of rational agents, in a competitive context of defined rules. Thus, it is possible to calculate an expectation of minimizing losses for each opponent during the game. In addition, they presented the possibility of coalition, where two or more individuals come together, to maximize their gains, thus presenting cooperation and competition. Consequently, game theory is about finding the best strategy for playing a game according to the defined (and not defined) rules.

2.2 Gamification

Gamification is the use of game elements and game-design techniques in non-game contexts, thoughtfully applying typical game-like elements to real-world or productive activities [9] [10][11][12]. Important to note is this approach does not require a self-contained "game". The success of gamification relies on the power of the motivation to induce desired actions. Chou proposed a gamification design framework called Octalysis, which includes eight core drives, that function as prerequisites for fostering motivation, and triggering the planned behavior [10]: (1) **Epic Meaning & Calling** refers to when people believe they are doing something greater than themselves; (2) **Development & Accomplishment** that drives performing better, developing skills and achieving mastery; (3) **Empowerment of Creativity & Feedback** for players engaging in a creative process; (4) **Ownership & Possession** motivates players by the feeling they own or control something; (5) **Social Influence & Relatedness** incorporates the social elements that motivate people; (6) **Scarcity & Impatience** drives wanting something simply because it is difficult to reach; (7) **Unpredictability & Curiosity** creates engagement because of the uncertainty of what comes next; and (8) **Loss & Avoidance** is the motivation to avoid a negative consequence.

2.3 Games and gamification in engineering design and development

Games, gamification, and game theory are distinct, and thus have different implications for education. Games are normally self-contained, played individually or in groups, and can include collaborative and/or competitive elements. Gamification would be integrated with other class activities, potentially as part of individual or group activities, which can include collaboration, and/or competition elements, thereby the teacher makes the class itself a game [13]. Finally, game theory finds optimal strategies according to the constraints set by the rules. It is usually taught as part of a course's content than used as a pedagogical approach.

Hartmann and Gommer [14] argue that, although educational games have the potential to enhance intrinsic motivation in students, other motivational approaches are necessary also to justify the reasons for including the game in the teaching environment. Hernández-Fernández et al. [15] state that the students' perceived learning from the games is related to the link between game and course discussions after game play, a realistic game content and the students' prior knowledge. By reflecting on these authors' findings, it is possible to conclude that gamification is more promising in the case of wicked problems (such as design), since they benefit from combination of different pedagogical methods.

According to Sánchez-Mena and Martí-Parreño [13] the four main gamification drivers are attention-motivation, entertainment, interactivity, and ease of learning, while the four main barriers are lack of resources, students' apathy, subject fit, and classroom dynamics. Djelil et al. state that a well-designed learning game should be useful from a pedagogical point of view, usable from a learner point of view and acceptable from the institution, the teacher/trainer and the learner points of views. Table 1 summarizes the aspects that motivate and demotivate the students/players according to Hartmann and Gommer [14] and Djelil et al. [16].

Table 1. *Students/players motivating and demotivating aspects.*

Motivational aspects (M)	Demotivational aspects (D)
M1. Clear instructions. M2. Have specific and clear goals that match with the instructional objectives describing the targeted skills and knowledge. M3. Including different difficulty levels and other instructional methods can address students' knowledge variance. M4. Right challenge of the game content. M5. Engagement through interaction. M6. Competition between teams. M7. Direct feedback on performance. M8. Have an internal representational world, which may also include metaphors and narration. M9. Appropriate and progressive difficulty levels. M10. Learners should be encouraged to persevere despite failure. Failures and mistakes have no real-world consequences, they are rather turned into learning moments where learners must question and explore different options to achieve their tasks. M11. The learner can make decisions and set strategies when solving problems and performing tasks.	D1. Instructions difficult to understand. D2. Too difficult or too easy game tasks. D3. Game tasks do not match students' current level of knowledge. D4. Insufficient time for finishing rounds or could not contribute due to large teams.

When searching the literature for learning games and gamification initiatives aiming specifically to PDD, several examples were identified, but none fully approached the problem stated in the introduction. [17] [18] [19] [20] [21] [22]. The game proposed by O'Sullivan and Sheahan [23] is the one that most resembles what is intended in this paper. They created a board game-like toolkit which allows the students to play through an example of a new product development to understand the process and the tools, before using it for their own product development efforts. A complimentary website is used to enhance the physical toolkit, and it provides more examples of the tools being used.

3 THE INGENIOUS GAME

The Ingenious Game was originally developed for the gamification of a first semester Mechanical and Industrial Design engineering master course. During the course, the students define a design development process fitting to a given product/system development scenario. The process definition must include and integrate the content related to (1) the design and development process's phases; (2) the best practices covering the design and development process areas; (3) the different development models that help organizing the design and development according to the specific aspects from the solution to be developed; and (4) the specific tools and techniques used by the diverse disciplines that can be involved during the development.

Defining the design and development process to be used in a particular scenario is an open problem, these problems' underlying uncertainty and ambiguity require critical thinking and creativity from the solvers [24]. Consequently, the course must give relevance and meaning to the previously mentioned content, so the students can create a mental model for integrating it according to the constraints from a given design and development project. As a result, the gamified course has the following learning objectives (LO), where LO1, 2, 3 and 6 are specific to the game. At the end of the course the students are capable to:

LO1. Select the appropriate development model according to the product complexity and development risks.
LO2. Select the appropriate design techniques according to the development process phase and the involved engineering disciplines.
LO3. Design a product development process based on the complexity and inherent risks from the solution to be developed.
LO4. Deconstruct the rationale for choosing the development model and or selecting the design techniques.
LO5. Reflect on the results from the selected development model, design techniques and the resulting performance from the created design and development process.
LO6. Carry out a collaborative project.
LO7. Judge trade-offs choices during a project execution.

In addition to the learning objectives, the game also fulfills the following requirements (R):

R1. The game should be playable either standalone or as part of a course gamification.
R2. The game should be an expandable, modular and flexible platform, that allows incorporating new engineering disciplines (i.e. chemical engineering technologies, tools, and techniques).

3.1 Game elements

The Ingenious card game includes the following elements (figure 1), where the Octalysis core drivers [10] are underlined in the descriptions:

- The **challenge scenario** describes the development challenge that give meaning to the game to be played.
- The **risk level** contributes to the sense of loss during the game, so loss avoidance is about keeping the risk level low. The initial risk level is indicated by the challenge scenario complexity, and the players development model choice (more complex developments are riskier, and therefore benefit from more iterations in the development process).
- The **risk dice** adds an element of unpredictability. They are rolled for each issue card to check if its related risk occurs. The result that triggers the risk varies according to the actual risk level.
- The **annotation board** helps the team keep track of the progress, it includes information about the initial and actual risk levels, the initial and actual budget, and the planned and performed iterations. By visually representing the group's accomplishment the board helps create social pressure.
- The **budget** is the amount of money available for the team to aquire techniques and best practice cards. Budget is also needed to play the bought cards during the game rounds, which represent the cost to acquire and apply the knowledge. The team receives an initial budget and additional budget is released after successfully finishing a development phase (game round). The budget adds elements of loss avoidance, scarcity, and accomplishment to the game.
- The **engineer cards** represents the engineering disciplines playing the game (mechanical, electrical, software etc.), and needed to solve the challenge scenario. These cards provide meaning and a sense of ownership. Each player in the team has a card and some techniques are more effective if acquired and played by specific engineers.
- The **tool and technique cards** represent design and development tools and techniques and show their capability to solve development issues according to their characteristics. The tools and techniques contributes to the sense of ownership, as they are not the team's property, but the property of each engineer that unlocked (learned) and acquired them, and only these engineers can play the technique during a round.
- The **best practice cards** guarantee that the widely accepted best practices for PDD are also included in the game. Like the tools and technique cards, these cards help solving issues.
- The **issue cards** represent typical issues from each design and development phase. A certain number of cards is randomly drawn in each round, which contributes to the game's unpredictability. To solve an issue card, the player needs to be playing a technique which the characteristics' values are equal or higher than the ones required by the issue. Each issue card also includes a risk, which may be triggered depending on the risk dice results.

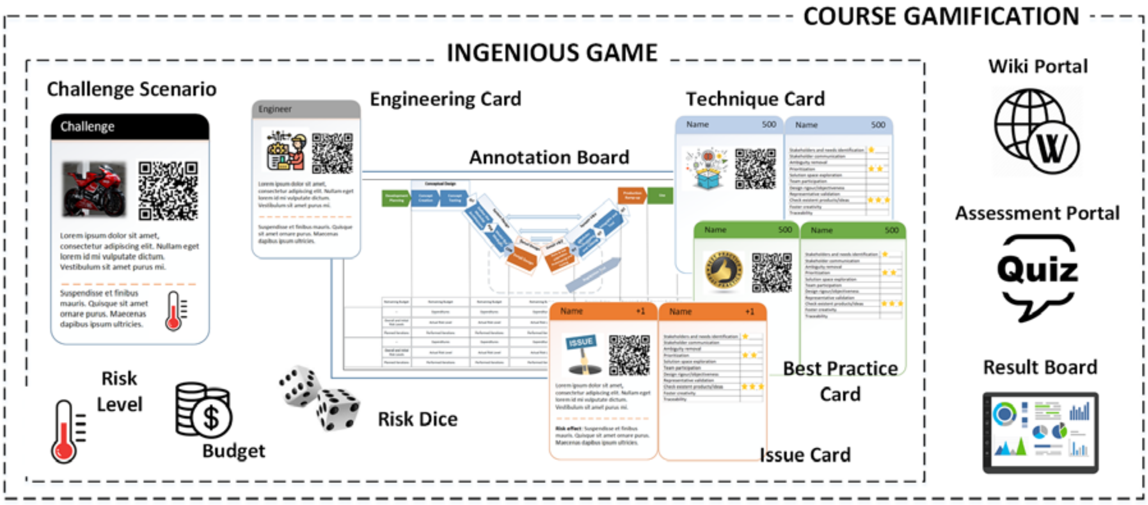

Figure 1. *Ingenious game and gamification elements.*

To fulfill the previously stated R2, the game has a modular architecture. New challenge scenarios can be added and align the game to different courses. New engineering cards, tools and technique cards and issue cards can also be added as expansions to the base game (i.e., cards related to chemical engineering challenges). Figure 2 shows a technique and an issue card sample. To solve an issue a technique must have matching stats and have traits with values equal or superior from the issue. Adding new cards require maintaining the matching and making sure that new issues are solvable using the existing techniques.

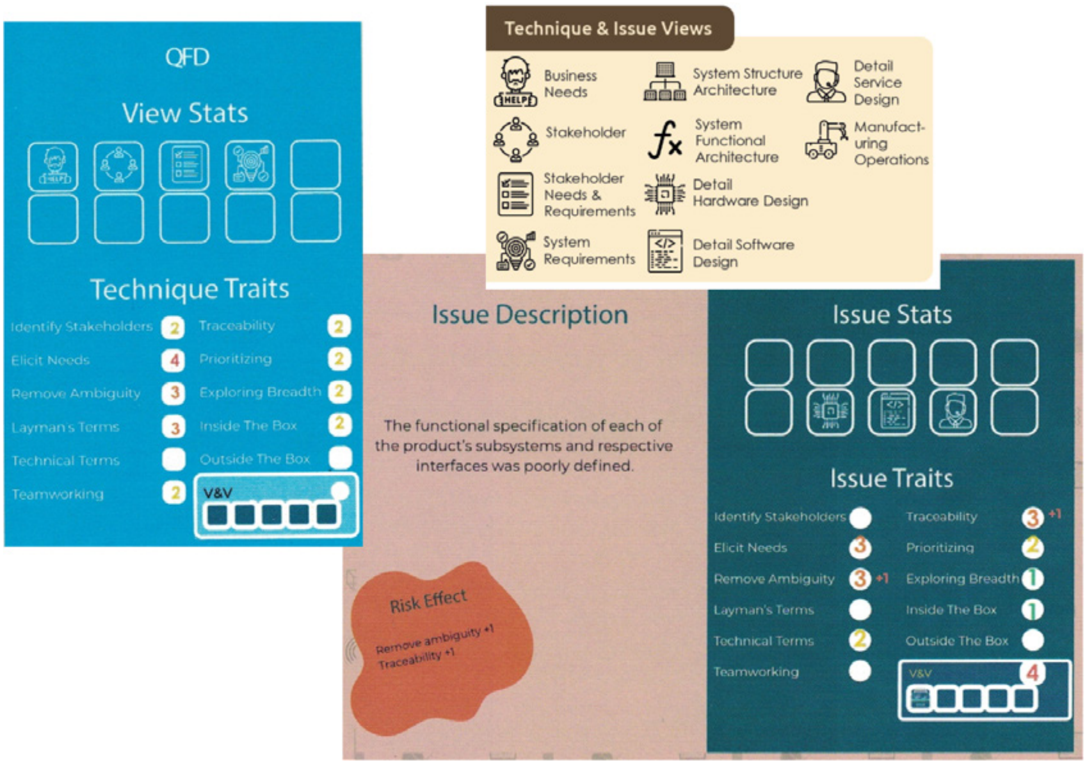

Figure 2. *Technique and issue cards example.*

Besides the game itself, the gamification setting includes a Wiki, an assessment portal, and a results board (figure 1). In the Wiki, the students can get further knowledge about the engineering tools and techniques included in the game, and that support their decision on which tools and techniques to acquire and play during each game round. The assessment portal includes quiz questions that cover all the tools and techniques, so successfully answering the quizzes can be used for unlocking the specific tool or technique before they become available to acquire and play. Finally, the result board displays the results (actual budget, risk level and number of performed iterations) of the teams, thereby increasing the social pressure and sense of accomplishment.

As a note, in relation to the Octalysis core drivers, empowerment was the only driver not included. Since the game was envisioned to be played only once over the span of a course, it was not possible to represent the teams gaining experience (climbing the techniques' learning curves), this could be solved in the case of playing multiple times, but it is outside of the scope of this work.

3.2 Game mechanics

When using the game to support the course gamification, the objective is to mimic a product design and development process execution during a new product development project. In the course setting, besides gamification, the other teaching strategies were a flipped classroom and just-in-time learning. No content is to be given beforehand, as the game's challenge requires that the students learn the theoretical content to progress in the game. Therefore, while going through the gamified project's phases, the students must select the knowledge delivered 'just-in-time' along side learning in a flipped classroom.

Figure 3 shows the game and the gamification mechanics using a simplified sequence diagram [25], which includes the gamified course activities sequence and the game activities sequence. The game activities and some of the gamification activities take place once in each round. In summary, the lecturer delivers the game briefing when the game rules and challenge are presented, and the students define the quantity of iterations they will execute during the upcoming game round 3 (more iterations mean reduced risk level, but there is an overhead cost of iterating). In each of the four game rounds (1. conceptual design, 2. system design, 3. detail design, and 4. system integration and test) the competing groups of students must select the tools and techniques to learn in the Wiki, unlock the tools and techniques by answering the quizzes, acquire the tools and techniques, define the hand (group of tools and techniques) to be played in the round, draw and solve the challenges (also considering the actual risk level and rolling the risk dice), and go to the next round/phase or repeat/rework the round, if the remaining unsolved issues do not allow progressing.

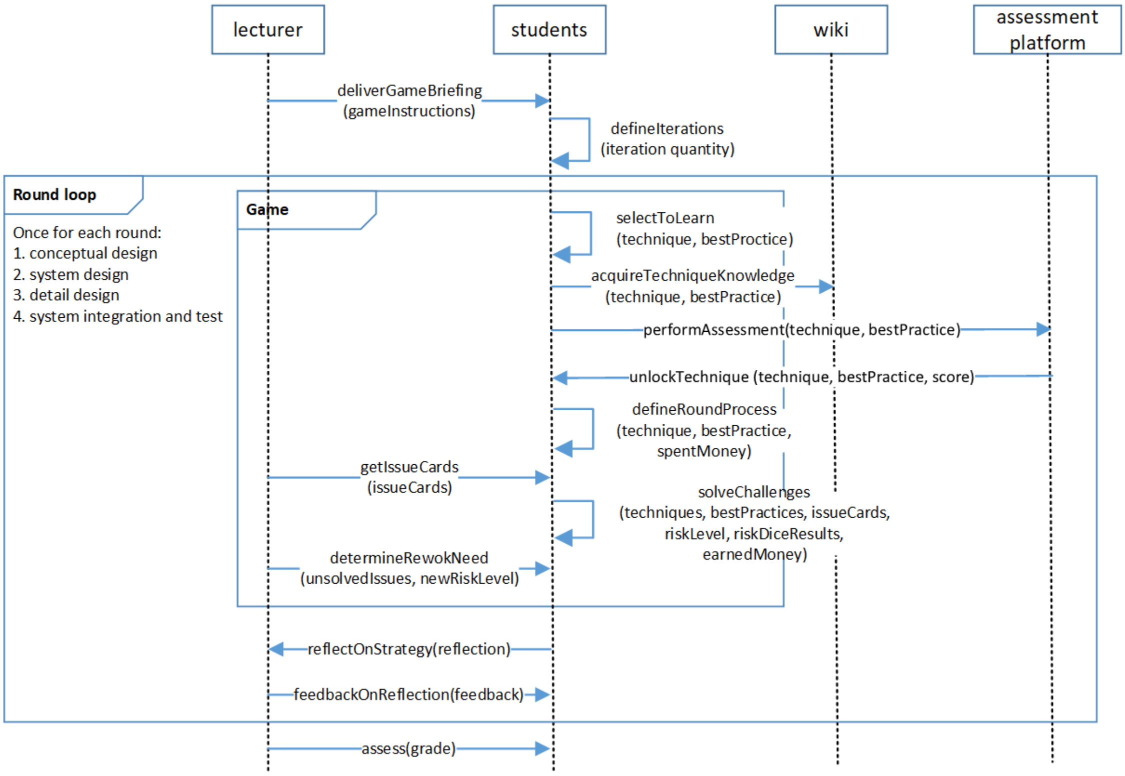

Figure 3. *Ingenious game and gamification mechanics*

At the end of each round, the students reflect on the rationale behind the strategy they set, the effectiveness of their choices, and what and why they would make differently in a similar situation in the future. The lecturer then gives feedback based on the students' reflection. After the four rounds, the final activity is to evaluate the students' work. Summative assessment is based on the reflections' quality and not on the game results.

4 DISCUSSION

At the current state, and before the Ingenious game and the design and development course gamifications strategy is used in a real course, they were validated against the literature by describing it according to the mentioned classification and by checking its coverage of the Octalysis drivers and on how it considers the motivational and demotivational aspects listed in table 1.

The Ingenious game is a learning card game that can be classified as: (1) n-person game, where the game can be played by just one group, where the members collaborate, or can be played with several groups, where the groups compete; (2) non zero-sum, since all the players can get partial scores; (3) with discrete movements with asymmetrical and discrete strategies, since it includes four rounds representing the PDD, when the players have a discrete number of cards available to play.

The Ingenious game covers, to some extent, all core drivers from Octalysis model, except empowerment. Empowerment can be added if the game is played as a sequence of scenarios during which the engineers get more proficient with the tools the more frequently they are used. Such applications though are outside this work scope.

Considering the motivational and demotivational aspects previously presented, the Ingenious game has an internal representation of the design process and the related elements (M8), has goals that match with the learning objectives (M2), fosters engagement through interaction with the team members (M5), whenever there is more than one team it includes the competition between the teams (M6), gives freedom to the learners making their own decisions (M11), provides direct feedback on the teams' performance by calculating each round's results (M7), and learners are encouraged to persevere despite of failure (M10). This last aspect is further emphasized by the gamification setting, since grading is based on the reflection related to both successes and failures.

Other aspects need to be further investigated through a pilot game and gamification runs, which includes the instructions clarity (M1/D1), challenge alignment between the course and the game (M4), the addressing of the students' knowledge variance (M3/D3), the difficulty level appropriateness and progressiveness (M9/D2), and the appropriate amount of time and team size (D4). Finally, the gamification capacity to deliver the LOs needs to be validated by offering the course and getting students feedback

5 SUMMARY AND ACKNOWLEDGMENTS

This paper presented the Ingenius game, which has been developed to teach PDD, and particularly the choice of techniques to be used during each PDD phase. Both the proposed game and gamification concepts were explained in terms of covering the Octalysis gamification model drivers and on tackling the motivation and demotivation aspects that affect learning games.

Seven out of the eight Octalysis drivers were covered, where only empowerment could not be considered: the game was envisioned to be played only once during a course, and it was not possible to represent the teams gaining experience, since different techniques are expected to be played in each round. Although the motivation and demotivation aspects seem to be approached, their validation require a practical application of the game. Consequently, the next step would be to put the game into practice during the master course for Mechanical Engineering and Industrial Design Engineering students, which will provide empirical validation of the game.

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PRINCIPLE OF SPIRALITY AND GRADATION IN THE USAGE OF TECHNOLOGY IN THE COURSES OF ENGINEERING MATHEMATICS

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Conference Key Areas: *Mathematics in engineering, Digital tools*
Keywords: *spirality, gradation, test and assessment system, engineering mathematics*

ABSTRACT

Our research group deals with the didactical questions of the role of computer algebra systems (CAS) and test & assessment systems (TA) in teaching STEM courses, mainly mathematics courses. We reflected on how the systemic use of technology can connect the blended learning methods with CAS and TA in different BSc and MSc courses levels. When the courses moved to an online platform during the pandemic situation, the relevancy of methodical research increases in higher education. In our paper, we present some examples of how the principle of spirality and gradation was used.

BSc 1. Semester: motivation from engineering practice, visualization (CAS only on lecture), oral explanation for symbolical and numerical problem solving, TA only for theoretical exam questions. The main point is to get to know the language and the construction of mathematics.

BSc 2. Semester: problem-solving using well-prepared CAS worksheets, numerical problem solving individually with TA, randomized homework, randomized and proctored exam with the help of TA. Focus on the mathematical concepts.

BSc 3. Semester: solving problems that go beyond the required curriculum with CAS, exams with and without CAS. Focus on mathematics in engineering practice.

MSc 1. Semester: within the course, there are two instructors, an engineer and a mathematician. Starting from a simple engineering problem, modeling the solution using new mathematical concepts, symbolical and numerical problem solving with CAS applications. Exam with TA, the students are allowed to use CAS for solutions.

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1 INTRODUCTION

As the Framework for Mathematics Curricula in Engineering Education [1] is mentioned, mathematical competence is the ability to understand, judge, do, and use mathematics in various intra- and extra-mathematical contexts and situations in which mathematics plays or could play a role [2]. In agreement with Niss & Højgaard [3] our goal is to develop for the engineering students the ability of thinking and reasoning mathematically, posing and solving mathematical problems, modeling mathematically, representing mathematical entities, handling mathematical symbols and formalism, communicating in, with, and about mathematics, making use of aids and tools.

In Bruner's spiral curriculum [4] is proved that the reinforcement of the information allows a logical progression from simple ideas to complicated ones; the complexity of the topic or the theme increases with each revisit.

Using the gradual release of responsibility model of instruction, the cognitive work shift from teacher modeling to joint responsibility between teachers and students, independent practice, and application by the student [5].

The theories mentioned above were developed for public education. The poor and different background of the refreshment students in the higher engineering education is the problem today (mainly because our students come from about 15 countries).

Maple computer algebra system (CAS) and Möbius Test and Assessment (TA) have been in use in our university for engineering mathematics. Our paper focuses on the didactical questions of the role of CAS and TA in teaching STEM courses, mainly mathematics courses [6]. We reflected on how the systemic use of technology can connect the blended learning methods [7] with CAS and TA in different BSc and MSc courses levels; how does it work in various levels of our engineering courses of mathematics.

When the courses moved to an online platform during the pandemic situation, the relevancy of methodical research increases in higher education. In the following chapters, we present some examples of how the principle of spirality and gradation was used.

2 DIFFERENT LEVEL–DIFFERENT METHOD

2.1 Level 0 and 1– BSc 1 Semester

Our students arrive at the university with different backgrounds. We organize a free course to review high-school-level mathematics. Last year it was organized using TA. For the main course, Engineering Mathematics 1, as is seen in Fig.1. at the first moment, it is an excellent motivation to understand the connection between the poor mathematics (sequences), the engineering practice (architecture), and our historic town.

The next step is to understand the process of problem-solving using the concept of George Pólya [8]. Understand the problem, devise a plan - develop a mathematical model of the problem, carry out the plan – solve the mathematical model and support or confirm the solution, look back – interpret the solution in the problem set. It seems to be a long time, but most students arrive without any explicit knowledge about problem-solving.

Only after this introduction starts to get to know the language and the construction of mathematics. After that, start the *traditional math lectures*, oral (face-to-face or online) lectures, explanations of symbolical and numerical problem-solving. On slides, the colors are used to make the difference between 'important' and 'less important' definitions and theorems. We use more examples instead of strict proof. During this course, computer algebra (*CAS*) is used *only for visualization*.

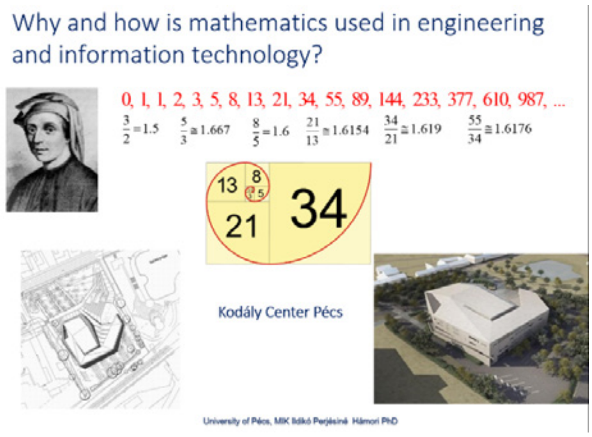


Fig.1. The first slide in 1. semester

Example 1. Solve the inequality

$$\frac{x}{2} > 1 + \frac{4}{x}. \tag{1}$$

Typical wrong algebraic solution: Multiply both sides by x,

$$x^2 - 2x - 8 > 0 \tag{2}$$

$$(x+2)(x-4) > 0,\ x < -2 \text{ or } x > 4$$

The inequality (1) and (2) are t equivalent to each other only if $x > 0$. If $x < 0$ then instead of (2), we get

$$x^2 - 2x - 8 < 0 \tag{2*}$$

Visualization of the problem student can plot the two sides as functions, and they understand the meaning of equivalency (Fig. 2.). The correct answer is

$$-2 < x < 0 \text{ or } x > 4$$

We use the *TA only for theoretical exams*, the question types are true or false, multiple-choice, essay, matching questions from the main definitions and theorems. Asking for numerical questions solution on paper and upload the solution to the MS Teams platform.

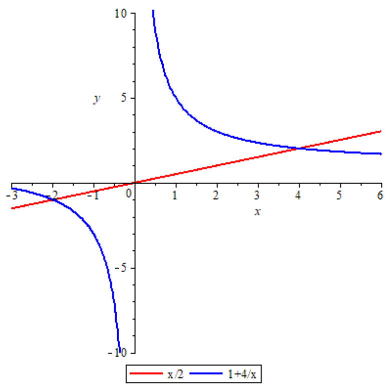


Fig. 2. Visualization of Example1

2.2 Level 2– BSc 2 Semester

During this semester, there is no difference between lecture and practice classes. For *project works,* well-prepared CAS worksheets are used.

Example2. Approximate the definite integral $\int_{-1}^{1} e^{-x^2} dx$ with $n = 6$.

Solution. For the solution, the package Student[Calculus1] of Maple is used (Fig. 3). There are so many experiments to understand the meaning of definite integral, as the limit of different types of sums, to create their simple repetition statements for approximation. If there is no pandemic, the classes are in a computer laboratory; during the lockdown, the students could reach the computer lab from outside.

Sometimes – thanks to CAS- we can look out from our strick topic, and we can mention some exciting aspects or some engineering problem using the discussed topic. For example, from Taylor polynomial (as an application of derivatives), the approximation of π can attract attention (Fig. 4).

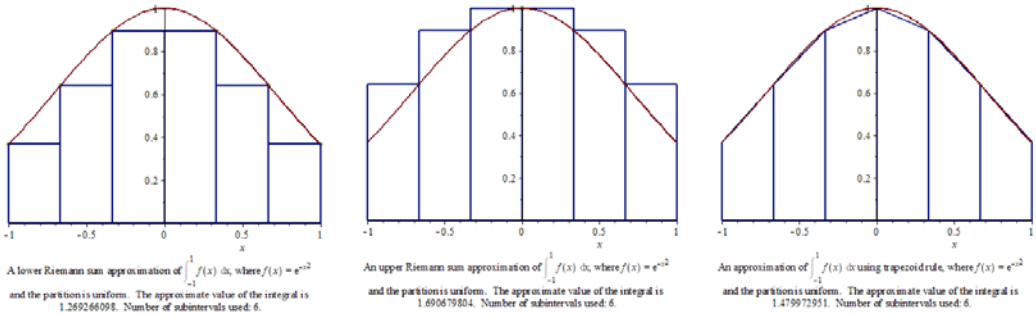
For individual problem-solving in the class, *randomized homework*, *randomized and proctored exam on TA* system was used. Even though our students are children of the 21st century, they are not very adept at using the computer as a tool for learning. Now they were forced to start learning in a self-regulated style.

There are so many didactical aspects of developing a question bank on TA.

It is profitable for students because it is based on cloud computing; users need only a browser and a user name. It understands the mathematical equivalence, gets prompt feedback, and can practice without a time limit.

Difficulties are liable to occur for students because there is no personal connection with the teacher. The mistype causes incorrect answers. For exercise solving, the student must use paper and pencil (not only click and choose a response); there is no cheating.

$> f := x \rightarrow \mathrm{e}^{-x^2}$
$> ApproximateInt(f(x), x = -1..1, method = lower, output = plot, partition = 6)$
$> ApproximateInt(\mathrm{f}(\mathrm{x}), x = -1..1, method = upper, output = plot, partition = 6)$
$> ApproximateInt(\mathrm{f}(\mathrm{x}), x = -1..1, method = random, output = plot, partition = 6)$
$> ApproximateInt(\mathrm{f}(\mathrm{x}), x = -1..1, method = trapezoid, output = \mathrm{plot}, partition = 6)$
$> ApproximateInt(\mathrm{f}(\mathrm{x}), x = -1..1, method = trapezoid, partition = 6); evalf(\%, 8)$



$> a := -1 : b := 1 : n := 6 : h := \frac{b-a}{n}$:

$$\frac{1}{3}e^{-1} + \frac{2}{3}e^{-\frac{4}{9}} + \frac{2}{3}e^{-\frac{4}{9}} + \frac{1}{3} \approx 1.4799729$$

$> integral := \frac{h\,(f(\mathrm{a}) + f(\mathrm{b}))}{2}$:
for i **to** $\mathrm{n}-1$ **do**
$integral := integral + h\,f(a + h\,i)$
end do:
$>$ appr_int_trapezoid := integral; evalf(%, 8)

Fig 3. Maple help for Example2

$> f := x \rightarrow \arctan(x)$
$> er := 100$:
$>$ **for** i **to** 100 **while** $er > 0.05$ **do**
$T[i] := convert(series(\mathrm{f}(\mathrm{x}), \mathrm{x}, \mathrm{i}+1), polynom);$
$appr[i] := evalf(4 \cdot subs(x = 1, T[i]), 10);$
$er := evalf(\mathrm{abs}(\mathrm{Pi} - appr[i]));$
end do:
$> T[i-1]; appr[i-1]$

$$f := x \rightarrow \arctan(x)$$

$$x - \frac{1}{3}x^3 + \frac{1}{5}x^5 - \frac{1}{7}x^7 + \frac{1}{9}x^9 - \frac{1}{11}x^{11} + \frac{1}{13}x^{13} - \frac{1}{15}x^{15} + \frac{1}{17}x^{17} - \frac{1}{19}x^{19} + \frac{1}{21}x^{21} - \frac{1}{23}x^{23} + \frac{1}{25}x^{25} - \frac{1}{27}x^{27} + \frac{1}{29}x^{29} - \frac{1}{31}x^{31} + \frac{1}{33}x^{33} - \frac{1}{35}x^{35} + \frac{1}{37}x^{37} - \frac{1}{39}x^{39}$$

$$3.091623807$$

Fig. 4. Approximation of π with error < 0.05

It is profitable for teachers because there are several types of questions (open-ended and closed-ended questions), each student gets different questions, it has flexible scoring, partial points, different assessments from the same question bank, possibility to follow up the student activity, and there is no need to correct tests. Levels from the teachers' point of view:

- simple questions, few Maple and programming knowledge
- complex questions, middleware Maple, and few programming knowledge
- difficult Maple packages, complicated response programming

The difficulties are that the question design is time-consuming, unconventional question definition is needed, a developer has to get ready for all kinds of answers, he/she needs some knowledge of computer algebra and programming.

During the design, Bloom's taxonomy was taken into account (the levels are knowledge, comprehension, application, analysis, synthesis, evaluation). Behind the Möbius TA, the Maple CAS is also working, so there is no problem with the equivalency; the questions could be randomized numerical and symbolical ones. Randomization is an excellent challenge to avoid cheating, but equal opportunities should be given to everybody. Sometimes it needs to develop Maple packages to prevent this problem. One typical question is seen in Fig. 5.

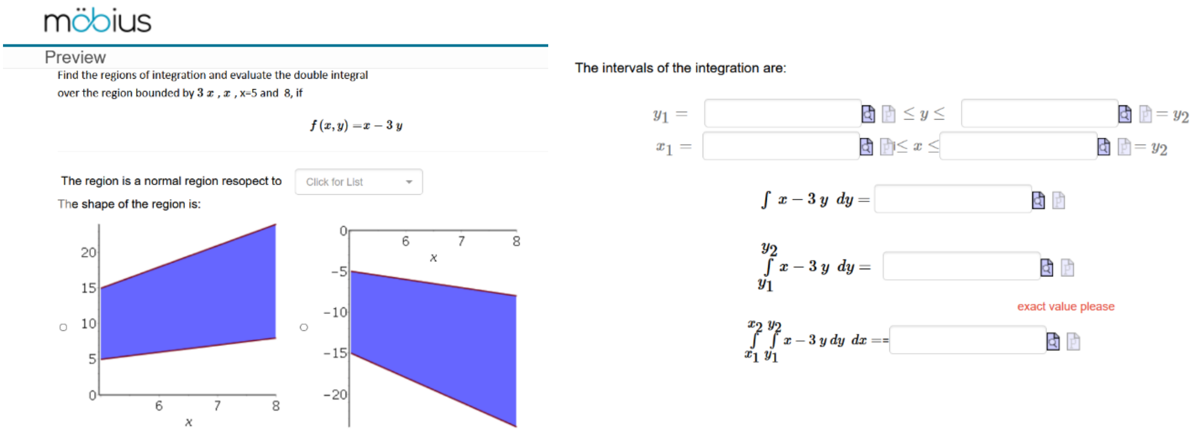


Fig. 5. One question from Math2 Midterm 2

2.3 Level 3– BSc 3 Semester

This semester, using CAS, we can also focus on solving problems *beyond* the required *curriculum*. The topics were specialized for different courses (electrical and civil- and computer science engineering). Focus on mathematics in engineering practice.

Example3. The SIR model for the spread of disease (solution of an ordinary differential equation system).

Solution. The differential equation system is

$$\frac{ds}{dt} = -b\ s(t)i(t),\ \frac{di}{dt} = b\ s(t)i(t) - k\ i(t), \frac{dr}{dt} = k\ i(t) \qquad (3)$$

where $s(t) = \frac{S(t)}{N}$, the susceptible fraction of the population

$i(t) = \frac{I(t)}{N}$, the infected fraction of the population

$r(t) = \frac{R(t)}{N}$, the recovered fraction of the population

b constants per day that are sufficient to spread the disease

k the infected group will recover during any given day.

Using the DEPlot possibility of Maple from the visualization of the solution is well seen what happens if the value of b is between 0.4 and 1.4 (Fig. 6.).

The exam and midterms had two parts; one was a traditional written exam, the other part was a CAS exam. In Fig. 7. the questions from the first midterm are seen. The first question is an ODE which is solvable analytically, but to plot the solution is not straightforward. The second question has a numerical-method solution. The numerical calculation is time-consuming without CAS. The third question is a second-order, inhomogeneous ODE, where the inhomogeneous part is not a continuous function.

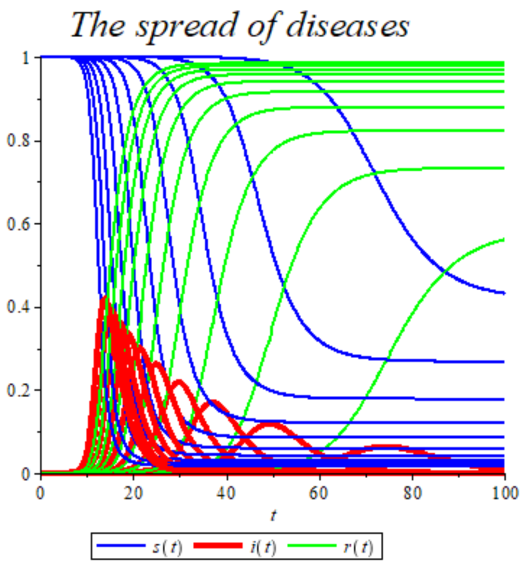


Fig. 6. SIR model

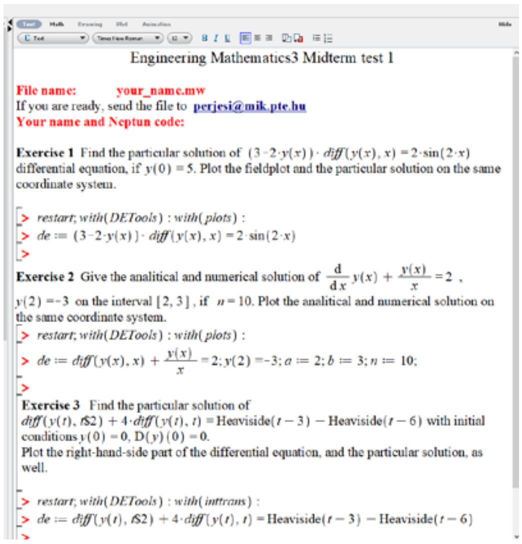


Fig. 7. Math3 Midterm Maple questions

2.4 Level 4– MSc 1 Semester

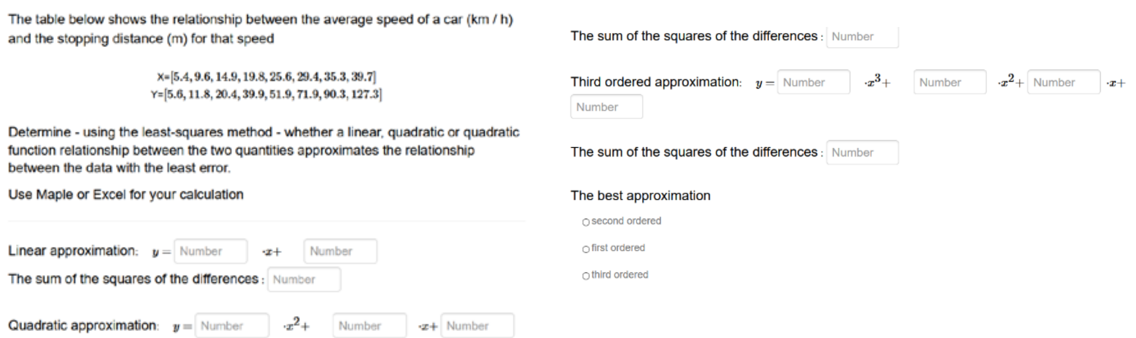


Fig. 8. Randomized exam question

Within the course, there are *two instructors, an engineer and a mathematician*. Starting from a simple engineering problem, modeling the solution using new mathematical concepts. Exam with TA, the students are allowed to use CAS for solutions. Fig. 8. shows one from the randomized exam question. The three functions' graf helps the student to find the correct answer.

3 RESULTS – WITH AND WITHOUT CAS AND TA

We compare two groups from Math2 classes, who were following the same syllabus and had the same homework in Möbius, but the civil and electrical engineers had a more traditional 'solve-it-then-upload-it' kind of test with static questions. In contrast, the computer science engineers had a similar assignment but with randomized questions. Comparing the two groups, we found a much higher degree of correlation between the homework average and the exam average for civil and electrical engineers than for computer science engineers (Table 1.). Unsurprisingly, identical (identically flawed) solutions were prevalent among civil and electrical engineers. The correlation between the homework and exam is much lower for those who used Möbius (0.3) than for those who wrote the exam on paper (0.86). Our explanation of this phenomenon is that randomized questions prevent unwanted student collaboration.

Table 1. Comparison of the results

	Civil- and Electrical Engineering (%)	Computer Science Engineering (%)
Homework Möbius average	70.48	64.79
Exam average - paper	77	
Exam average - Möbius		66
Correlation	0.8559	0.3594
Homework variability	21.73	9.86
Exam variability	21.20	16.10

4 SUMMARY

When the internet generation arrives at the universities, we had to transform the teaching-learning process. Our goal was to use new techniques and methods during the engineering math classes without compromising topics and themes. Instead of the strict axiom-definition-theorem process, we brought mathematics closer to engineering subjects; we focus on the applications and the outlook for higher mathematics.

During the whole engineering education process the mathematics education is considered a complete unit. When selecting topics, we took into account both the needs of the engineering sciences and the internal structure of mathematics. The used method in different courses was based on the background of the students and the place of the course in the curriculum. The spirality and gradation in our education system mean when a new topic is introduced, the earlier knowledge is reviewed using new technologies. In this way – because of the lack of time – students can bring back the forgotten topics according to their needs.

The results of the usage of this new methodology were that the dropout rate decreased, and students better understood the need for mathematics in the engineering practice. The cooperation between the students and the teachers increased, the teaching process shifted toward self-regulated learning. The teacher became a moderator between the knowledge and the student, he/she is a catalyst of the procedure.

In the future, it seems to be an excellent way to develop project works, but we had to consider the construction and the scaffolding of mathematics. We had to speak a lot with the engineering colleagues to find the best cooperation.

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Lessons Learned: Digital Semester for Engineering Courses at the Technische Universität Berlin

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ABSTRACT

From March 2020, Technische Universität Berlin switched to an emergency mode in an unprecedented situation for staff as well as students to prevent further spread of the Covid-19 disease. All German universities took similar precautions. Students were denied access to the physical facilities of the university for the rest of the year. For several weeks, the main body of the staff could not access the buildings either. The staff worked mostly from home and professors as well as teaching assistants started to prepare the summer semester 2020 to function as a complete virtual semester for the students. They had less than a month to rearrange teaching formats, develop digital learning materials, and implement technical solutions for the so-called "Digital Semester." This paper presents examples of undergraduate engineering courses that were held during the Digital Semester in order to compare them to their former versions and to work out commonalities and differences. Thus, we draw conclusions that can be helpful for shaping future courses. The presented courses capture a broad range of different types of courses reaching from seminars and practical courses up to large courses of more than 800 students. In the end, we summarize the key findings with respect to identified pitfalls and positive transformations for this variety of different courses including recommendations on the technical usage of systems.

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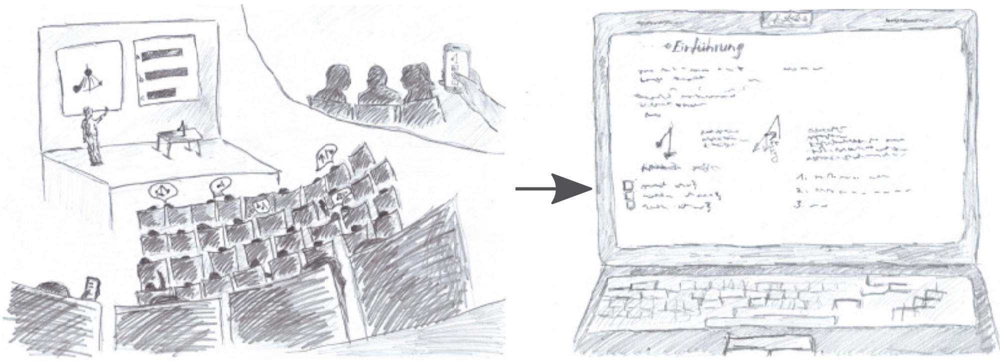

Figure 1: Transforming face-to-face on-site lectures to remote digital education.

1 INTRODUCTION

In March 2020, due to the spread of Covid-19, the Technische Universität Berlin switched to an emergency mode in an unprecedented situation for staff as well as students to prevent further spread of the disease. All German universities took similar precautions. Students were denied access to the physical facilities of the university for the rest of the year. For several weeks, the main body of the staff could not access the buildings either. The staff mainly worked from home, and professors and teaching assistants started to prepare the summer semester 2020 to function as a complete virtual semester for the students. They had less than a month rearranging teaching formats, developing digital learning materials, and implementing technical solutions for the so-called "Digital Semester". This paper's general idea is to present examples of courses held during the Digital Semester to compare them to their former versions, work out commonalities and differences between these courses and their effects, and draw conclusions that can help shape future courses.

We present the shift to remote education for larger courses with several hundreds of students as well as for those with smaller numbers of participants like seminars (see Figure 1). For the larger courses, we present engineering courses about Modern physics and System programming. Both are challenged with the management of communication between students and teaching staff and provide chances for students to interconnect themselves through online services [1]. Differentiations are also depicted in their final exams, where the physics course shifted to online assessments, while the programming course applied regular exams that required personal attendance. Additionally, the execution of a computer science seminar, a course about numeric methods and a module on C++ programming for engineers are presented. All three are held typically for smaller groups than the other two courses, like 50 to 150 participants. The first consists of intensively interactive meetings discussing advanced research topics. The second combines classic lectures with the practice of programming in small groups. In the third, students practice the basics of coding. These courses undertook a transformation to ensure the same benefits of a small group, intensive, interactive form of meetings, but in an online manner and was challenged with higher numbers of participants than ever before. In the end, we summarize the key findings with respect to undertaken pitfalls and positive transformations for this variety of different courses, including recommendations on the technical usage of systems.

2 BEST PRACTICES OF ENGINEERING COURSES

The following five sections describe five different engineering courses and their rapid adaption to the remote teaching setup.

2.1 Introductory physics for engineers

For the Digital Semester, we had to modify fundamental elements of our course "Introductory Physics for Engineers," based on a traditional lecture, flipped classroom sessions, and tutorial sessions, including working on blackboards and experiments in small groups (5-30 participants), so far. Every year, up to 800 students of at least twelve bachelor degree engineering and all STEM (science, technology, engineering, and mathematics) register, of which about 80% are in the first year. Our course is accordingly an introduction to classical and modern physics. It can be viewed as a journey of key experiments, associated theory, and concepts, beginning in the winter term with classical Newtonian mechanics and ending at the end of the summer term with an introduction to quantum mechanics and solid-state physics. In 2017, we started to reform key course components, implementing new flipped classroom sessions, exercises, and concept tests, promoting conceptual understanding and reasoning; see Ref. [2] for details. All course material is also made available to students via the university's Moodle platform.

This recent modernization has received a substantial boost thanks to motivated and enthusiastic undergraduate teaching assistants during the university's shutdown. In addition to the lecture, which is now conducted online via Zoom and supported by videos and applets, we formed a video team with our undergraduate teaching assistants, producing at least two videos a week screencasts on essential topics. The 5 to 15 minutes long videos follow the curriculum and are embedded in weekly so-called learning guides, which help students through the material. In these learning guides, students are motivated to deal with the contents of the course actively. For example, they should read a chapter in a script newly created for this course (49 pages), watch the corresponding screencasts, and solve the weekly exercises. Afterward, the students must pass a self-test with concept-tests and algebra-based exam tasks before the subsequent learning guide is activated. We also implemented two mock exams that students took via the university's Moodle, like the final exams. Additionally, we created flashcards (Ankiapp.com `github.com/ankitects/anki`, 2021/8/3) to help students learn physics laws and typical diagrams on their PCs or cell phones to prepare for the exam. A guide to implementing microlearning videos, online exercises, and virtual exams into such a large university course and any other course typical for the STEM fields can be found in the conference proceedings at Ref. [3].

Not only, but primarily because our course mainly involves first-year students, communication among and with students is crucial for the (perceived) effectiveness of teaching and learning, which studies also suggest [4, 5]. Similarly, student's ability to self-organize is critical to their learning success. Therefore, we have built infrastructure for various social media to connect with students and encourage collaboration with their peers.
First, we made ourselves available as instructors for daily consultations via Zoom (two to four hours daily), in which students could discuss the lecture and the weekly exercises with us. In parallel, we set up a chat (Rocket.Chat `github.com/RocketChat`, 2021/8/3). The chat has the advantage that here exercises, videos, sketches, and mathematical content can be shared easily. Also, students can enter formulas and solutions or share them with the teaching staff as a photo of their worksheet, which is considerably more cumbersome during a Zoom session. In Zoom sessions, there are always multiple students listening and students have to be willing to share their thoughts and calculations with their peers, which can be awkward.
However, less than 10% of students took advantage of these offerings. In particular, participation in the video consultations dropped sharply in the middle of the semester and again rose sharply a few days before the exam. In contrast, we found that students communicated with their peers primarily through messenger channels, with about 200 students participating more passively than actively. Due to low demand, we reduced our weekly consultations to two hours, which led to a significant increase in demand. Suddenly, more than $\sim$30% of students

participated in the consultations stimulating discussions. However, this is no comparison to the participation and dynamics during the on-site tutorials and flipped classroom sessions. It is needed to counter these difficulties, as students are left alone and lost during the semester, as we can see in the number of participants and reduced participation in the final exam.

Together with the lecture and office hours, the weekly assignments, mock exams, and the script form a framework that aims at intensive independent learning, which is rather unpopular among students. We tried to compensate for this by making ourselves available via social media and video consultations. On the other hand, the videos and lectures were very well received, and about a quarter more students participated than in the face-to-face lectures and exercises.

2.2 Introduction to Industrial Information Technology

The module "Introduction to Industrial Information Technology" is organized in the typical format of a lecture and a seminar. Whereas the lecture covers the broad field of industrial information technology, the seminar has been designed to teach engineering students the basics of C++ programming. Before the Digital Semester, the lecture was held as a classical weekly face-to-face routine on campus. For the seminar the roundabout 100 participants were split into four groups to attend their own seminar. Each seminar group was again divided into working groups of three. It was within these working groups that the students had to prepare a number of assignments throughout the semester. If the learning objectives were met was tested via weekly kahoot! quizzes on the one hand and a written exam at the end of the semester on the other hand, covering lecture as well as seminar content.

For the Digital Semester the lecture was held as a live stream at the gaming platform twitch.tv allowing for real-time student-teacher interaction via the chat function while recording the live stream to be uploaded as a video file into the Moodle course for the students. The seminar was turned into a video-based self-learning course. Creating the entire content as screencasts took a while. However, the production effort for a weekly screencast session was approximately the same as conducting the session face-to-face with four groups each, as had been done earlier. Therefore, the production could be realized along with the curriculum week by week. Still, the students had to form groups of three for the weekly assignments. However, due to rules of social distancing, the session exercises that had formerly been worked on as a team with one computer on site were now to be done individually at home. To guarantee regular contact between teaching staff and students despite working remote, individual weekly online consultation hours were defined for each team.

Those measures had a number of effects. The first visible effect was a 50% increase of enrolment compared to former courses. This might have been due to the fact that passing a course covering C++ is compulsory for many of the universities students and we were simply one of the first chairs offering an online version of such a course. The first lecture stream was even viewed by five times the number of people that usually sat in the lecture hall. We assume that among the participants were also some colleagues who wanted to get an impression of how other disciplines implemented online lectures. The number of participants soon dropped to the average percentage of participation known from the previous years. It is noteworthy that our students attended the live stream at the set dates although they had the option to view the recordings on the Moodle platform at any point in the follow-up. The number of students that actively used the chat function to ask questions was slightly higher than that of those who used to participate actively during the lectures on site. Therefore, it does not seem to have been the possibility to interact that made them attend the live stream. However, the Digital Semester required a great deal more self-structured learning of the students than they were used to. We presume, they recognized attending the lecture at a given time each week as being helpful with regard to structuring their study activities.

Another effect was seen in the usage behavior of the seminar screencasts. The weekly screencasts were viewed an average of 3.5 times per participant. In the face-to-face seminar of previous years, this option for multiple presentation of the content did not exist. Although it used to be possible to ask questions directly in the seminar, which meant that uncertainties could be clarified quickly, those who had missed something used to find it difficult to get back into the explanations. Due to the online consultation hours, there was also a regular opportunity to clarify open questions in a small group during the Digital Semester. However, the students had to search for answers on their own until the consultation hour and deal with the material more actively, which apparently happened, for example, by watching the screencasts several times.

In addition, the students had to be more active than before in completing the exercises. While they still worked out solutions together in their groups, they each completed the programming exercises on their own. Previously, the often uneven distribution of prior knowledge or work efficiency among the students frequently led to group members with less prior knowledge or slower work speed taking a back seat during the exercises on the jointly used computer. By working on the exercises individually, everyone had to work at their own pace, which certainly had advantages for the learning process.

The individualized work mode and the option to repeatedly watch lecture, seminar and exercises resulted in a significantly higher percentage of enrolled students who took the exam than in previous years. At the same time, the failure rate decreased by almost 50% from 14.1% to 7.7% and the grade point average improved by almost half a grade from 3.1 to 2.7.

Overall, we have learned from the Digital Semester that students benefit from synchronous arrangements also in digital formats. The biggest advantage, however, is the individualization of the learning process.

2.3 Numeric methods in civil engineering

Up to 150 students attend the course "Numeric Methods in Civil Engineering" each year. According to the study schedule, they should be in their fourth semester when taking it. In the Digital Semester the traditional lecture was changed to a flipped classroom format: corresponding documents were released on the digital Moodle platform of the university and a meeting was scheduled usually a week after publishing the documents. Exercises in which the calculations had formerly been demonstrated in a way of a traditional lecture, were now given to the students as short video clips. Also a meeting for questions and further explanations was scheduled usually within a week. Both, exercise and lecture were evaluated in the week they were scheduled, asking our lecture students whether the documents/slides and the lecture notes were useful; and our exercises students if the shown approach (in PDF) and the video clips were helpful. The third question was "What was bad/left out or can be improved? Are there unanswered questions?". Participation was optional and the feedback anonymous. Students frequently used the answer to question 3 to place own questions regarding the content prior to the upcoming meeting. This was helpful for preparing the meeting and making sure that the crucial points were understood. The evaluation was answered frequently in the first weeks of the course. During the semester the participation decreased, probably because there were only minor problems.

In addition to lecture and exercise, there are practical trainings for programming and to practice calculations every week. The group of students at each session counts 20 maximum.

The practical trainings are intended to take place at a computer pool. Due to the Digital Semester every student had to use his or her own device. The needed software is free and the requirements are relatively low for programming in java, but the provided help via tools like Zoom seemed like it was not as helpful or appreciated as in a presence meeting. The tasks and the solution were published in advance to the practical training. To create the same work atmosphere as at the practical training in the computer pools, the students were divided into groups. Each group consisted of three people and the tutor checked on every group regularly. Nonetheless, the attendance decreased over the course of the semester stronger than in former years.

The practical training was also evaluated with three questions every week like lecture and exercise. In the first question the students told us what they did as preparation for the practical training like watching the video clips of the exercise. The second questions asked about the difficulty of the training in their opinion. The answers of these two questions together were helpful for adjustments in the assignment. It is more likely for students to find the task harder when they are ill-prepared and this way it was easier to assess their feedback. The third question was the same as for lecture and exercise - we asked for suggestions to improve our content and if there are further questions.

The evaluation at the end of the course showed that a lot of students valued aspects such as fast responses to emails and the numerous possibilities to ask questions. Students profited from the fact that almost the entire course content was digitally available. Consequently, some stopped attending most of the live meetings and only came to prepare for the test. However, more students passed the course compared to former years and nearly all evaluation participants stated that they understood why this course is important for their studies.

2.4 System Programming

The course "System Programming" teaches theoretical concepts of modern operating system designs and provides practical experiments for hands-on experiences. It is an undergraduate course for more than 800 Computer Science and Computer Engineering students in their first year. The 12-week course consists of a series of weekly lectures for the large group of participants, while also providing more practical exercises for smaller groups of around 30 students in weekly sessions. The grading process is split into mainly two areas: Theoretical and practical. The theoretical concepts are assessed with a written exam, while for practical tasks, groups of four students are handed bi-weekly exercise sheets. The university's Moodle platform is used for distributing digital materials, handing in the exercises, and providing a digital discussion space for students in forums. In order to provide our best individual feedback, our teaching team consists of 17 persons, from out of which 14 cover the practical sessions and 3 the lectures and overall organization of the course.

All the sessions, which had formerly been conducted physically inside the university buildings, had to be digitalized. This has been carried out by producing video content for asynchronous learning and additional non-graded exercise material, as well as by providing additional digital space to discuss questions about the videos, combined with a live session, where students were able to ask questions about the content of the videos, similar to the flipped-classroom principle. Videos were newly produced for both lectures and practical sessions and uploaded weekly at the beginning of the week (Monday morning). For the rest of the week, the content of the videos of the current week was discussed during live sessions via Zoom. As additional materials, Multiple-Choice questionnaires (for each video around 10 tasks), were produced for students to self-assess their understanding of theoretical concepts explained in the videos. The grading process did not change much compared to pre-Covid-19 conditions: The practical

Figure 2: Situation for writing an exam with enforced rules writing in large air-conditioned rooms, increased distance, and wearing face masks due to Covid-19 pandemic.

tasks were distributed via the Moodle platform as well as the hand-in-process. The written exam was carried out on site in large exhibition halls with specialized rules (see Figure 2). The key rules were that students needed to wear masks for the whole duration staying in the building, and at least 2 meter of space between students needed to be ensured. All tables had to be disinfected before and after writing the exam. The exam took place in mid-August, where the numbers of new Covid-19 infections were low all over Germany.

Attending sessions was optional for the students, which led to just a small number of around 10%-15% of the students attending the live sessions, while more than 800 students handed in the bi-weekly practical tasks. Participation in the Moodle forum was less frequently used compared to pre-Covid-19 years, with 3-5 questions per video that were asked with this asynchronous offer. Also, the teaching personnel needed to adapt to the remote teaching setup, in which students obviously hesitated to ask questions at the beginning of the live sessions. Therefore, the format was adapted by showing key aspects of the videos in the beginning of the sessions, from which discussions arose much more frequently.

The number of watched videos and the number of used non-graded material (especially the MC tests) indicate the usability of our newly created digital material. The overall grades of the courses did not change significantly. Consequently, we consider that the production of new videos and further material was successfully applied.

2.5 The Software Horror Picture Show

The course "The Software Horror Picture Show" is a seminar mainly focused on topics concerning software errors, bugs, or failed projects related to such problems. Examples for such topics are the crash of the first Ariane 5 space launch vehicle, the crashes of the two Boeing 737 MAX, or even the virtual pandemic in World of Warcraft in 2005. Usually, 30 students enroll for the course. A weekly course meeting is used to present basics of how to present and write for the scientific community. The students carry out exercises and discuss the topics. Over the semester they give two five minute talks each, both on the same topic to allow them to incorporate the feedback of the first talk in the second. At the end of the semester, students give a 20 minutes talk each, followed by a discussion on the topic and participants hand in an additional essay on their topic.

For the Covid-19 edition of the course, instead of the usually about 70 applicants almost 200 students applied to participate in the course. Therefore, the course size was increased to 50 participants. The attendance phases were discarded. Instead, a course on the university's Moodle platform was used. Each week, the students could access screencasts explaining the basics of presenting and writing. The screencasts stayed online for the duration of the course. Additionally, a team chat using Mattermost was used for the course where the instructor answered questions. Most weeks, the students had to collectively work on an exercise on the collaborative platform Etherpad, e.g. answering questions on the quality of two given sources. As the students could see the answers of the other participants, they often discussed or argued in these Etherpads. The five minute talks were handed in as self-filmed videos by the students, which worked very well. The final 20 minutes talk was given in small groups via Zoom conferences, therefore at least some discussion in-between students was possible. The final essay was handed in as in regular semesters in a digital form.

Overall, the course worked well in the Corona edition. However, the active participation and especially the discussion in the chat as well as concerning the final talks was far less lively. The exercises on the Etherpads were used very well and the comparison of results was an interesting factor, influencing the answers of the students. The grades of the students that participated were similar to the non-digital semesters.

3 LESSONS LEARNED

Summarizing the presented courses, the lessens learned are two-fold. At first we present key digital tools used for the interaction between teaching staff and students. Afterwards, we continue with the key overlaps of shared observations among the different courses, concluding the long lasting impact of changes also shaping the courses after the pandemic.

Table 1 presents different digital tools and applications for various needs in the interaction and communication between teachers and students. For most presented lectures, the key management platform Moodle was utilized for student enrollment, assignment of tasks, distributing material, etc. As Moodle is an open source platform, there exist a lot of freely available plugins. The main and most useful plugins applied in our lectures were: Quiz activity, CodeRunner, Course feedback, and Learning paths. While Quiz activity and CodeRunner are foremost interesting for examination purposes, Course feedback is applied for collecting anonymous feedback from students for the lectures quality assurance. Lastly, the plugin Learning paths provides the opportunity to establish guided organization and structure for self-paced learning. Live-sessions were carried out through the tools of Zoom, Twitch, and Jitsi. The diverse landscape of different tools was caused by the late establishing of high quality video streaming platform setups at the university. Most teachers had to setup own solutions, but switched soon to Zoom since it was the recommended platform for teaching for the Technische Universität Berlin. While live-sessions were carried out, the students were able to ask questions by using the chat systems from Zoom, Rocket Chat, and Mattermost. Platforms including chat systems like Zoom provide a beneficial combination offering an optimized environment without the need of additional screens. Lastly, Anki Cards are utilized to present students digital materials similar to conventional learning cards.

Table 1: Digital applications used for the communication between teachers and students.

Management Platforms	Live-Sessions	Chats	Additional Tools
Moodle (Plugins: Quiz activity, CodeRunner, Course feedback, Learning paths)	Zoom Twitch Jitsi	Rocket Chat Zoom Chat Mattermost	Anki Cards

All presented courses created additional recorded teaching materials like videos and screencasts. Key advantages results from the 24/7 provisioning of this material on the Moodle platform, enabling the students to repeatedly watch them and thus and learn in their own pace. The production of videos and screencasts is time-wise comparable to a teaching situation when the same content has to be presented several times a week. Further reusing such material for the following semesters increases the saving of time on the teachers' side. Then again, the change of single parts within a videos/ screencasts is much more difficult than changing single slides within a PowerPoint slide-deck. The update gets even more complicated when new or different lecturers want to change parts of the video, as audio sequences and presentation styles might impact the quality of the video material significantly, ending up with producing the whole video over again. We propose to prepare screencasts showing slides without video- and audio-recordings of lectures. The audio should be added later when creating videos with long duration. Another option is to split longer video material in small chunks, which can be individually reproduced quickly.

When including the recorded/live videos and screencasts into the lecture, we presented different approaches leading to different findings. The replication of traditional lecture formats with fixed time slots per week for a presented live-stream was widely accepted in one course despite the option to watch the recordings at a later point in time. A possible explanation is that such fixed appointments helped the undergraduate students to structure their learning process and thus master the suddenly unusually high expectations regarding self-directed learning in the Digital Semester. Contrary, when applying the flipped-classroom concept with adding self-paced learning material with live-sessions to discuss the uploaded material, it led to a low rate of attendance (10-15%). We presume that the new flipped classroom format together with the transition of the learning setting from on-site to digital learning was overwhelming for first year students in undergraduate courses as such young students have little experiences in self-regulated learning [6].

Compared to pre-Covid on-site lectures and face-to-face consultation offerings, students attended less frequently digitally offered consultation hours and forums. Due to the lack of attendees, the offers for consultation were reduced each week, causing a rise in interest to the end of the semester. Hence, we propose to rather prepare some qualitative consultation offerings than overwhelm students with too many opportunities.

For the lectures, additional chat opportunities were established concurrently with the live session so that students could ask questions during the session. For such situations, the participation was greater compared to face-to-face lectures. This shows that live-sessions reduce the barrier to attending lectures compared to on-site lectures for which students have to come to the university.

Group work and group assessments were carried out also during the digital semester. The groups were able to establish connections and organizing their work with various digital tools like WhatsApp, Telegram, Overleaf, or Google Docs. Still, the assigned work was mostly carried out by individuals, while most of the group members had hidden in participation. In the future, we suggest taking the advantages of automated evaluations, provided by platforms like Moodle, to frequently ask for individual assessments instead of group assignments. By this, we hope to help students establish self-learning strategies who would otherwise tend to ignore their own learning needs as long as they can still pass the course without tackling that weakness. Nevertheless, we suggest to still include some group work to provide the possibility to connect and network even in remote working situations.

The changes introduced during the pandemic are going to influence how lectures will be organized and presented in the future. Especially rather short videos/screencasts with long-lasting content is going to be used in future courses. As has been shown, such newly introduced digital material is beneficial to students, allowing them to study in their own pace. Also didactic insights will change the way group work is organized and consultation offers are designed.

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A STRUCTURED DIGITAL OFFER FOR DEVELOPING LEARNING STRATEGIES AS ADD-ON FOR HIGHER EDUCATION ENGINEERING CLASSES

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Keywords: *learning strategies, course design, podcasts, active listening*

ABSTRACT

Early entry age of university students, little self-learning experience and courses with several hundred students: bachelor students are often poorly prepared for university requirements. Since individual support for first-year students is hardly possible with student numbers that have been rising for years, the course design is adapted by putting weight on highly structured teaching-learning arrangements, clearly restricted learning objectives, and narrowly defined examination content. However, the techniques for self-organized acquisition of knowledge, which allow for an individual holistic approach to learning are neglected. As a result, learning content is often memorized rather than absorbed - and thus forgotten again a few weeks or even days after the exam, leaving the "learner" with a lack of both, expertise and the skills necessary to acquire it. In 2020 we set out to enable young students to experiment with learning strategies without coaching them individually. A podcast series and short e-exams were developed and didactically embedded in a basic cross-sectional course for around 160 students. The evaluation showed great acceptance and appreciation from the students' side for the intervention. They experienced themselves as effective learners while picking up learning strategies seemingly in passing.

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1 INTRODUCTION

When students enroll at university, they come with at least 12 years' experience with learning in formalized settings. However, many find themselves unprepared for what their new intellectual surroundings expect from them regarding learning strategies and learning behavior. This often results in students experiencing immense psychological stress (which hinders learning progress) and developing a grade-oriented rather than content-oriented learning behavior for the sake of passing courses, thus falling short of their capabilities and even dropping out.

The maxim to prepare young people for the labor market in an ever-shorter period, requires highly efficient, standardized processes of teaching and learning. The techniques for self-organized acquisition of knowledge, which are necessary for lifelong learning, have no place in such a schooling concept. However, self-regulated learning and its according learning strategies are still a basic requirement of higher education. As a common helpless reaction, university staff often expresses the attitude that simply not everyone is personally qualified to study at university and young students quitting is, therefore, a logical consequence of selection. However, this "consequence" results in a loss of possibly very capable young people for the scientific or professional field, as well as in reduced performance of a large part of the remaining group. Others have put a lot of effort into active learning approaches, trying to offer their students self-learning experiences e.g. by demanding project-based learning. However, those formats usually require basic knowledge and are thus designed for higher semesters, which means that those students who probably need such learning opportunities most, might have given up before getting there.

Of course, there are books and introductory training courses on how to study that are recommened frequently by teaching staff. However, young students who already feel overwhelmed by the sheer amount of compulsory coursework will not invest their scarce capacities for supplementary activities. A much more promising approach would be, to integrate learning experiences that foster new competencies into basic compulsory courses in such a way that students can immediately experience the usefulness of changes in their learning behavior. This was also our starting point at the Department of Industrial Information Technology at Technische Universität Berlin when we set out to develop a digital teaching-learning arrangement that enables young students to experience self-efficacy with learning strategies while actually doing basic coursework. The product is a didactic concept that includes a podcast series and self-examination quizzes in careful timing with the weekly lectures. In the following section, we discuss didactic and psychological basics upon which we developed our concept. Afterwards we present the didactic concept and its implementation before describing the evaluation and discussing the results.

2 STATE OF THE ART

While learning is common to all living beings, humans are distinct by their capability to reflect upon their own learning process and thus develop strategies for efficient learning behavior. When high school graduates enter universities they are already equipped with numerous such learning strategies specific for the school setting. Helpful as those might have been for mastering school, they are often not sufficient or even obstructive to meet learning expectations at university level [1]. According to Schiefele and Wild [2] learning at university requires

(1) cognitive learning strategies (e. g. repetition strategies, organizational strategies, elaboration strategies and critical thinking),

(2) metacognitive learning strategies (e. g. planning learning activities, assessing learning activities and regulating learning activities), and

(3) strategies for using internal and external resources (e. g. directing attention and effort, organizing the learning environment and forming learning partnerships).

To develop those strategies, a rather sophisticated understanding of knowledge is required. However, in young students' experience, learning success is bound primarily to learning strategies of simple memorization. This comes from having studied so far with the strongly simplified representations of reality found in school books targeting dualistic assessment of learning outcomes via school exams. Furthermore, high school students are used to a setting where they are told what exactly they are expected to learn or rather memorize [3]. The entire process of selecting and organizing information oneself plays a subordinate role at school but is a required basic competence at university.

2.1 Self-directed learning

Many researchers involved in university teaching emphasize the need to help students to overcome obstructive ideas of knowledge and learning right in their first year as a major condition for them to succeed in their studies [1], [3], [4]. Self-directed learning is the first out of five readiness dimensions of students defined by [5]. It classically includes taking on responsibility to understand own learning needs, establishing learning goals and implementing learning strategies and evaluation [6].

From a psychological perspective, self-regulation includes control of cognitive, metacognitive, volitional and behavioral acts to monitor and assess the own learning process [7]. Learning, in general, is a highly constructive process on the side of the leaners who have to create complex neuronal networks and establish cognitive representations of the learning subject to transform external information into internally knit-in knowledge. The more cognitive representations and the more neuronal connections already exist, the easier learners find it to integrate new information and put it into relation with what is already there, e.g. learn more. Learners that are inexperienced in a field, however, do not have many representations yet that would help them to file new fragments of knowledge into existing concepts. They must look at and make sense of each fragment singularly before tentatively putting it somewhere until something else might come up that they can probably put it into some kind of relation with.

2.2 Memory and cognitive representations

The basis for many psychological memory models today, although thoroughly adapted, is the multi-store model by [8]. The authors claim the brain to have three different storages, (1) sensory register, (2) short-term storage, and (3) long-term storage. The sensory register represents visual and acoustic impulses as pictures or sounds for few seconds. If those appear irrelevant, we forget them immediately. The long-term storage is where information is stored for an indefinite time, provided, the short-term storage has processed the information thoroughly. In later models, short-term storage and sensory register are both integrated in the instantiation “working memory”. The working memory does all major cognitive work. It is responsible for both, assessing new information and recovering information from the long-term storage to interpret situations or find solutions.

According to the “Levels of Processing model” the representation (memory) in the long-term storage gets stronger and more accessible with duration and intensity of an information’s processing by the working memory. This means the more often and intensely learners make use of an information they have acquired by applying it in different contexts, and thus making connections to other information, the stronger a cognitive representation will they build. Transferring the model back into didactics, we find definitions of “deep” and “surface” approaches to learning [9]. Deep approaches thus refer to e.g. consciously relating ideas to previous knowledge and experience and looking for underlying principles. Surface approaches, on the other hand, are characterized by e.g. treating the course as unrelated bits of knowledge and memorizing facts.

Effective learning techniques mirror those findings. Repitition, for example, makes use of the spacing effect [10], meaning that memory performance is higher when splitting the learning time allocated to an information piece into several shorter slots distributed over time. This effect is explained among others by the “Encoding Variability Theory”, which states that over time a bigger variety of context referring to a specific information can be stored, which makes it easier for a person to retrieve the information. Also according to the “Study-Phase Retrieval Theory” the mental traces, which can be seen as guiding paths towards a specific representation, are strengthened every time they are activated, e.g. the representation is retrieved. Both theories have been shown to be significant for the “lag effect” [11], which is the positive effect of longer pauses in between retrieval of an information on the learning outcome. It is important to notice that the lag effect’s function follows an U-shape. Thus, while it can be considered useful to let some time pass in between first encounter and first retrieval of an information, the positive effect wears off after a while. A pause of one to two weeks seems to be optimal as suggested by research.

2.3 Understanding the own learning needs

Learners can increase their memory performance even more by checking the quality of the representation they are recalling during repitition via feedback [12]. Feedback is utterly important to young students since they usually lack the ability to judge their own competency within the new field [13]. E.g. well-presented lectures that take seemingly little cognitive effort to follow, mislead students to believe that they have learned a lot while listening, although the content can actually not be stored in the long-term storage if there are yet too few cognitive representations to integrate the new information and if it is not repeatedly revised. This negative correlation hinders students' active engagement and taking on responsibility for their own learning processes. One could say, only when learners must try to make sense out of things themselves will they start to realize their lack of understanding. Feedback can help them realize that they have been misled.

2.4 Active engagement in passive learning arrangements

Deep learning strategies are often associated with students' active engagement. "Active" as an operationalized term is defined as opposed to "passive" formats; the latter foremost refers to classical lectures. Nevertheless, students can cognitively engage actively also in passive formats, foremost by active listening. Active listening requires effort and skill and is the precondition for integrating lecture content into the own cognitive representations [9]. Since top students show strong cognitive, affective and psycho-motor active listening skills [14] it is a predictor for learning success. Helping students develop that skill becomes even more important since distractive stimuli have become omnipresent with digitalization [15]. Students who might have mastered school teachers' lectures by day-dreaming are now allowed to bring electronic devices to the lecture room that connect them to the entire digital world. Thus they need to develop the skill to keep up following the person standing several meters away while being exposed to constant competing stimuli right before their noses.

In summary, university students often arrive at their new learning surroundings with school-related concepts of learning that are obstructive to mastering higher education. They lack basic competencies regarding self-regulated learning, which are necessary to build up professional expertise through cognitive representations and associative networks as well as for life-long learning in less structured learning environments. They need learning experiences that help them challenge former concepts and establish a deep approach to learning by actively engaging with course content. They need to identify lacks of knowledge as well as ineffective learning routines in order to take over responsibility for their learning process.

3 CONCEPT FOR INTEGRATING LEARNING EXPERIENCES

Based on the ideas above we decided to develop a didactic concept and materials for one of our cross-sectional bachelor courses that should help our students make valuable learning experiences and develop effective studying routines. The cross-sectional nature of the course seemed particularly suitable since it requires our students to connect knowledge from different engineering fields, thus building up complex representations.

The didactic goals of the concept were to give students the chance to

1. build up basic concepts before listening to the lecture to experience that preparing oneself helps following the lecture and thus makes attending it more effective
2. check how much they have learned directly after listening to a set of information to realize that listening is not automatically learning and develop active listening skills
3. continuously learn throughout the semester instead of shortly before the examination to experience the effect of distributed learning over time and of giving the brain the chance to shift information to the long-term storage.

Regarding scarce staffing we decided to go for a digital solution for our approx. 160 students. We did not want to change the lecture itself, which had just undergone thorough revision. Therefore, we needed a concept that could be integrated as add-on. In accordance with goal 1, we had to provide our students supplementary information before the lecture in a way that they would actually use it. Thus, we decided to offer bonus points for using it. Also for motivational reasons we decided to go for a podcast, featuring a young lively teacher that was on good terms with our students, interviewing experts for the upcoming lecture topics in each episode. We planned the interviews to have an unofficial note to them, taking care to use first names only and use simple language. The episodes should loosely introduce basic concepts of the corresponding topic, its importance in practice, and current trends in the field.

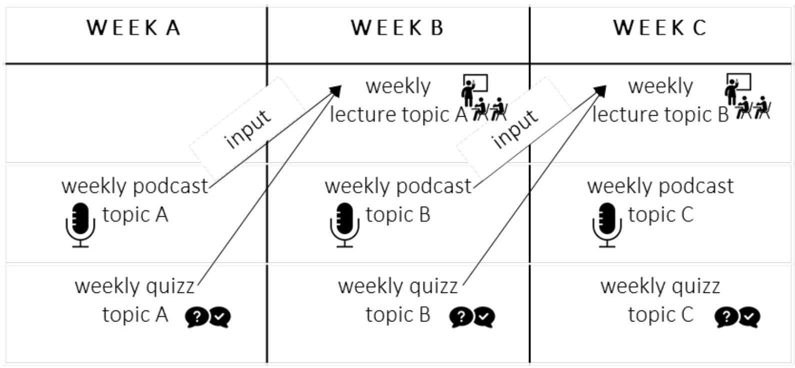

Fig. 1 Structure of the weekly lecture, podcast episodes and quizzes

In order to allow our students to realize that while listening they might not actually having been listening (goal 2) we added an online quiz to each episode. Students would only receive the bonus points if they scored 100 % with no more than two attempts. Since they were able to listen to the podcast episodes as often as they wished, this was achievable. We planned to release each episode and quiz on our learning management platform one week before the corresponding lecture, and close it again the moment the lecture began

Fig. 1), so that the students could benefit noticeably and immediately from the preparation effect during the lecture.

The lecture would recall many of the cognitive representations that the students had yet already built up. By reactivating those representations few days after first encounter in slightly different contexts they should be strengthened due to encoding variability theory and study-phase retrieval theory. In practice, our students should make the experience that they had better access to what they had learned. This would also nourish the learning experience that recalling what they had actively learned all semester long by considering, repeating, and integrating it into their own constantly growing cognitive representation of the subject, was much easier than trying to memorize mere facts in big number shortly before the exam (goal 3). To help our students feel the difference between applying the techniques we offered and not doing so, we only released every second podcast, letting every other lecture stand for itself.

4 IMPLEMENTATION AND EVALUATION

The course we chose was "Fundamentals of Industrial Information Technology", which covers the basics of information technology and the use of respective tools. The module consists of an exercise in the form of tutorials and guided project work as well as the lecture, which we intended to enrich with our new didactic concept.

We created the podcast episodes gradually over the course of 2020, winning experts for the topics from among our scientific colleagues at our department and our partner institute Fraunhofer IPK. The interviews were initially recorded in the professional recording studio and assisted by technical experts at TU Berlin. Due to Covid-19 restrictions, we had to switch to online recordings via ZOOM later.

To avoid contradictions between podcast and lecture, we revisited the lecture slides together with the according expert. We then together developed a loose script to which the interviewer and the expert could adhere during the interview. The focus was on introducing the general lecture topic by providing hands-on application examples. For this, we first needed to develop a common understanding of the key aspects with our expert partners. Since the podcast was designed as first encounter with the respective topics for our students, contradictory aspects were avoided. We also pre-phrased complicated issues in simple language together with our expert partners.

After an interview had been produced, it was time for the quiz to be developed. For this, a didactic expert tutor once again compared podcast and lecture content and also considered structure and content of the module’s main exam to make sure the quiz would refer to all those elements. The quizzes contained about ten multiple choice and multiple answer questions for each podcast episode. There was no time limit when taking the quiz so that students could even interrupt the quiz to check the podcast once more. After finishing the quiz, the students received automatic feedback on which items they had answered incorrectly, without providing the correct answer, and were offered a second go, which they could take right away or later during the week. After the second attempt, they again received their feedback and the quiz was closed for them. Students could access both, podcast and quiz, freely during the week before the related lecture.

To evaluate the success of our concept we checked the usage statistics and administered a short feedback survey on our concept to our students in the end of the semester. We asked them how many episodes and quizzes they had worked with, how they liked the format and how much it had helped them. Since we also wanted to measure if the concept had a side-effect on the students' learning outcome we assessed their scoring in the main exam, comparing answers for which they had, according to their own statement, prepared themselves using podcast and quizzes with those for which they had not.

5 RESULTS

We had not considered spontaneous responses from our students in our evaluation plan since we did not expect to get too much. Nevertheless, we could gain interesting feedback in this regard. Unsolicited emails kept coming in to the teaching team praising the podcasts as a great teaching format and actually thanking us for the production. This was something we had never experienced before. Looking at the usage statistics, 86 % of our 159 students had listened to all of the podcasts, and 14 % had listened to at least some, which was unsurprising due to the bonus system. In addition to this initial incentive, however, students quickly took a personal liking to the offering. In the survey, 81 % of the 159 students said they would have listened to at least some of the podcasts even if there had been no bonus points for doing so (Fig. 2). For the quizzes, however, only 62 % said this. In addition, 56 % of respondents rated the podcasts as "really good" and 38 % as "mostly good" in response to the question of how much they liked them. Only 6 % of students rated the podcasts as mediocre or indicated that they rather disliked them. The worst category "not at all" was selected not once.

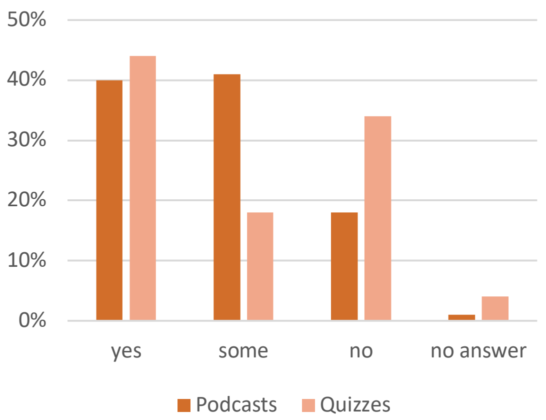

Fig. 2 Students' answer to " Would you have used … without bonus points?", n=159

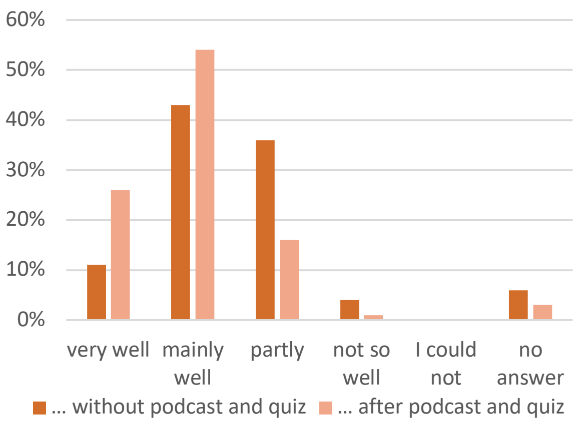

Fig. 3 Students' answer to "How well could you follow the lecture …", n=159

We asked the students how well they had been able to follow each lecture, depending on whether they had prepared for it or not. The comparison showed that 80% of the students who had worked with the podcasts and quizzes were able to follow the corresponding lecture "very well" or "mainly well", while this was only true for 54% of lectures that had not been prepared accordingly (Fig. 3). However, comparing the results from the major exam no differences showed between neither intra- nor interpersonal comparison of scoring in sections for which the students had used podcast and quizzes and those for which they had not. The average grade even decreased from 2,97 to 3,30. However, grades of this semester are difficult to compare to former semesters, given that this was a challenging time for both students and teaching staff alike, being the first “digital semester” to be held remote under the conditions of the COVID-19 pandemic regulations.

With 68 %, the majority of students was satisfied with the limited availability of the podcasts in the week before the corresponding lecture. This was the most frequently selected response option to the question of when the podcasts should be released, although a good third of the students also stated that they would like to be able to work on the set after the lecture. When asked about their preferred media format, 56 % of the students rated the podcast format as better than video interviews or as equal to them. 39 %, on the other hand, would have preferred video interviews.

6 DISCUSSION

To evaluate knowledge and changes in students’ mindset is very difficult. We expect distorting effects due to our decision to offer bonus points, for example. We are not able to tell if our students would really have used the podcasts and quizzes without the incentive but we believe that such incentives are necessary at least until the students had a chance to realize the benefits they gain from preparing and revising apart from the bonus points. We interpret our students proclamation that they will use the format even without bonus points as indicator for the effectiveness of the concept. Also the unusual act of sending us compliments and notes of thanks in our opinion shows that our concept addresses a sensitive spot.

Our concept did not include students’ guided reflection on learning experiences, which is considered a necessity for self-regulation in learning [16]. Our focus was on creating a learning situation in which our students got the chance to compare different approaches to learning as spontaneaous personal reaction to their immediate experiences, without someone telling them to do so. We expected a certain degree of resistance in some of our students if we would give them additional tasks that were not obviously related to course content. This was the reason why we carefully designed the learning experience to be integrated into the coursework as unobstrusively as possible. However, it might very well be that asking students explicitly to reflect upon their attitudes, actions and results would further strengthen the effects of the intervention.

Our students did not score higher in the exam due to the concept. This is no surprise since learners invest their resources when they do not feel prepared enough for examination by the coursework. In our case, they already invested extra time in repeatedly listening to the podcast and doing the quizzes, usually scoring 100 % at the second attempt, thus feeling well prepared and allocating their energy to other fields, e.g. the lectures for which no additional material had been offered. However, we did not target high scores but wanted to tackle our students' concept of learning. We are aware that a few months of doing things differently can probably not weigh out 13 years of former experience. However, if our students feel that their school-based learning strategies are of limited use in the university setting, they now have already experimented with an alternative approach to learning.

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DOES NATIONALITY COMPOSITION AFFECT STUDENT GROUPS' COLLABORATION AND PERFORMANCE? A CROSS-CASE ANALYSIS

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Keywords: *International classroom, group composition, nationality, collaboration*

ABSTRACT

A Dutch STEM university is aiming to create an inclusive international classroom where diversity is appreciated as an indispensable element of the quality of learning. One aspect of the international classroom is to enable students to acquire international collaboration skills through working in mixed nationality student groups. In a previous interview study, we found that group composition of nationalities has consequences for collaboration, in which having just one 'token' international member group seems particularly ineffective. This paper presents a follow-up observation study that compares collaboration and performance in three compositions of mixed-nationality student groups. We analyzed online meeting recordings, evaluation questionnaires, and self-reflection reports. In the cross-case analysis, we focused on: 1) members' participation in the meetings (frequency of utterances), 2) disagreement episodes (triggers and solutions), and 3) group performance (teachers' grading and students' perceived performance). The results suggest that in the group with one international member, group meeting conversations were skewed towards the domestic Dutch students. This group encountered more process-related disagreements, competitive disagreement

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solutions, experienced a low level of trust, more emotional discomfort (such as pressure), and experienced less satisfaction. By comparison, in the other two groups where nationality was more equally distributed, members evenly contributed to meetings. These groups were observed to have more task-related disagreements, more information elaboration and agreement solutions, and higher levels of trust, satisfaction, and group belongingness. This observation study contributes to awareness of student diversity effects that allow teachers to take the next step towards facilitating mixed-nationality student groups in the international classroom.

1 INTRODUCTION

1.1 Research background: creating an international classroom

Many future engineers will work in multidisciplinary and international teams on open engineering problems. This requires engineering education in an international context, working in diverse teams, and gaining international collaboration experiences. A Dutch STEM university, located in the center of one of the worlds' leading technology hubs, is currently working towards creating a diverse and international classroom, resembling the make-up of the high-tech labor force [1]. Recently, the university has formulated its policy on the international classroom. The policy defines "International classroom" as: a learning space of a group of students in which 1) different nationalities with different cultures are represented, 2) the common instruction language is English, which is not the first language of most students present, 3) students and staff engage in and appreciate diverse and mixed nationality teams, and 4) the diverse learning environment is (created) such that it enables students to gain international and multicultural experiences and enhances the education quality.

The lack of interaction between domestic and international students in project courses has become a common concern in most English-speaking countries, such as the US and UK [2]. The most often referred challenges of working in a mixed nationality student group have been reported to comprise language barriers, academic culture differences, and a negative experience with and/or a stereotype view of international students [3]. In the Netherlands, this could be even more complex since English is not the native language for both domestic and (most) international students. This research project aims at exploring the challenges and gains in international student teams as well as finding factors that facilitate/hinder students' collaboration and group performance in the current international classrooms. By achieving the research aim, it contributes to strengthening the international classroom and facilitating the successful implementation of the international classroom at the university. It also contributes to engineering education, i.e., forming effective culturally diverse work teams in project courses. As outlined in the SEFI position paper (2018) [4]: "substantial progress must still be made to achieve the SEFI vision: 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. [4]"

1.2 Our initial studies on student group work in the International classroom

The project started with an inventory study of the degree of current internationalization per subject /course [5]. The inventory study identified subjects and courses that involved student group work as well as a substantial number of international students suitable for our next studies. Based upon the above inventory of suitable subjects and courses, we selected ten master students from different study programs who had mixed nationality student group work experiences for an in-depth interview. These ten students included five Dutch students and five international students (one Portuguese, one Pakistani, and three Chinese).

Our interview study showed some issues in group compositions and group collaborations in the current international classroom [6]. Firstly, forming a mixed nationality group is not naturally happening as we wish to see. Domestic and international students often sit separately in the classroom, and they tend to form a group with those who are similar to them. Secondly, becoming the only international member in a domestic Dutch student group has brought great challenges to the international students. International students as a minority group in some courses often face a situation that they have to join a group with a majority of domestic Dutch students. As a token international member in a group, domestic Dutch students are more inclined to switch to speak Dutch and thus make the international member feel *frustrated*, *distanced*, and *excluded*. Thirdly, domestic Dutch students often perceived the extra efforts taken to effectively collaborate with international students in one group, due to different cultural backgrounds and language issues.

In sum, our interview study showed the current challenges of mixing Dutch and international students in international classroom group work and indicated the consequences of student diversity for group collaboration and performances. Based on the results, we concluded that the vision of international classroom has not yet been achieved. It provides a starting point to further compare group collaboration behaviors and group performances with members of varying nationalities (nationality balancing group and token international member group) to see the consequences.

1.3 Current study design: observing students' collaboration behaviors and group performances

This is a follow-up study of the interview study, aiming to explore the student diversity consequences on group work by observing students' collaboration behaviors and group performances across three types of compositions of mixed-nationality student groups.

Group diversity composition

Diversity refers to differences between team members, and it could refer to any attribute of differentiation. Given that our study is about diverse student groups in international classrooms, we limited our explorative focus primarily on differentiation in *nationality* (place of birth) but also taking into account *gender and expertise* differentiations. Based on this, we selected three student groups to observe their collaboration behaviors and group performances. Suppose there are four students in one group. Group 1 would then consist of only one international student, and the remaining three are Dutch students. Group 2 consists of two international students who have the same nationality, and the remaining two are Dutch students. Group 3 would then consist of two international students with different nationalities, and the remaining two are Dutch students.

Intragroup collaboration behaviors

Nationality diverse students have often been reported to bring a variety of perspectives and approaches to the group, which contributes to the quality of learning and decision making, compared with homogeneous groups [7]. However, nationality diverse groups encountered more challenges such as misunderstandings and caused discomfort, poor interactions, a lack of trust, and perceptions of more interpersonal conflict [8]. “Disagreement”, different perspectives among group members, is found to be one of the key processes in mixed nationality student group work collaboration behaviors, from our interview study results. Such group conflicts have been studied extensively in the educational field. For example, Lahti et al. [9] observed small groups of student teachers’ collaborative learning and found three types of conflicts: “content-specific argumentation between different views and conceptions” (task-related conflict), “conflicts concerning responsibilities and the division of tasks” (process-related conflict), and “interpersonal issues” (relationship-related conflict) (p.151) [9].

In general, task conflict is seen to positively affect individual learning and team performance, as it stimulates members’ engagement into explaining, arguing, and negotiating their positions while coordinating their opinions on the task. In contrast, process and relationship conflicts are seen as negatively affecting team performance [10]. Dealing with conflicts in a group has been shown to enhance learning, enhance critical thinking, and lead to higher-quality solutions to complex problems [11]. Aarnio et al. [12] have created a framework to identify how student groups handle their conflicts using the following dimensions: elaborated/not elaborated, individual/collaborative, and conforming/competitive [12]. “A conflict episode is not elaborated on, if students either accept counter arguments immediately (Conforming), or adhere to their original conclusions without explaining them, and reject others’ ideas without showing interest in them (Competitive). A conflict is elaborated on when one student explains the justification of his/her opinion (Individual), or when two or more students contribute to resolving the conflict using argumentation (Collaborative). Elaboration of conflicting ideas can also be competitive if students give a rationale for their ideas only to prove that they are right” (p. 219) [12]. In the current study, we used the above knowledge conflict solution dimensions to analyze how student groups handled their intragroup disagreements.

Group outcomes

Social categorization holds that people are more positively inclined toward those who are similar to them rather than dissimilar, and as a result, the more homogeneous the workgroup, the higher member commitment, and group cohesion will be leading to higher group performance [13]. The information/decision-making perspective holds that the diverse groups are more likely to process a broader range of task-relevant knowledge, and leads to creative and innovative ideas and solutions [14].

We choose to measure group outcomes by focusing on *group report grade*, *satisfaction with the group*, and *experienced inclusion*. In general, group performance and affective outcomes, i.e., satisfaction are important group work outcomes that lead to success and continuation of group work [15]. Besides, we added group inclusion as a third outcome, as it is an important concept in diversity groups. In our study context, we wanted to know how students in diverse groups feel included by the group, particularly from the perspective of the international students.

1.4 Research aim and research questions

So, building upon our previous interview study, this study aimed at comparing student intragroup collaboration behaviors and performances across three types of group diversity (mainly nationality) composition, and thus exploring how the group diversity composition influences group collaboration process and performance. By identifying the differences in group collaboration behaviors and group performances, it is expected to contribute to enhancing teachers' awareness of diversity effects in composing student groups in the international classroom.

To achieve the above research aims, two research questions were formulated as:

RQ1. Do student-group intragroup collaboration behaviors differ across types of group diversity composition, and if so, in what way?

RQ2. Do student-group performances differ across types of diversity composition, and if so, how?

2 METHODOLOGY

2.1 Participants

This study was approved by the Ethical Review Board of the university <ERB2020IEIS46>. Participants in this study were 13 master students (three student groups) from a multidisciplinary course offered by the Department of Industrial Design. We purposefully selected this course, because it contained a group assignment (counting towards 50% of the final grade), and there were a relatively large number of international students enrolled in this course. Students need to design a recommender system for food as a group in eight weeks.

Group 1 consisted of three Dutch students and one Chinese student; Group 2 consisted of two Dutch students, one French and one Chinese student; Group 3 consisted of two Dutch, two Chinese, and one Indian student. These 13 students agreed to participate in this study and gave their informed consent.

2.2 Data collection

The research data consisted of 1) student groups' meeting video recordings, 2) a short performance evaluation questionnaire, and 3) students' reflection reports – evidence for individual learning goals and the reflection on group process.

Since students' meetings were organized online, we chose to use the non-participant observation method to collect video data to maximize students' comfort in the online learning environment. One student from each group was assigned the task of video recording their meetings (with all group members present) three times: a first group meeting, a second group meeting halfway along with the deadline, and a third meeting before group assignment submission.

A short digital questionnaire was sent to all students to measure their perceived group performance after receiving the last meeting recording, and students were required to complete the questionnaire before they received their group grades. The questionnaire scales included *expected group performance*, the *satisfaction of working in this group*, and *group work inclusion*.

To obtain additional evidence for individual learning goals and the reflection on the group process, students were asked to voluntarily share their self-reflection reports with the researcher, which is a mandatory deliverable in the course. In the end, we received 11 (out of 13) self-reflection reports.

2.3 Data analysis

A cross-case analysis was used to compare the intragroup collaboration behaviors and performances with three foci: 1) member participation (frequency of utterances), 2) disagreement episodes (triggers and solutions), and 3) performance (teachers' report grade and students' perceived performance).

The unit of analysis for video data is a disagreement episode, defined as a series of interactions where students deal with disagreements on assignments. A disagreement episode begins from a situation where a student utters an idea that is contradicted with a counterargument, non-confirming, or a critical question by another student [16]. A disagreement episode ends when students agree on the issue, change the topic, or confirm what is claimed.

The number of utterances by each student was calculated to understand group members' participation in the group conversations in each case. We did not specify the types of utterances; whatever the student said was counted once.

The means of questionnaire scales were calculated to compare group outcomes across three cases. Open coding method was used to analyze students' learning gains from their self-reflection reports.

3 RESULTS

Table 1 displays an overview of three cases' information, including group composition, group disagreement episodes and handling disagreements, and group outcomes. We gave an interpretation of group diversity compositions across three cases, followed by presenting two research results to two main research questions.

Table 1. Comparisons of three cases

	Case 1 (N = 4)	**Case 2 (N = 4)**	**Case 3 (N = 5)**
Group composition (Nationality, gender, department) Note: ID = Industrial Design; IE&IS =	1. Dutch, Male, ID 2. Dutch, Male, ID 3. Dutch, Male, IE&IS 4. Chinese, Female, ID	1. Dutch, Female, ID 2. Dutch, Male, ID 3. French, Male, ID 4. Chinese, Female, IE&IS	1. Dutch, Male, ID 2. Dutch, Male, ID 3. Indian, Female, ID 4. Chinese, Male, IE&IS

Industrial Engineering & Innovation Science			5. Chinese, Female, IE&IS
Frequency of utterances by each student	Dutch, Male (259) > Dutch, Male (207) > Dutch, Male (154) > Chinese, Female (97)	Dutch, Female (389) = Dutch, Male (389) > Chinese, Female (359) > French, Male (295)	Dutch, Male (290) > Dutch, Male (258) > Indian, Female (157) > Chinese, Male (101) > Chinese, Female (80)
Number of disagreement episodes	Task-related disagreement (73%) Process-related disagreement (27%)	Task-related disagreement (95%) Process-related disagreement (5%)	Task-related disagreement (100%)
Triggers of disagreement	Different perspective (54%) Different understanding (27%) Different perspective & understanding (9%) Distrust (9%)	Different understanding (66%) Different perspective (33%)	Different understanding (50%) Different perspective (37%) Different background (12%)
How disagreements handled	Elaborate, individual, agree (18%) Elaborate, collaborative, agree (54%) Elaborate, competitive (27%)	Elaborate, individual, agree (57%) Elaborate, collaborative, agree (33%)	Elaborate, individual, agree (25%) Elaborate, collaborative, agree (75%)
Group grading from teacher (N = 50 points in total)	42 points	40 points	41 points
[2]**Individual expected group performance (Mean)**	2.58 (Positive)	1.42 (Positive)	1.73 (Positive)
[2]**Satisfaction within the group (Mean)**	3.25 (Slightly positive)	1.25 (Positive)	1.87 (Positive)
[2]**Work group inclusion (Mean)**	4.17 (Slightly negative)	3.34 (Slightly positive)	4.60 (Negative)

3.1 Group compositions of three cases

Taking a closer look at our three group member compositions, Case 1 included only one international member, and she hardly shared any similarity with the remaining three Dutch members. The international student was the only female, non-Dutch, and had completed her bachelor's program in her home country. Although she was enrolled in the Industrial Design program, like two of the three Dutch students in the group, this had not created an opportunity for her to get acquainted with them in advance. Besides, she was a first-year master student and this group assignment was probably one of her first courses taken in this new country. Due to the influence of COVID-19, all teaching activities and social activities (e.g., introduction weeks for first-year students) had been scheduled online, which greatly reduced social activity opportunities. By comparison, Case 2 and 3 at least had crossed differences in nationality and gender. We added the task-division situations across three cases to better understand the composition of differences in each case. In Case 1, the group work was divided into three parts taken by two Dutch male members, one Dutch male

[2] 7-point Likert scale (1 = strongly agree; 7 = strongly disagree).

member, and one Chinese female member. Case 2 divided their group work into four parts taken by an individual member. Case 3 has divided the group work into three parts taken by one Dutch male member, one Chinese female and one Indian female member, and one Dutch male and one Chinese male member.

3.2 Comparison results of intragroup collaboration behaviors

Table 1 shows differences in international student member utterance participation and different types of disagreement episodes including triggers and solutions across three cases.

In general, Dutch members' group conversation participation was the highest across three cases. In Case 2, four members' utterance frequency was more or less equally distributed. By comparison, Case 1 and Case 3 showed more skewed conversations towards two Dutch members within each case. So, the international members particularly Chinese members' utterances were low in Case 1 and 3. Although the Chinese female member's utterance was the lowest one in Case 3, it was because she only attended the last meeting for about ten minutes due to another exam. So, the Chinese female member's utterance in Case 1 was probably the lowest among the three cases.

Overall, more task-related than process-related disagreements were found across three cases, and we did not find any relationship-related disagreements. Case 1 experienced more process-related disagreements than the other two cases, which indicated more time spent on discussions about the division of the task and management of responsibilities. Case 2 has experienced the most task-related disagreements, which indicated more time spent on the elaboration of the task-relevant information. Case 3 experienced task-related disagreements as many as in Case 1.

The majority of disagreements were triggered by either different perspectives or different understandings across three cases. Case 1 was triggered more by a different perspective compared with the other two cases. Different perspectives indicated the exchange of information and perspectives. For example, students in Case 1 often gave counterarguments or asked critical questions like: "I think the idea wasn't correct with how the machine learning works. So it's better to move forward… It sounds good to have a unique selling point, however, we need to combine it with machine learning…" Different understanding contained the exchange of interpretations of information and perspective, to seek mutual understanding. For example, students in Case 3 displayed more exchange of understanding behaviors, like "… Yes, that means you don't like any dish that is shown on the screen right now, then you don't need to wait till the end of scrolling…"

All three cases used elaboration to handle these disagreements, namely students (individual or collaborative) explain or justify ideas to resolve the disagreements. Case 3 has experienced more collaborative elaboration to resolve disagreements than Case 1 and 2. Case 2 has experienced more individual elaboration (two group members involved) than the other two cases, and only Case 1 experienced elaboration with competitive resolution.

3.3 Comparison results of group outcomes

We compared student intragroup collaboration outcomes based on report grade, students' evaluation questionnaire results, and students' self-reflection reports.

The total grade for the group report is 50 points. Only minor differences were found in group grading across three cases: 42 points for Case 1, 40 for Case 2, and 41 for Case 3.

Differences were found in students' evaluation questionnaire results and their self-reflection reports. Case 2 showed the most positive expectation about their group performance, highest satisfaction of working in this group, and highest sense of inclusion by the group. By comparison, Case 1 showed the least positive expectation about their group performance, less satisfaction of working in this group, and less sense of inclusion by the group. Case 3 in general showed positive expectations about group performance and a higher sense of satisfaction of working in this group, however with the lowest sense of inclusion by the group.

Although Case 1 received the highest report grade across three cases, group members showed less positive expectations about group performance and less sense of satisfaction of working in this group. Students' self-reflection reports indicated that Case 1 experienced an imbalance workload distribution issue among four members, so two Dutch male members with a high level of stress of doing too much and the remaining Dutch male and Chinese female members were ambivalent about what to do. For example, one Dutch male member with a lot of pressure reported that "*There was a lot of stress within the group due to work imbalance and missing skills to help out in areas where more work was needed to be done. A team member and I tried to take on as much work as possible to keep the process going, resulting in an even bigger work imbalance. After asking guidance from the teacher, … I can focus on my learning goals and less on the work that just had to be finished*." Another Dutch male member with ambivalence about their group work reported that "*It would be wise to make explicit what my personal responsibility would be, in case I had a shared responsibility with a teammate, then I could have prevented that my teammate had already done a large share of the work before I knew it…*" From students' self-reflection reports, we found one facilitating factor of timely teacher guidance and feedback that helps Case 1 get back on track working towards a shared goal.

4. Summary and implications

This study compared intragroup collaboration and performance across three student groups, each with a different nationality composition. Case 1 consisted of one international student with three Dutch students, and Case 2 and 3 had two or three international students with two Dutch students. We observed that the Dutch students in Case 1 dominated the group meeting. This group encountered more process-related disagreements, competitive disagreement solutions, a low level of trust, more emotional discomfort (such as pressure), and experienced less satisfaction. By comparison, group meeting conversations were more evenly distributed in Case 2 and 3, particularly in Case 2. These groups had more task-related disagreements, more information elaboration, and agreement solutions, reported higher levels of trust, satisfaction, and group inclusion. These differences contribute to the awareness of student diversity effects that allows teachers to take the next step towards facilitating mixed nationality student groups in the international classroom. Based on this study, we draw three tentative implications. Firstly, from a group composition perspective, a deliberate mix of Dutch and international students appears necessary to guarantee a feasible group composition. In particular, having one international member in a Dutch student group should be avoided if possible. Secondly, having a concrete inventory of individual member's backgrounds, expertise, learning goals, etc within the group provides a solid base for collaboration for mixed nationality student groups. Thirdly, timely teacher (coach) guidance is important to facilitate student groups (particularly with only one international member present) who experienced troubles and issues in continuing collaboration.

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BLENDED LEARNING IN AEROSPACE COMPANIES' TRAINING COURSE: CONVERSION OF A CLASSROOM-BASED TRAINING TO BLENDED FORMAT

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ABSTRACT

A network of German aerospace companies and academic institutions initiated the research and the development of a (re)training for new employees who enter aerospace software development with different educational and professional backgrounds. Based on the analysis of the companies' and the labour market's demands, a classroom-based training was designed. After implementing and evaluating the training, the participants' feedback led towards further development beyond traditional classroom boundaries and the individualization of the training material.

To fulfil the participants' needs, the blended approach was chosen among other learning approaches. A blended format was developed to surpass the limitations of classroom-based training and includes various teaching methods and customized content while still offering face-to-face interaction. This paper describes the conversion from the classroom-based training to a blended format for new employees entering aerospace companies.

This conversion required selecting the suitable teaching methods and the topics that ought to be converted and conveyed digitally. The content, the difficulty level and the pros and cons of each teaching method were taken as criteria to determine the selection. Depending on their educational and professional background, the participants can choose the content and their learning environment without time and place restrictions.

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The training is currently under development and scheduled to be conducted in autumn 2021. The evaluation following the training will offer feedback from the participants' perspectives to endorse the focus on their learning needs. Due to the COVID-19 pandemic situation, alternatives such as online training are considered but the blended format remains its priority.

1 INTRODUCTION

Back in 2017, before the challenges that COVID-19 brought to education worldwide, a network of eight German companies formed under the publicly funded research project “Avionic System Software Embedded Technologie-2” (ASSET-2) formulated the demand for a training course for new employees entering the aerospace industry. Ingolstadt University of Applied Sciences (Technische Hochschule Ingolstadt – THI) designed a classroom-based training to cover the companies' demands for a common elementary introduction to aerospace software development. These demands derive from the recruitment process in the aerospace industry that also affects employees from pertinent fields, e.g. automotive engineering and STEM. Aerospace companies have to reach out to software engineers and architects with a wide variety of academic and professional backgrounds. Afterwards, the challenge remains at each company to train the new software engineers through further training courses or whilst on the job.

The development of the classroom-based training, as the fundamental training development strategies indicate, started with the needs analysis; followed by the implementation and the evaluation of the training. The feedback from the participants and the companies revealed the need for individualization of the training. The participants expressed their individual learning needs and were in favour of the opportunity to self-regulate which parts of the training they will attend. Based on this feedback, the further development of the training started in 2020 under the publicly funded research project “Integrierte Design- und Entwicklungsumgebung für Aerospace” (IDEA) aiming at a customized outcome for the participants within a network of twelve German aerospace companies and academic institutions. It sought to cover the learning needs of the individual employee and the different companies' demands by supporting his/her prior experience. The companies' demands concern also the necessity for data protection and confidentiality regarding the employees and the training material.

2 THEORETICAL BACKGROUND

Catalano concludes that Blended Learning (BL) enables the personalization of the learning process by using different learning and teaching methods physically and virtually [1]. BL involves the use of technology and remote learning and combines classroom and eLearning sessions [2]. This learning approach enables the transition to the current demanding situations with numerous benefits. The potential of personalization and individualization of the training is extremely important for this training for the introduction of new employees in the aerospace industry. The classroom-based training from the ASSET-2 project has a duration of eight days, which can take place in either two or four parts. Both possibilities demand extra time for travelling to the training facility. The effort to find common available dates for employees from different companies and cities while also having a sufficient number of participants at training is challenging and delays the implementation of the training. A delay for an employee can undermine the value of attending. For example, if an employee waits six months to take part in the classroom-based training, he/she may already have needed the knowledge that the course contains. Afterwards, when the training finally takes place, he/she may have already acquired the knowledge that the training intends to transmit.

Considering such problems, this blended learning format aims to enable employees to access the content and obtain useful knowledge for their new position before the face-to-face (f2f) sessions. This research implements the “flipped model” of blended learning [3], [4]. After the online part, the participants attend the f2f sessions and meet with the trainer where they have the opportunity to acquire competences through different practical exercises. Thus, a blended format for this training lowers the cost and establishes exchange opportunities for the network among the companies and their employees.

3 METHODOLOGY OF CONVERSION

The starting point of this research is the evaluation of the ASSET-2 classroom-based training that took place in 2019. The ASSET-2 classroom-based training is divided into five modules and lasts 56 hours. Questionnaires and interviews were conducted with 11 participants of the training, 16 subject matter experts and eight managers of this field. The evaluation of the classroom-based training revealed the need for individualization and customization of the training. The outcome in 2019 when companies and employees were hesitant towards online trainings was the preference for f2f sessions. The benefits of expert discussion sessions were considered a highlight for such entry-level employee training. The research of IDEA project aims at the customization of the classroom-based training for employees entering the aerospace industry. Customization provides learners with the opportunity to choose and construct mostly independently the training they need. How a classroom-based training can offer this independence and individualization is answered through digital technologies. During the last year many, if not all, universities, schools, and educators were unexpectedly forced to move classroom-based courses into an online environment. Courses about various topics, from numerous fields and for different audiences were obligated to switch to online. In many cases what happened was the substitution by digitalizing the material that was already available and delivering it via a learning management system (LMS) that acts as an online platform. From lecturing live in a classroom, the trainer began lecturing through a camera live or asynchronously. The obligatory transition to a remote working and learning lifestyle is not necessarily equal to a transformation of the training courses. Different terms try to describe such processes but neither all mean the same nor reflect the desirable and ideal process. The term “conversion” has been chosen for this research because it describes the act and active decisions about the process [5]. This differentiates it from “transition” that refers only to the process of changing from one state to another.

The goal of this blended format is the customization of the training in order to serve the personal learning needs of the new employees. This format includes an online part and a f2f session. The online part takes place first. The participants have a period of two months to access asynchronously the content via the LMS. The LMS contains all digital materials such as e.g. videos, documents, a discussion forum and chat sessions. The obligation to complete the online course materials before the f2f session depends on and is determined by the participants. They can access the training material any time from a place of their choice. The obligation to complete it does not necessarily apply to all material because the participants can differentiate the content depending on their educational and professional background, needs and preferences. They are able to choose which part they will devote more time to and if they skip or re-watch a video. The introduction and the structure of the training along with the information for each chapter and subchapter provide a brief overview of the subjects. The participants are informed about the content of the video and if they are already familiar with it, they can fast forward a sequence or skip it. The material is always available which means that they can return at a later time and watch it, in case a question appears.

For the conversion of the classroom-based training to a blended format, the curriculum design of the classroom-based training is necessary to be subjected to change. The demands about the content of the training remain the same, but the teaching and learning methods ought to change according to the blended format. Since the learning and teaching methods change, the curriculum design of the classroom-based training had to be converted because it cannot serve the blended format. The curriculum design incorporates the learning objectives, teaching and learning methods, time schedule, structure and assessment.

The way a training developer should choose the suitable method and tool for every chapter is answered through the following criteria: The differentiation starts by choosing which content will take place online and which f2f. The blended format, as explained above, ought to have a f2f session for practical exercises, expert discussion and direct live exchange opportunities among participants and between participants and trainers or experts.

1. The first criterion is the distinction according to the chosen teaching method of each subchapter. Possible teaching methods for this training are practical exercises, group projects, discussion sessions, expert discussions and instructor-led training (ILT). According to the theories behind these teaching methods, some are more suitable for f2f sessions, while others for the online part of the training. The learning objectives affect the method of delivery according to which skills needed to be developed. There are practical exercises where the participants ought to work hands-on or need access to laboratories or specific software. Therefore, practical exercises and group projects are a priority for the f2f sessions, where the application can take place and the participants have direct contact with their fellow participants and trainers. Discussion sessions among participants can take place in f2f and online using various tools without any drawbacks. The categorisation for these sessions will be finalised after taking into consideration the following two criteria. Expert discussions suit both options. However, since direct contact

between participants and experts is desired, expert discussions are also implemented into the f2f sessions. Otherwise, it would be possible to organize such an online session for discussion among experts and participants. ILT can serve well the learning objectives in an online eLearning environment [6], [7]. Therefore, ILT is classified to be part of online sessions and practical exercises, group projects and expert sessions of the f2f sessions.

2. The second criterion is the subject of each chapter and each subchapter. The difficulty level, the depth and the complexity of each subject influence also the decision between online or f2f sessions. The comprehension of these subjects requires examples and practical application. Theoretical parts related to the content of the exercises need to be summarized and performed in the f2f session as an introduction to the practical exercises. Regarding examples that can be included in every teaching method, eLearning can enhance considerably their presentation with e.g. animations, but there are still cases where the trainer can predict that additional explanations will be requested [7], [8].
3. The third criterion is the overall structure and planning of the training. The available time for f2f sessions can affect the final categorisation. Here, subchapters such as discussion sessions that can take place online as well as in f2f session, will be respectively divided depending on the available time and the thematic relation with the rest of the f2f subjects. Subchapters e.g. that can offer a thematic summary before an exercise can also belong to the f2f sessions.

With categorizing the subjects using these criteria, the training is divided into two kinds of sessions: online and f2f. The training developer examines in detail which online platform and tool can serve the online part, always taking into consideration the learning objectives of each chapter. The training budget and the restrictions of participants' companies need to be examined here thoroughly to avoid complications afterwards when conducting the training. This blended format allows the learner to individualise and self-regulate the online part. This concerns apart from the content, also, the teaching and learning methods of the online part. The research aims at the individualisation by examining the different types of training videos and the preference on the teaching methods by the participants in order to enhance the comprehension of the subjects. Such are videos where the trainer is a) facing the camera, b) recording with voice-over or c) broadcasting live a video. In a) there may be a green screen behind the trainer in order to change the background and/or add slides with relevant information e.g. written text, animations or graphics. For b) the options are similar as the participants see the slides, animations, graphics etc. while only hearing the trainer's voice. These two options can be recorded either with one camera (front or rear-facing), with multiples cameras or via software screen recording. A Webinar is option c); a live video broadcast in which the learners participate synchronously and the camera can be recording from different perspectives as mentioned above. Other tools used on online platforms are discussion forums, chat rooms and quizzes. To list here the vast variety of tools available for an eLearning training developer is impossible; for the sake of brevity, we referred to the relevant tools for this training.

At this point, the learning methods have been chosen, but not the duration of the online and f2f sessions. The online sessions need to have a small duration between five and 15 minutes. The f2f sessions will be planned at the THI with the intention to exchange views within the practical exercises and converse about different roles. We incorporate additional social activities outside of usual working hours to enhance the networking among the participants of the network that hold different positions. Hence, the participants gain insights on other companies' approaches and procedures. The online aspect of blended training brings out further features that need thorough consideration and planning such as the development of videos for the online part. The user experience of the participants in eLearning affects the learner's experience [8], [9]. Therefore, the design of the platform, the duration of a session, the features, the video and audio quality, the quality of the background, slides or figures and everything that is shown in a video and every tool used on the platform needs to be previously examined and tested.

This blended format ends with the evaluation. The participants complete the training with an online exam for the assessment of the learning. They decide for themselves when and if they take the exam depending on their personal goals and company's demands. In addition, the participants will be asked in form of questionnaires and interviews to assess the content, the learning methods and the structure of the training. The evaluation aims to elicit the learning preferences of the employees after participating in this training and their capability of applying the acquired knowledge. This aims at the further development and potential improvement of the blended format. The questionnaires and interviews will also enlighten the second perspective of the evaluation; how the research goal is achieved. The participants evaluate if their learning needs are covered with this format. The investigation of their opinions and satisfaction level regarding their experience with the training's customization are the desired outcome.

The evaluation occurs in three steps; firstly, the participants will answer the online questionnaire (Q1) before starting the training, secondly, the questionnaire after participating in the training (Q2) and thirdly, three months after the training they will assess the training in a semi-structured interview (Fig. 1). The first online questionnaire (Q1) prior to the training investigates the learning needs of the participants at the beginning of their onboarding. In Q2, the participants assess the training and in which level the materials of the online and f2f sessions and the learning and teaching methods correspond to their needs and learning preferences. The interview takes place purposely three months after the training so that the participants are able to evaluate the training after gaining relevant experience in their new position.

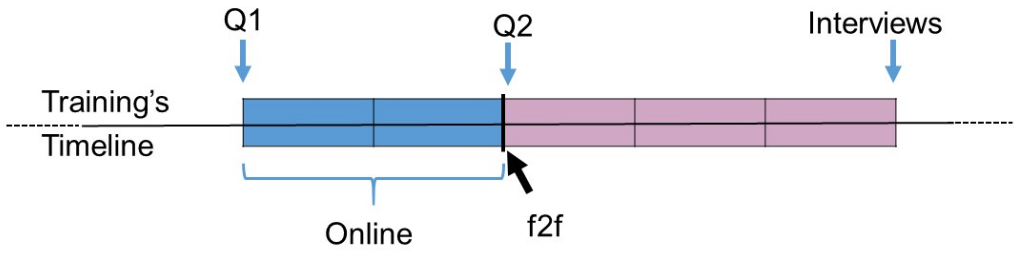

Fig. 1. Timeline

4 IMPLEMENTATION

Currently, the training is divided into online and f2f sessions. The material for the online sessions and the f2f sessions that will take place in the second or third quarter of 2021 is under development. The structure of the training is clearly defined and presented as an introduction where the participants can see the chapters, the subchapters and the learning path overall.

The categorization of all subchapters of the training using the three criteria resulted in the blended training with 21.65% f2f and 78.35% online sessions as described in Table 1. According to the first criterion, 11.34% of the training would be conveyed in f2f and 96.91% in online sessions. The 11.34% belongs to practical exercises, group projects, discussion sessions, expert discussions that the training subjects contain and need the f2f interaction among participants, trainers and experts as explained above. Based on the second criterion we examined thoroughly the difficulty of the subchapters; increased the f2f session to 19.59% and decreased the online sessions to 80.41%. The third criterion led again to an increase of the f2f sessions to 21.65%. A subchapter, for example, that is thematically close and important for a practical exercise is categorised to the f2f sessions according to the 3rd criterion.

Table 1. Assessment Criteria

	Training sessions	
Criteria	f2f	online
1st	11.34%	88.66%
2nd	19.59%	80.41%
3rd	21.65%	78.35%
Final	21.65%	78.35%

Selected for the delivery and support of this training is the Moodle platform. The participants access the Moodle platform of THI with a personal email address before the f2f session. This platform is user-friendly, fulfils our requirements for data protection and confidentiality and supports the learning process with various features and plugins. While developing the online material, we intend to use all aforementioned types of online videos in order to explore how learning styles are satisfied. The videos are being developed with the green screen technique to add slides and backgrounds, voice-over text and with different camera perspectives, in cases where the content can be promoted. The participants will be able to choose among the different video types and communication channels according to their preferences. After the training, the participants fulfil the Q2 to evaluate the training overall; the content, the learning styles and methods. In telephone or in-person interviews three months after the f2f session the participants will analyse their learning preferences and needs regarding customization. An assessment of learning within this training by taking the exam is not intended because of confidentiality of personal data.

5 CONCLUSION

Through this blended format, THI converted the classroom-based training while surpassing the previous limitations of classroom-based training for corporate training. The methodology of the conversion sought to document and enrich the literature of training development. The blended format we defined in this paper includes various teaching methods and customized content while still offering f2f interaction. This format offers the benefits of an online course that does not interrupt the participants' workflow. It answers the companies' demands while not restraining the different individual learning needs. The new software engineers and architects of different companies, while coming from a wide variety of academic and professional backgrounds acquire a customized outcome based on their personal needs. The importance and benefits of f2f interaction and contact with experts, trainers and employees from other companies and departments enhance the onboarding and networking among the employees and the companies. The example of this training's conversion can also be applied by training developers and educators in other fields. An additional expected research result is the data about the attitude and the preferences of the employees today. Interesting remains to perceive if and how the attitude and the preferences of the employees changed, more than one year after the start of this digital and remote working reality that everyone was forced to enter. Alternatives such as a fully online training are being considered due to the current situation, but the blended format remains a priority for the ongoing project.

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GAMES AND GAMIFICATION IN BLENDED ENGINEERING EDUCATION

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ABSTRACT

Blended learning is a powerful way to make the student responsible for their learning. However, ensuring proper preparation is often difficult. Motivation can be gained by a stimulating application of knowledge. Games and gamification can provide both a strong incentive, support and application of knowledge for blended learning.

This paper will identify the relevant theory to support this idea as well as discuss a new application for the Maritime Engineering programme at the Delft University of Technology. The development is done in a bachelor level course and uses gamification in the form of a VR practice to teach relevant practical insights, this is a new development and the first insights will be shared.

1 INTRODUCTION

In 2002 it was predicted that blended learning would become the standard of higher education [1]. COVID-19 and the need to teach millions of students remotely was not yet an issue or even foreseen at that time. Of course, COVID-19 has given blended education a significant boost [2-6], breaking existing reluctance and demonstrating the possibilities of online, remote and especially blended learning. Much of the staff indicates that they will keep quite some aspects of online teaching alive, even when the universities reopen completely.

Osguthorpe and Graham [7] are mostly cited as the first publication using the term Blended-Learning, but the approach of course started much earlier, with various attempts to make use of a combination of online and regular education. In an extensive literature study by Güzer and Caner [8], blended learning is linked to distant learning, which goes back to the correspondence and discussion by letter between various scholars and also their (former) students. However, blended learning is much broader. It does contain a, to some extend self-paced, or asynchronous part of the remote study (supported by technology), but also contains a synchronous element where this knowledge is applied, discussed or otherwise deepened. It is also quite often linked to flipping-the-classroom, where students study individually first and use lectures to apply the theory, instead of hearing about the theory in class and practising on their own.

In this paper blended learning is combined with gamification and applied to two distinct course developments. The first course is a first-year bachelor course and this is a new development, whereas the other development started about 10 years ago and has led to a successful course design that is now not only provided at the home institute but also seven other education programmes. While the first one serves to inspire and convey lessons learned after one year of implementation, the long-term application of the second one allowed us to pinpoint critical aspects to consider in such an application and link this further to existing educational theories.

The remainder of this paper is organised as follows. In the next session games and gamification are shortly discussed from a literature perspective, to underline why such approaches were chosen, although not that common in Engineering Education. As it is not the goal of this paper to provide a complete overview, reference is made to recent overview papers on the relevant subjects. This is followed by the discussion of both developments and concluded with a short reflection.

2 LITERATURE STUDY

Games and gamification are often not clearly distinguished in daily conversations. They are, however, two quite different concepts when consulting the scientific literature. Albeit, that these two terms do show some overlap in coverage. There is even a third term, though not often linked to academic education, which is game-based learning. It is relevant in this discussion of terminology as it also could overlap parts of the previous two terms. This is represented in Figure 1 below, showing large distinct areas, but also overlap between two terms and even all three terms. Serious games in general is a term used for any game (offline and online) used to introduce a concept to the players. It is often introduced to change cultures or discuss new perspectives in a relatively safe environment [9-12]. Game-based learning (GBL) is a game focussed on learning certain materials. E.g. an online typewriting course in the form of a game, or online mathematic games for children. The difference is that in the serious game, the game itself is the learning goal, whereas, in game-based learning, the learning goals are supported by creating an actual game around it [13-15].

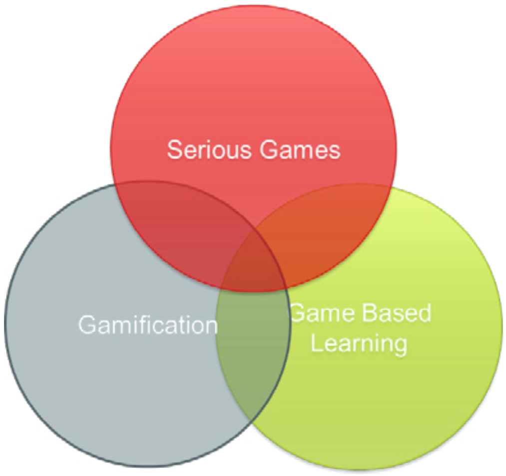

Figure 1: Representation of the three main game concepts in education.

The third term is gamification, which means the use of game mechanics to enliven the coursework. It should be clear that GBL is a form of gamification, but it results in an actual game. However, with gamification, the goal is not to create a game, but only to apply game elements to a regular learning situation. A scoreboard for good behaviour in primary schools is an example, but also the election of an employee of the month, or earning credits and status with activities on your favourite forum. Also in this case there is a clear overlap between this term and the other two [16-19]. To conclude an example that should illustrate the differences; using a list of equations and asking a student to solve as many as possible in a set time, is a form of gamification. However executed online in a race simulation against other students would be game-based learning and finally being required to do many similar equations, though not explicitly, to take the right decision, could be part of a serious game, with a focus on education.

With these differences identified, recent research in this area is discussed next. The use of GBL in academic education is not discussed in the literature to our knowledge and the amount of literature on serious games is also quite limited. However, gamification is studied quite extensively and although not often in the same, or even a related field, a benefit is that it allows for different mechanics in a game to be researched independently. As in each application, a limited choice of mechanics is only applied and this can be varied.

Most game-related research investigates motivation [16-19] and concludes on the aspects that promote or hinder the motivation of the participants. There are many game aspects study for their impact on motivation. A common division is given below with a brief explanation to give an idea of the elements relevant when considering gamification:

- Achievements; what is your current progress or an award after completing an element.
- Social; Interact with others, learn from each other, but also compete with others.
- immersion/onboarding; how much the experience draws you in, is it addictive to continue
- Freedom of choice/to fail and feedback; the fact that you are encouraged to learn from mistakes instead of repeating the teacher.
- Visible Status/Leaderboard; how are you doing compared to others? Strong links with achievements and social aspects.
- Personalization; to what extend can you create your experience. This is not only the creation of a character but also the option to skip certain parts or to try out your ideas.

Almost all game aspects influence the motivation of the students involved positively. Several researchers warn against the use of a leader board [16, 20] however. The reason for this is that although it does affect the average and well-performing students positively, it also seems to cause disengagement by the students in the bottom quarter to third. Therefore, this should be applied with care and preferably in such a way that it motivates all students and allows for the formulation of achievable goals.

Students have a limited capacity to absorb new information [21], which is also known as the cognitive load theory. When using a game in education, learning the game may already take a lot of the learning capacity of the student. Either significantly increasing the time required to complete the course or reducing the actual learning, as many aspects are not considered and therefore not understood. The burden of learning the software is often underestimated by expert users. This is not only the case with games, but relates to any new tool introduced as a means to reach the learning goal. The use of CFD software in hydromechanics classes would also require a lot of consideration on how to approach learning the tool and its limitations as well as the goals of the course. When not properly addressed, learning results will be below the expectations or the required effort will far exceed the intended course load.

Finally, the idea of using VR in education is not new, already in 1996, a paper was presented on how to use VR for teaching experiments with potential risks to students [22]. However, since 2015 a strong increase in publication on the subject is seen [23]. Although a search on applications in the maritime field yielded only one result [24] with a focus on safety training, the amount of literature on the subject is actually large. With a slightly wider search on engineering education, the result set was abundant and a choice was made to focus on recent review papers with a focus on benefits and problems and related to engineering education to pick out the key lessons. This was done as the majority either described an application of VR in education or summarized the state of the art based on these papers, without judging the applicability of VR for education.

In general, the majority of applications of VR are found in engineering education [23, 25], though the applications may vary from teaching about VR to teaching in VR. When considering teaching in VR, the goal in this project, visualization covers about two-thirds of the applications. Training and operations are only one-third. Potkonjak et al. [26] might have a good explanation for that. A key issue with VR is that it does not feel real and a student may be tempted to become playful, rather than serious. To counter this sessions should not be overly long and portrait a high sense of reality.

Based on the discussed literature games and simulators offer a way of applying knowledge and increase the intrinsic motivation of students to learn the course subjects. With these benefits in mind, as well as the warning on cognitive overloading and the disengagement potential of leader boards, two applications in the course programmes have been designed. The use of VR simulations to learn about shipbuilding at the start of their study and the use of a serious game to learn about the link between economics and technology towards the end of their studies. These implementations will be discussed next.

3 RESULTS

To apply the idea of gaming/gamification to a course is of course not new. Even within the curriculum of Maritime Technology, there is already a longstanding use of a serious business game for teaching economics and law to the master students. This course is not only offered at TU Delft but also other master programmes related to maritime technology and maritime economics. It is the success of this course that led to the initiation of the use of VR in the bachelor course.

Within this chapter, the development of the VR exercises for the first-year bachelor course is discussed. Each section will discuss one step of the ADDIE approach for course development [27], Analysis, Design, Development, Implementation and Evaluation. The main focus is on the design as this was the first year of implementation and only partially executed due to an increase in the Covid-19 measures during the course.

3.1 Bachelor Course Analysis

Several lecturers of the second- and third-year bachelor had the feeling that the basic knowledge and vocabulary had declined compared to five years ago. Although there was no concrete evidence at this stage, it was indicated that more often than before they had to explain concepts that were previously known by the students.

Based on a discussion between various staff members, it was hypothesized that the source of this was a combination of adaptations to the curriculum. First, the industry practice in the first year was cancelled, due to capacity issues. This meant that a strong frame of reference (working 2-3 weeks in steel construction) was lost. Furthermore, the set-up of a small course and a small project was replaced by one large project. This meant that students had to learn the vocabulary within the project. However, as for the project mentor groups of 6-8 students were used, work was often divided between the students. In turn, this led to not studying all materials, but only a fraction.

Unfortunately, there was not yet enough data available to verify this assumption, something to be addressed in the redevelopment as well.

3.2 Bachelor Course Design

It was decided to redevelop the course set-up, using blended learning to allow for a more individual learning approach. In Figure 3 the content focus of the course is displayed. Each subject represents a week of study, the remaining three weeks of the course are used for a project assignment, where all knowledge is combined and brought together. To ensure that the students study the materials the week before, the knowledge is provided in the form of lecture notes, book chapters, videos, and papers. The first evaluation is a formative quiz to assess the knowledge. Students are given 10 random questions and need to answer 8 correctly. They do have as many re-sits as they require. As information literacy is part of the course, they are also searching and studying papers on the subject and finally, the lecture time is used to further work with the subjects. This could be a pub quiz, or a small assignment to work out in the classroom or in one case even a take-home assignment.

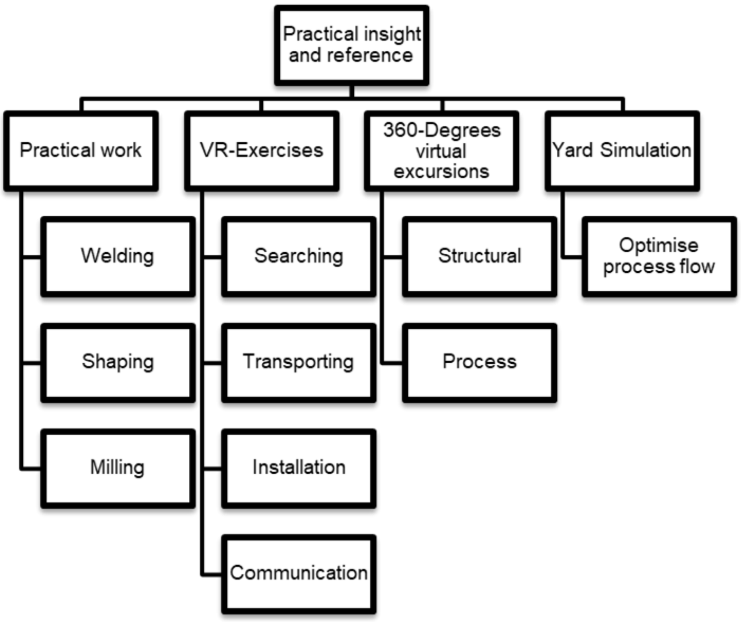

Figure 2: Blended set-up as an alternative for an internship.

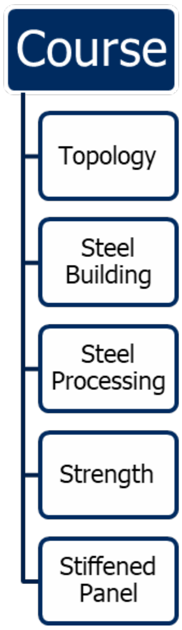

Figure 3: Course subjects

To support the development of a frame of reference a combination of practical exercises was designed to cover the most important aspects and insights from the actual industry practice. As can be seen in Figure 2. There is practical work in a workshop, there are virtual exercises related to production in a VR environment and there is video material (in 360-degrees) to show all elements. Finally, there is a yard simulation to study the relations between activities in a playful way.

As can be seen in Figure 2, there are four VR-Exercises. The complete set takes about two hours to complete for a group of four students. VR was chosen from an immersive perspective. With the goggles and headset on, you are completely cut off of the actual world and fully immersed in the virtual world. As we also added shipyard sounds, the only thing missing is the smell of welding and grinding steel. For each element, the goal is clearly described, but students are left completely free in the way they pursue this and are learning from their mistakes and experiences, rather than from lecturers explaining it. Furthermore, each exercise has its unique focus and aspects and will be shortly described below.

The first exercise is called searching. This is an individual exercise where students are asked to find 10 randomly selected ship elements within the VR ship. (See also Figure 4). This tests the vocabulary learned in the first two weeks of the course and makes the student familiar with the VR environment and controls. To allow for the cognitive load, this exercise is performed individually, reducing the complexity of the exercise. The gamification aspects that are introduced within this part, are a leader board for the fastest time and the instant reward for correctly identifying an object in the form of your next task (visually in your VR world). There is no overall competition, just between the four students in the session.

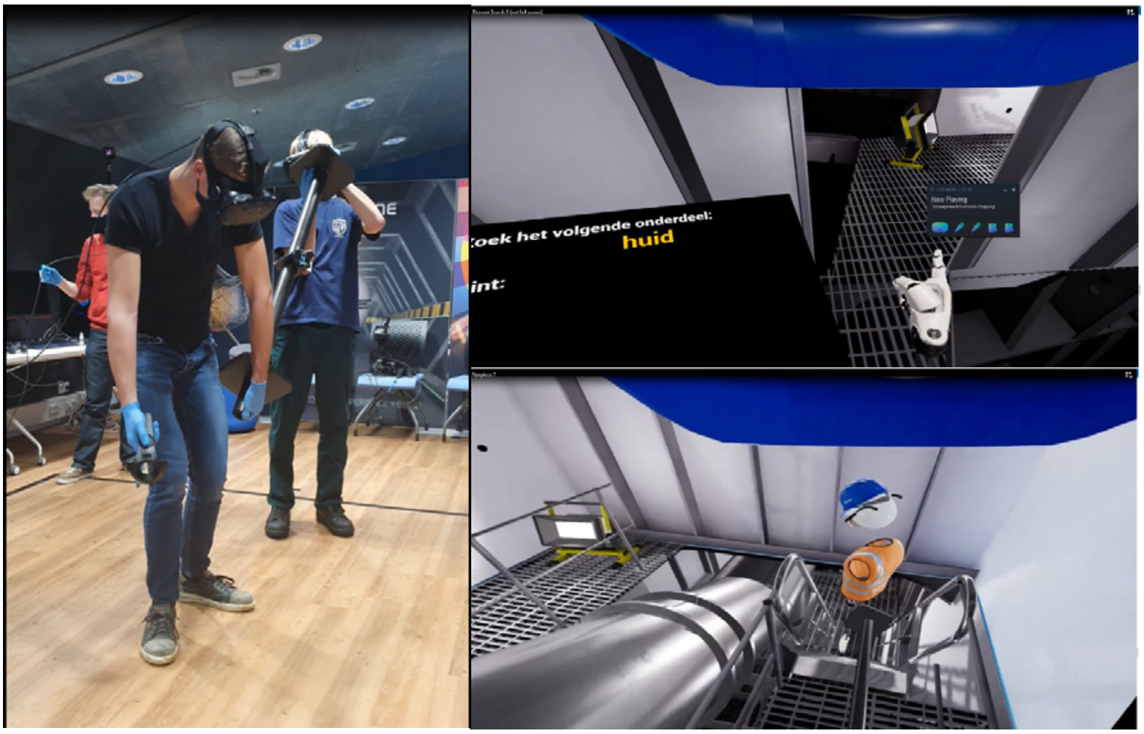

Figure 4: Search (top right) and Transportation (Left and bottom right)exercise impressions.

In the second exercise, the students are transporting a pipe piece through the ship. The key goal here is to understand how cumbersome this can be for the people working on the yard and again to understand how much time is lost on transportation. In this case, time is not measured, but the students are given a real piece of pipe in their hands, which is also visible in the VR world. This enhances the immersion significantly [26] and is to our knowledge the only example of such an application. The weight of about 25 kg is a good motivator to try to complete the session as soon as possible, with a clear reward in the form of letting go. As with the previous exercise this one is also done in pairs, though without walkie-talkies, hence similar socialization is achieved as well.

The third exercise is called installation. In this part, two students work together to correctly install a number of stiffeners on a plate. This requires the use of a crane as well as communication via (virtual) walkie-talkies. The key goal of this exercise is to experience that even relatively simple actions in shipbuilding tend to take quite a long time. Especially when communication is hampered by one-way traffic (with walkie-talkies, you cannot hear the other one if you are pressing the talk button, so waiting and clear closing statements are key). As the sense of time is not easy in the VR world the time is measured and discussed with the students afterwards. The progress to the end goal, installing three stiffeners, is easy to follow visually and the socialisation is also present as there is one crane operator and one metalworker who have to work together.

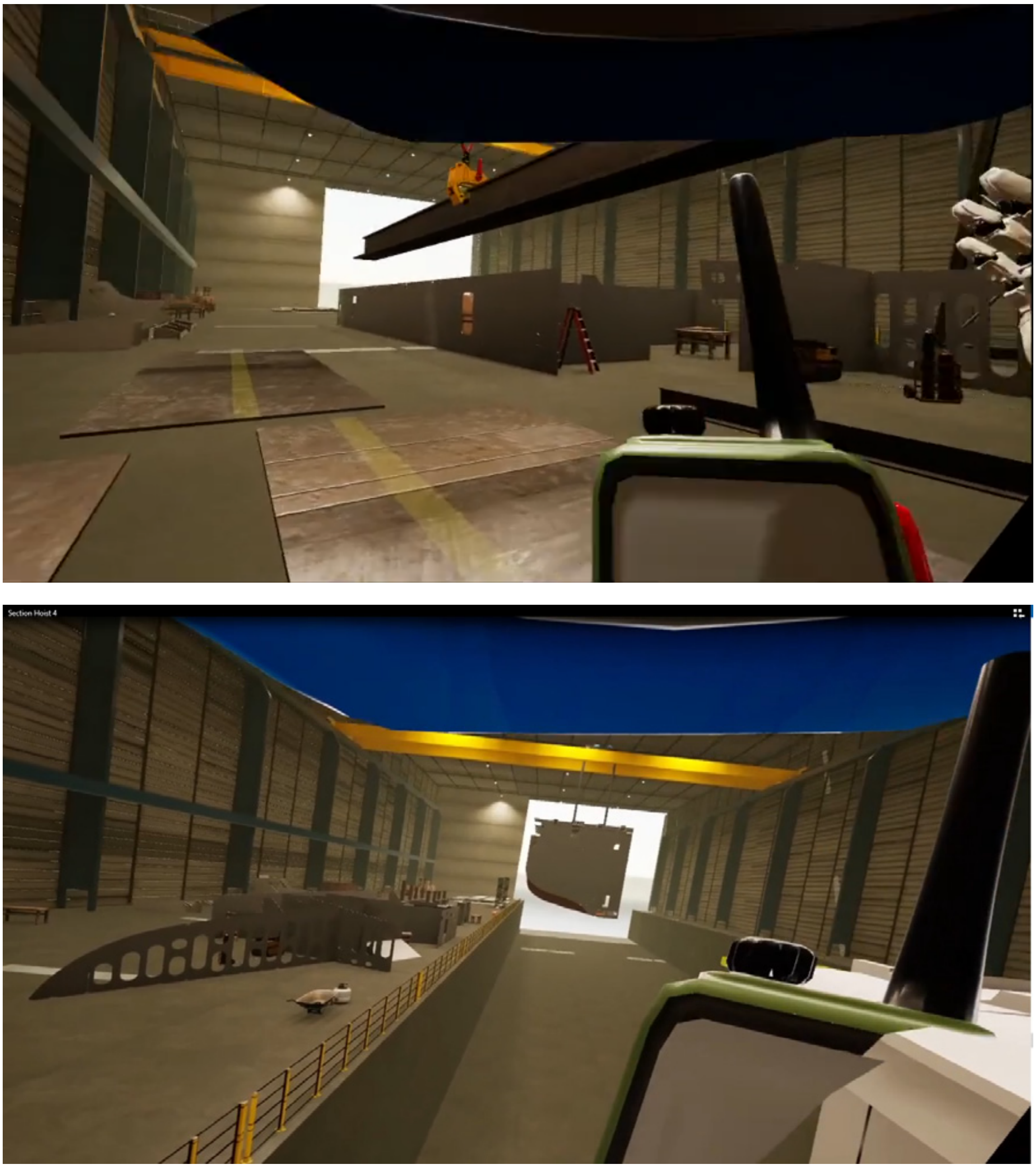

Figure 5: Installation (top) and Communication (bottom)exercise impressions.

The last exercise is done with all four students. It is focused on moving a section (a large part of the ship construction) into place. Clear communication is a key element here, as the crane driver cannot see and avoid all obstacles just by himself. With four people the issues in clear communication are increased. Also, the fact that this process is very slow, due to the danger of swinging and damaging the construction, is conveyed in this exercise. Although not addressed with the previous two exercises, the cognitive load is supported by slowly increasing the difficulty of the exercises and allowing for familiarisation with the controls and concepts in the previous exercises.

3.3 Bachelor Course Development and Implementation

The VR practicals were developed with the support of the VRZone, an organisation within the TUDelft with the goal to support both the access of students to VR and the implementation of VR in education. The total duration of the exercises is about two hours, keeping in line with the recommendations of not doing long exercises [26]. The results were already shown in Figures 4 and 5. Unfortunately, due to the COVID-19 situation, only about half the students were able to do the VR exercises in the first year, as the library was locked down for the second half of the course and even the next quarter.

3.4 Bachelor Course Evaluation

Based on [27] evaluation consists of three distinct aspects: perception, learning and performance. As this was the first year of implementation, results on this aspect are incomplete and mostly informal or subjective. In the next years, more data will be collected to identify the impact of the changes and to continuously improve knowledge attainment and retention.

The perception evaluation in this course consists of two parts. An informal discussion at the end of the session between the students and TAs; What was good, what could be improved. The feedback received was positive, students appreciated the insights and possibility to do something and check their knowledge in this way. The second part is the faculty course evaluation form, usually provided three weeks after the quarter ends. In the last year only seven out of 63 students filled in this evaluation. Furthermore, as another element of the course did not go smoothly, this received the most attention in the review and it is not possible to draw any conclusions for the VR part at this moment.

The learning achieved is assessed by the lecturer and consists of the exam results. Compared to previous years a slightly larger fraction has completed the course, though based on this single observation, this could be regular variation, an influence of the lockdown or an actual improvement in knowledge absorption. Overall there was consensus between the lecturers that in the final group assignment, fewer questions on processes vocabulary were asked, especially considering that an excursion to a real shipyard, was not possible this year, but did take place in the previous years.

The final element is performance. As the initial complaint that started this course revision was a lack of knowledge retention, especially on the side of vocabulary and process knowledge, the focus of this part should be on establishing the knowledge retained from this course. In order to assess if an increase in knowledge retention is achieved, the quiz questions used in the self-study part of the course are re-used at the start of follow-up second and third-year courses. As this was the first application of the course, we cannot study the results yet but it has given us some insight into the retention rate. Irrespective of the year of the later course, the students of the previous course set-up scored on average around 35-40% correct in their answers. This is a low score, especially when considering the question focus on basic concepts and principles. What this value does indicate, is that there is merit in the initial observation that the knowledge level is quite low and perhaps even lower than before. If the redevelopment of the course is a success, an increase in the test scores would be expected. The results will be monitored for the coming years, with these values forming the baseline values to compare against.

4 REFLECTIONS AND CONCLUSIONS

Comparing the development of the VR application with the development of the business game, this is only the beginning. It took at least five years to fine-tune all aspects of the latter course and the VR application was only applied one time so far. Understanding both the capacity limitations as well as how gamification can impact the motivation and results, has helped the creation of these exercises and provided solid ground to continue these developments.

The formative assessments at the start of the follow-up course we're also a new development. These also will require some further fine-tuning but would be a valuable addition to the bachelor in general. Supporting both the lecturer of the preceding and following course in assessing the knowledge retained or present at the start. Furthermore, it would provide students with this insight as well and could be accompanied by links to previous work to facilitate a quick recapture of previous work.

To conclude, the implementation of gamification in courses could support an increase in knowledge retention as the students learn from experience, rather than from instructions. The results for the current case course development are not yet sufficient to validate this at this point, but the impact will be monitored and evaluated in the coming years, leading to a follow-up of this work with a focus on the impact measured.

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TASK DESIGN IN ENGINEERING MATHEMATICAL COURSES: THE CASE OF PROBLEM POSING AND PUZZLE TASKS

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Keywords: *Mathematics, task design, problem posing, puzzle tasks.*

ABSTRACT

Several studies have reported that engineering mathematical courses are not appealing to some engineering students, and they found these courses dry and boring. This paper shares our experience of using problem-posing and puzzle tasks in two mathematical engineering courses, differential equations and calculus. In the first study, 135 first-year undergraduate engineering students from a public university in Iran engaged with eight problem-posing tasks related to integral calculus. In the second study, 135 undergraduate engineering students from the same university engaged in solving four puzzle tasks related to the first-order differential equations in self-selected groups of two or three students. Students' attitudes towards engaging in these two types of tasks were explored using questionnaires and semi-structured interviews. The findings indicate that more than 50 percent of engineering students had positive attitudes towards using mathematical problem-posing tasks in engineering mathematical courses. Regarding using puzzle tasks, the findings indicate that more than 50 percent of students were unanimous puzzle tasks are entertaining and enjoyable activities and perceived that solving puzzle tasks could improve students' problem-solving skills, modelling, and thinking skills in engineering differential equations courses. The findings of these two studies suggest that

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problem-posing and puzzle tasks could be used more often in engineering mathematical courses to motivate students to learn mathematics.

1 INTRODUCTION

Engineering mathematical courses are not appealing to some engineering students, and they found these courses dry and boring [1-2]. As tertiary mathematics educators, we need to think about what type of tasks could make the teaching of mathematics at the tertiary level for engineering students more appealing and at the same time engage them in inquiry into mathematics and activate higher-order thinking. In the 21st century, simply remembering and applying mathematical knowledge in familiar situations is not enough, and students need to engage in activities that prepared them for solving real-world problems [3]. In this paper, we share our experience of two types of tasks, problem-posing and puzzle tasks, that we speculate engineering students would enjoy engaging with them and finding them interesting. Additionally, these two types of tasks were highlighted as tasks which can activate higher-order thinking in the students' mind [3-4]. In the following, we define problem posing and puzzle tasks and describe the relevant literature about them before presenting the research question.

2 LITERATURE

2.1 Problem-posing tasks

A problem posing activity in mathematics is "the process of formulating and expressing a problem within the domain of mathematics" [5, p. 2]. Problem posing can play an important role in mathematical teaching and learning [5]. Mathematical problem-posing activities have been found beneficial for both pupils and teachers in school mathematics. Previous studies have suggested that engaging with problem-posing tasks could help students to develop their conceptual understanding of mathematics [5], develop their critical thinking skills [6], problem-solving skills [5], and positively impact their attitudes towards mathematics [7]. It can also help teachers better understand students' mathematical thinking [5].

Several frameworks have been proposed for designing problem-posing tasks [7-8], and how students posed problems can be evaluated [7, 9]. In terms of designing problem-posing tasks, students could be given pictures, diagrams, equations, a solution, or a short story, and then they will be asked to pose problem(s) with this piece of information [3, 8]. In terms of evaluating posed problems, several dimensions have been considered in the previous studies [7, 9]. For instance, we could investigate whether the posed problem is solvable based on the given information, or we could analyse the context of the posed problem whether it is situated in a bare mathematics context, or the posed problem is realistic or authentic [9].

2.2 Puzzle tasks

A task is called a puzzle if it has most of the four following criteria: *Generality* (help us to learn some of the general mathematical problem-solving principles), *simplicity* (easy to state and remember), *entertaining* (presented in an entertaining way), and after solving it we experience the *Eureka* moment [2]. Additionally, three types of puzzle tasks have been identified in the previous literature: *Sophism*, *paradox*, and *puzzle* [1]. A sophism can be defined as an “intentionally invalid reasoning that looks formally correct, but in fact contains a subtle mistake or flaw” [1, p.1106]. A paradox is a “surprising, unexpected, counter-intuitive statement that looks invalid but in fact is true” [1, p.1106]. Students, when engaging with sophisms and paradoxes, analyse the given tasks and evaluate reasoning(s) included in them, which often help them to have a deeper understanding of the concept(s) included in the tasks [3]. The third type is called puzzle, which is a “non-standard, non-routine, unstructured” [1, p. 1106] task presented in an entertaining way, and they are similar to modelling mathematics tasks.

Puzzle-based learning (PzBL) refers to engaging students with puzzle tasks to enhance students’ problem solving and thinking skills [2]. Previous studies have suggested that PzBL could improve students’ motivation in learning mathematics and help students solve real-world problems [10]. Students engaging in puzzle problems could learn various problem-solving strategies that could be used to solve problems in their future careers [2, 10].

Higher-order thinking can be activated by engaging students with puzzle tasks, as students are required to analyse and check all the reasoning used in sophism and paradox tasks to verify or refute them [3]. Also, students need to analyse and check all information given in puzzles to create an appropriate solution [3]. Including puzzle tasks in the teaching, alongside routine problems, can encourage students to participate in classroom discussions [2].

Considering the usefulness of problem-posing and puzzle tasks in improving the quality of teaching and learning of mathematics and lack of research into how problem posing and puzzle tasks have been perceived by engineering students in university mathematical courses, this study seeks to explore undergraduate engineering students’ attitudes towards engaging in problem-posing and puzzle tasks. The research question sought to answer in this paper is: *what attitudes do undergraduate engineering students have towards engaging in mathematical problem-posing and puzzle tasks?*

3 METHODOLOGY

In this study, we reported two research studies that have been completed separately. In both of these studies, an explanatory mixed-method approach was designed. In the first study, 135 undergraduate engineering students participated in a problem-posing test and completed a questionnaire about their attitudes towards engaging in problem-posing tasks. Students’ problem-posing competencies were explored using eight problem-posing tasks based on Christou et al.’s taxonomy [8] related to the fundamental theorem of calculus and integral-area relationships. Furthermore, students' attitudes towards problem posing were examined using an attitude questionnaire which consisted of twelve items on a 5-point Likert-style scale and two open-ended questions. Then, using purposeful sampling, nine students with different levels of competency and attitude were invited to participate in semi-structured interviews.

Similarly, in the second study, 135 undergraduate engineering students participated in solving four puzzle tasks (one sophism, one paradox, and two puzzles) about first-order differential equations in self-selected groups of two or three students. Then, students' attitude towards engaging in sophism, paradox, and puzzle were explored separately using a questionnaire which included sixteen Likert-style items and three open-ended questions. Finally, to explore further students' attitudes towards puzzle tasks, thirteen students were invited to semi-structured interviews.

Two senior lecturers in mathematics education examined the validity of both questionnaires. The reliability of the questionnaire was explored using Cronbach's alpha. The questionnaire items had good internal consistency; Cronbach's alpha was .89, .92,.90, and .87 for problem posing, sophisms, paradoxes, and puzzles, respectively. Students' responses to the open-ended questions and the interviews were analysed using thematic analysis. Before presenting the findings, we need to highlight that the items in the attitude questionnaires were different. In the Figures presented in the results section, PPT refers to the items of the problem-posing attitude questionnaire, and PzBL relates to the items of the PzBL attitude questionnaire.

4 RESULTS

In the following, we first present the results of some of the questionnaire items, and then the findings related to the open-ended items and interview data are presented.

4.1 The questionnaires' findings

Students' responses to the first two questionnaire items (Figure 1 and 2) showed that over fifty percent of students agreed or strongly agreed that problem posing and puzzle tasks (sophism, paradox and puzzle) are enjoyable activities. In particular, regarding Item 1, students' responses showed that 51.8% of students agreed or strongly agreed that problem-posing activities are enjoyable, and 55.9% of the students enjoyed solving sophism problems. A higher percentage of students (63.4% and 76.1%) believed solving paradoxes and puzzles are enjoyable activities to learn mathematics (Figure1).

For Item 2, around 55% of students found the challenges of problem posing appealing. Regarding the puzzle tasks, approximately the same percentage of students believed they could learn mathematics in an entertaining way by solving sophism (56%) and paradox (60%) tasks. However, a higher percentage (77.6%) was found for puzzle tasks (Figure 2).

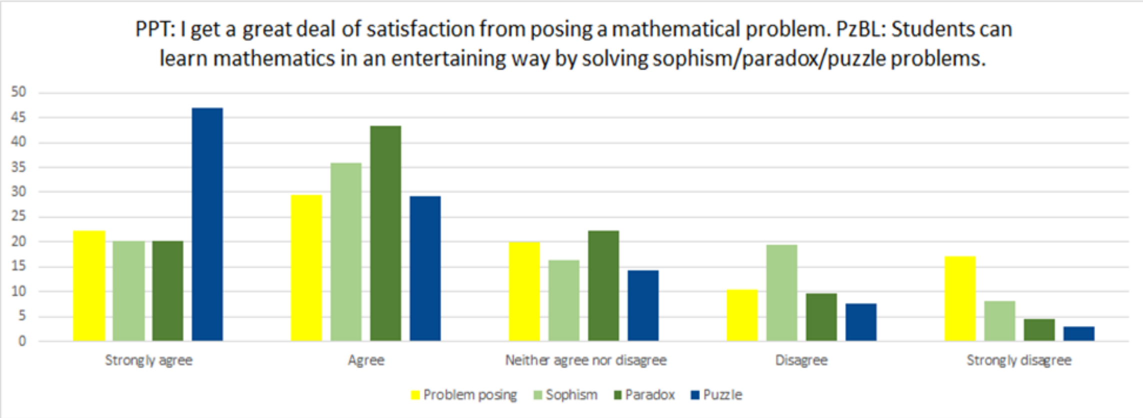

Fig. 1. Students' responses to Item 1 of the questionnaires

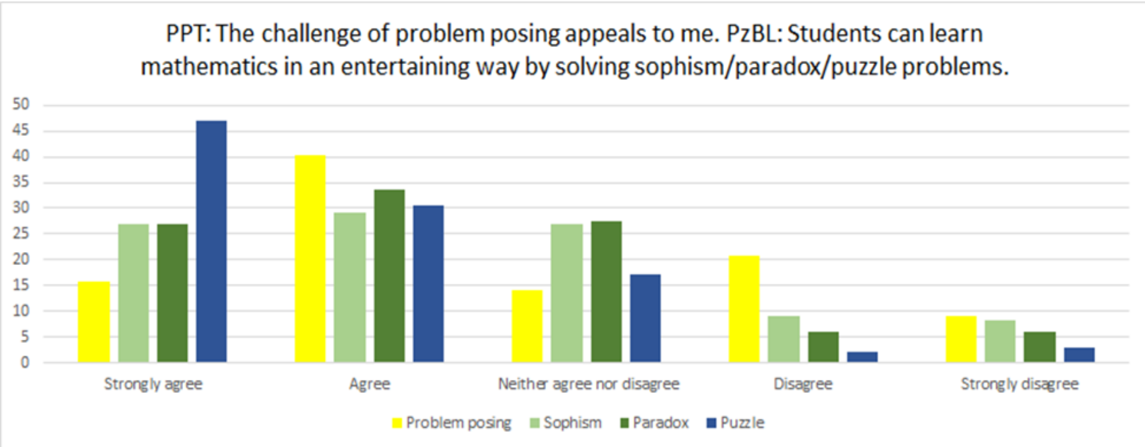

Fig. 2. Students' responses to Item 2 of the questionnaires

For Item 3, students' responses showed that over 70% of students were interested in developing their mathematical skills using problem posing, and over 58% of students concurred that solving puzzle tasks can make them motivated to learn mathematics. In more detail, 73.1% of students agreed or strongly agreed that they would like to develop their mathematical skills using problem posing. Regarding puzzle tasks, 58.2% and 66.4% of students believed that solving sophisms and paradoxes increase their motivation to learn mathematics, and a much higher percentage of students (76.1%) agreed or strongly agreed that solving puzzles can motivate them to learn mathematics (Figure 3).

Students' responses to Item 4 of the questionnaires indicated that over 60 percent of students agreed or strongly agreed that engaging with problem-posing and puzzle (sophism, paradox, and puzzle) tasks could help them improve their problem-solving skills. The highest percentage was for puzzle (83.6%) and then paradox (71.6%). The percentage for sophism (67.2%) and problem posing (64.2%) were closer to each other (Figure 4).

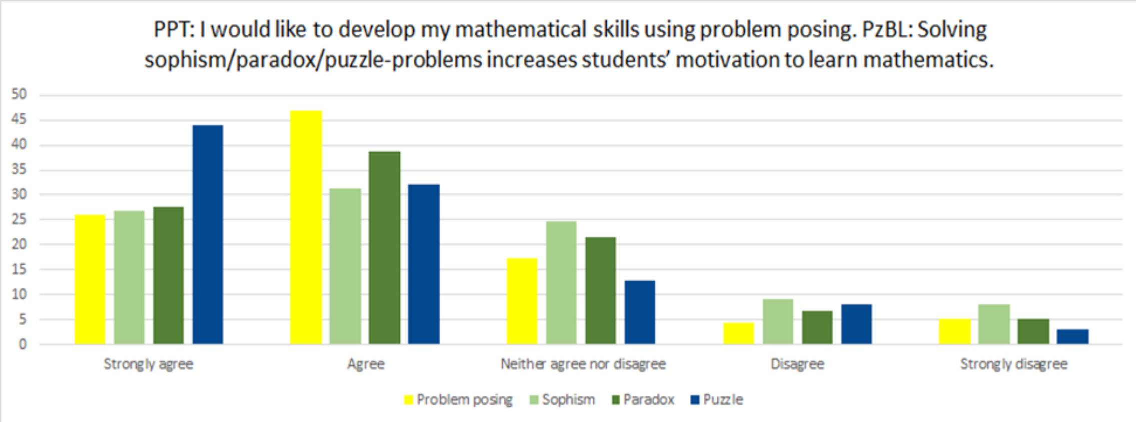

Figure 3. Students' responses to Item 3 of the questionnaires

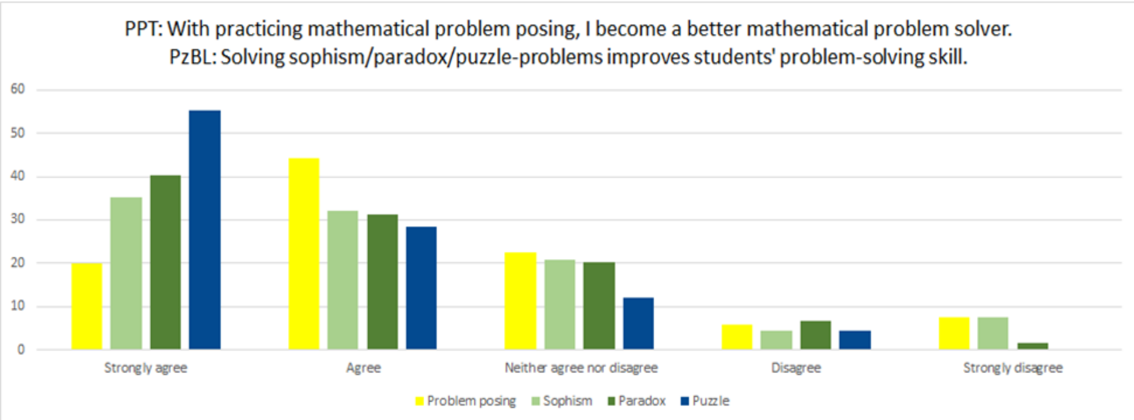

Figure 4. Students' responses to Item 4 of the questionnaires

4.2 Findings of the open-ended questions and the interviews

Eight main themes were identified during the analysis of qualitative data. Of these, six were found for both types of tasks, and two were only identified for puzzle tasks (i.e., *helping students develop thinking skills* and improving *mathematical modelling skills*).

Enjoyable activity: One of the themes identified in students' responses is that students found problem-posing and puzzle tasks enjoyable activities. For example, one of the students highlighted: "problem-posing activities are very enjoyable for me because they can challenge my mind and broaden my vision when solving other mathematics problems".

Improve mathematical problem-solving skills: Some of the students' responses showed that they believed engaging in problem-posing and puzzle tasks can improve their mathematical problem-solving skills. For instance, one of the students mentioned: "By engaging in puzzle tasks, students learn useful strategies that can be used to solve mathematical problems. As a result, students become good problem solvers".

Increase awareness about applications of mathematics in the real world: Some of the students believed that engaging in problem-posing activities help them to improve their awareness of applications of mathematics in the real world and its relationship with other disciplines. Additionally, many students mentioned that solving puzzles related to their major can help them increase their awareness of applications of mathematics in solving real-world problems: “By solving puzzles, students become more competent in solving real-world problems that they may encounter in the future. Unfortunately, most of the students only deal with routine problems in their university study”.

Improve students’ mathematical understanding: The majority of students believed that engaging in problem-posing and puzzle tasks can improve students’ mathematical understanding. A sample response was: “Solving puzzle leads to a better understanding of the topic, and more sustainable learning can happen when you find the correct answer after a lot of effort and consider it from different angles”.

Helping students develop thinking skills: The majority of the students believed that puzzle tasks could improve students’ mathematical thinking skills (e.g., creative, critical, and lateral thinking). Students’ responses showed that they believed solving sophisms and paradoxes can be more effective in improving critical thinking, as they need to analyse all the reasoning(s) provided in the tasks. Moreover, they mentioned that to find suitable solutions for solving puzzles, students need to be creative and look at the given task from different aspects. A sample response was: “students should critically analyse the tasks [sophism and paradox] and analyse all the reasonings used in it. However, solving puzzles needs more creativity, and students should apply their knowledge and connect them to reach an appropriate solution”.

Improve mathematical modelling skills: Many students believed that puzzles could improve students’ competency in solving mathematical modelling problems, which help them prepare for their future careers. For instance, one student said: “Puzzles are closer to reality and prepare students to solve such problems in their future work environment. Particularly in engineering, we usually need to find a model”.

Improve classroom communication: A few students pointed that communication between students and lecturers can be improved in classroom discussion using problem-posing and puzzle activities. One of the students highlighted: “some students do not like to engage in classroom discussion because mostly lecturers choose the traditional way to teach and that makes some students not like to contribute in the class activities very much; but when engaging in problem-posing activities, students can tell their opinions in the classroom”.

Improve the quality of teaching: Some students believed that problem-posing and puzzle tasks could improve the quality of university teaching. For example, one of the students expressed that “I believe posing a problem can help lecturers explain the subjects more widely and try to make a connection between different fields; therefore, it can improve the quality of teaching in the class”.

5 DISCUSSION AND CONCLUSION

The study findings indicate that many students had positive attitudes toward problem posing and puzzle tasks. In detail, the findings showed that over 50 percent of the engineering students who participated in our study found these tasks enjoyable. Among these tasks, students enjoyed solving puzzles more than sophism, paradox and problem-posing tasks. This is probably because puzzles are similar to real-world problems and students found them more relevant to the problems they may encounter in their future careers [10].

Students also perceived that engaging in problem-posing and puzzle tasks can help them to improve their mathematical understanding in calculus and differential equations courses. Moreover, many students also believed problem-posing and puzzle tasks could improve their problem-solving skills. These could be because these tasks are not routine and encourage students to inquiry into mathematics and engage them in higher-order thinking [3], such as thinking about the relationships between the mathematical concepts that they know and develop new connections between them [10].

Furthermore, many students believed puzzle tasks could improve their modelling and thinking skills in engineering mathematical courses. In detail, puzzles were perceived as more effective in developing creative and lateral thinking, while sophisms and paradoxes were perceived as more useful for improving students' critical thinking. This could be because when solving sophisms and paradoxes, one needs to analyse and criticise all the arguments in these tasks to be able to verify or refute them; while when solving puzzles, students should make a connection between all information given in the puzzles and look at it from different angles to create a solution for the puzzle which as stated above is a non-routine task [3]. To conclude, the results shared in this paper suggest that problem-posing and puzzle tasks can be included more often in engineering mathematical courses to motivate students to learn mathematics and provide opportunities for students to develop their conceptual understanding of mathematics.

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REMOTE WORK IS IN MY BLOOD - REFLECTIONS ON MOTIVATING FIRST YEAR STUDENTS DURING THE COVID-19 PANDEMIC

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Conference Key Areas*: Methods, formats and essential elements for online/blended learning, Social aspects and communication in online/blended learning*
Keywords*: Motivation, student well-being, blended education, online education*

1 INTRODUCTION

Transitioning from high school to university is tough, but doing so in a year where campus is effectively shut down due to a global pandemic is especially tough. Isolation from peers, dissociation with a campus they may have never even visited, and limitations on the amount and mode of live interactions with teachers all can take a toll on the intrinsically motivated first year student. This was the challenge faced by the ~450 student first year cohort of the Bachelor of Aerospace Engineering degree at Delft University of Technology (TUDelft), of which ~40% are international students. A unique approach was taken to motivate students to persevere and navigate themselves through these challenges by leveraging the common interest of their degree - aerospace. Students were asked within an introductory engineering mechanics course to assume the role of a pioneering astronaut on a journey to become the first person to set foot on Mars. Using this form of role-play, strategies and solutions to overcome the aforementioned challenges were given to the student that allowed them to gamify their approach to dealing with the pandemic situation. In this paper, we will present the main strategies and solutions, along with their analogy to a long duration space mission, that were employed in the course, and reflect on their impact on student performance as well as student well-being.

2 COURSE CONTENT

To set the context for the strategies used during the COVID-19 pandemic period of online education, an overview of the course content and learning objectives is presented. The course, entitled *Statics*, is an introductory course in Engineering Mechanics which is commonly taught in the first year of many engineering degree programmes. In the Aerospace Engineering bachelor programme at TUDelft, this course takes place in the first quarter (7 weeks) of the first year of the bachelor programme. The course in its content is not fundamentally different from other similar courses taught in Mechanical and Civil Engineering degree programmes; however, being taught in an Aerospace Engineering faculty, the context for learning was heavily focused on the analysis of aircraft and spacecraft. An overview of the learning objectives and the organization of the course are given below.

2.1 Learning Objectives

At the end of this course, the student will be able to solve basic problems dealing with statics. They will be able to:

- Define the basic terms in statics such as force, moment, body using the appropriate units and notations
- Use Newton's 1st law to determine the reactions on 2D and 3D bodies and particles in equilibrium
- Calculate the centroids and mass and area moments of inertia of elementary shapes (including thin-walled structures)
- Analyse whether a structure is kinematically and statically determinate and calculate the normal forces in a truss
- Calculate and construct diagrams of the distribution of internal normal forces, shear forces, bending moments and torsion moments as a result of external loading including distributed loads following a standard definition and recognise when diagrams do not follow this definition
- Use the principle of virtual work to derive internal and external forces and moments of structures and systems

2.2 Course Content Overview

The table below provides an overview of the content of the course. Each week consisted of three 2hr lecture slots, and weekly homework assignments (COZ), weekly quizzes, and instruction sessions. Instruction sessions are held in smaller groups of no more than 40 students and are led by teaching assistants. They are not formal lectures, but sessions designed to promote supervised group interaction and problem solving. Colour coding in the table is provided as a visual means for students to identify what lecture topics are associated with what assignments, quizzes, and instructions.

Table 1: Course content and activity by week

	Weekly Quiz	First Lecture		Second Lecture		Third Lecture		COZ		Instruction
Week	Date	Module Prep.	Relevant Reading	Module Prep.	Relevant Reading	Module Prep.	Relevant Reading	Assignment	Due Date	Activity
1.1		1.1 Course Introduction	Brightspace course info.	1.2 Forces & Vectors	Ch. 1 & 2 (review from High School)	Static Equilibrium of a Particle	Ch. 3.1-3.4	COZ1	06/09/2020	Livestream in Teams
1.2	07/09/2020	2.1 Moment of a Force	Ch. 4.1-4.6	2.2 Modelling of Force Systems	Ch. 4.7-4.9	2.3 Equilibrium of Rigid Bodies (2D)	Ch. 5.1-5.4	COZ2	13/09/2020	Livestream in Teams
1.3	14/09/2020	3.1 Truss Struct's - Method of Joints	Ch. 6.1-6.2	3.2 Truss Struct's - Method of Sections	Ch. 6.3-6.5	3.3 Frames & Mechanisms	Ch. 6.6	COZ3	20/09/2020	Livestream in Teams
1.4	21/09/2020	4.1 Load Path & Int. Force Concepts	NVM Reader	4.2 Generalized Int. Force Relationships	NVM Reader	4.3 NVM diagram applications 1	NVM Reader	COZ4	27/09/2020	Livestream in Teams
1.5	28/09/2020	5.1 NVM diagram applications 2	NVM Reader	5.2 Resultant Forces & Moments in 3D	Ch. 5.5-5.6	5.3 Equilibrium of a Rigid Body in 3D	Ch. 5.6-5.7, 6.5	COZ5	04/10/2020	Livestream in Teams
1.6	05/10/2020	6.1 Centre of a Body	Ch. 9.1-9.3	6.2 Area Moment of Inertia	Ch. 10.1-10.2, 10.4-10.5	6.3 Mass Moment of Inertia	Ch. 10.5, 10.8	COZ6	11/10/2020	Livestream in Teams
1.7	12/10/2020	7.1 Virtual Work	Ch. 11.1-11.2	7.2 Virtual Work (cont.)	Ch. 11.2-11.3	Review Lecture		COZ7	18/10/2020	Livestream in Teams
1.8	19/10/2020	White Week								
1.9/1.10		Online Exam - Date TBD								

3 GDPR AND ONLINE TEACHING TOOL LIMITATIONS

A key boundary condition faced in delivering the aforementioned course online during the 2020/21 academic year was the available tools for online teaching. Due to GDPR requirements, there were only a limited number of online teaching tools permitted for use within the university. Of the tools available, only the Livestream functionality of Microsoft Teams could accommodate the class size of approximately 500 students. Unfortunately, this functionality is meant for broadcasting rather than interaction, which resulted in several limitations:

1. The use of cameras and microphones were not available to students. Communication from the students could only be achieved through a text-based chat functionality.
2. The broadcast nature of the livestream functionality resulted in a non-negligible time delay of one to two minutes between what the teacher was doing and what the students were receiving.
3. The use of breakout rooms could not be accommodated without students having to exit the livestream and enter a new platform or Microsoft Teams meeting.

These limitations resulted in an extra degree of separation between the teacher and student body and severely limited the potential for live interaction in lecture settings. This, combined with the awareness that first year students would feel isolated by the absence of face-to-face connections with their peers, became the trigger for the Mission to Mars analogy that the course was structured around.

4 THE MISSION TO MARS ANALOGY

The psychological effects of long duration human spaceflight have been a topic of concern and study for potential human missions to Mars [1–3]. Isolation, cultural clashes with crew members, and adjustment to a new environment can all have a significant impact on an astronaut’s well-being and general performance. The same could be said for a student entering a new university programme during the COVID-19 pandemic. They would be entering a completely new environment transitioning from high school to university, likely have moved a great distance and entered a new culture to do so, and are isolated by the quarantine and lockdown measures in place during this period of education. Yet, for many students studying a degree in Aerospace Engineering, a manned-mission to Mars is something they dream of taking part in.

This raised the question of whether an analogy between the period of pandemic education and a human space mission to Mars could tap into the intrinsic motivation and drive of students studying an aerospace engineering degree. The remainder of this section describes how the course team organized elements of the course to leverage this analogy in an attempt to help students on their journey through this pandemic period of education.

4.1 Loss of Time Perception

A major challenge for astronauts during long duration space flight is a warped sense of time due to the loss of familiar cues such as sunrises and sunsets. As a result, many activities an astronaut would normally self-regulate based on their own perception of time, such as exercise and meals, are rigorously scheduled.

The loss of time perception was identified as a risk for students as well. Studying from home meant the boundaries between studying and their personal life were blurred. Other factors, including the ability to watch recorded lectures in their own time, could further distort a student's perception of their progress within a course.

To combat this, the course team organized a blended approach to the course where special attention was paid to scheduling. The course was divided into five main activities:

1. **Lecture Preparation**: This activity involved completing online blended learning activities such as watching videos, readings, and polls to test conceptual understanding. This activity was unscheduled, but expected to be completed prior to the live online lecture.
2. **Live Online Lectures**: Live teaching interaction between the teacher and the entire class in a Microsoft Teams Livestream environment. These sessions focused on reflections on concept polling results, application of pre-lecture theory to problem solving, and question and answer sessions.
3. **Homework**: Required weekly homework assignments were administered through an online assignment platform known as *ANS*. Assignments were assessed as complete or incomplete based on whether the student made an honest attempt at solving the problems.
4. **Online Instructions**: Live online help sessions in groups of ~40 students. These session were run by teaching assistants and included interactive polling, problem solving, and the opportunity for students to ask questions in a more manageable group size than the lectures.
5. **Weekly Quiz**: A time-constrained graded quiz in the *ANS* platform. The quiz element provided a manageable weekly assessment and feedback opportunity and provided an opportunity to train students in the use of the digital examination environment that would be used for the course final exam.

Delivering the education online eliminated one of the biggest constraints that had driven scheduling in past years – availability of necessary rooms and facilities. As a result, it was possible to set up the weekly schedule so that all of the course elements worked together (see Figure 1). The traditional 2hr lecture slots were divided in half, to reduce the amount of continuous screen time for students, and to offset the extra pre-lecture preparation we were asking of students. The other half of these lecture time-slots were allocated to working on the homework assignments. This ensured that a set time was scheduled where students could work with each other to complete the homework. Online instructions at the end of the week served as a milestone for students to have completed the homework and learning activities of that week and provided an opportunity for seeking help before their understanding was assessed in the weekly quiz at the beginning of the following week. Teaching Assistants also reinforced staying on schedule and keeping up in these instruction sessions. Finally, it was emphasized that course elements could be completed within the work week, leaving weekends free for students.

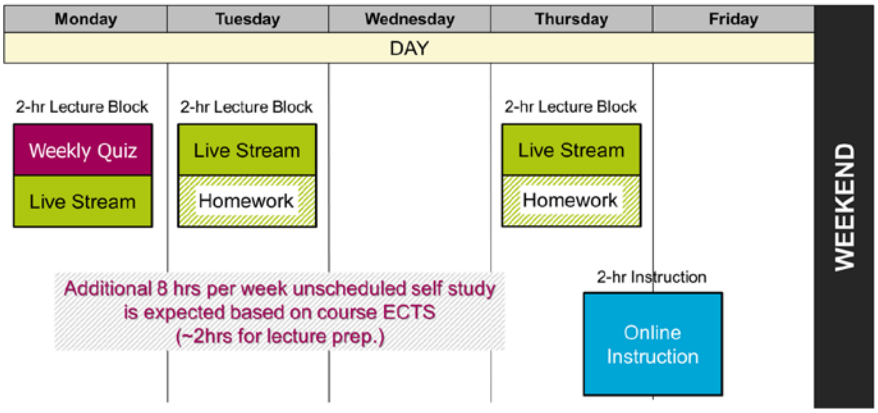


Figure 1: Weekly schedule of course activities

Although the effort put into scheduling and alignment of the learning activities may seem logical, it should be pointed out that this was overlooked by many teachers in other courses within the authors' institution. One of the biggest criticisms from students was the amount of additional planning needed on their side associated with all of the video and blended content added to the courses. So the actions of reducing the live lecture time to offset time spent on this additional content and scheduling activities such as homework were well received by the students.

4.2 Checklist and Procedures

During a long duration space mission, an astronaut is faced with many complex tasks that involve too many steps to commit to memory. Since the astronaut's safety often depends on the successful completion of these tasks, checklists are often used to capture critical information and record the successful completion of tasks. Although there are human factors related issues around checklists [4], they still serve a vital role in human spaceflight.

This risk was also identified for the incoming first year students. There was a higher reliance on students to manage course elements (ie: lecture preparations) on their own and a danger that they could miss, forget, and/or fall behind on necessary activities with little awareness of the situation. To mitigate this risk, checklists for monitoring student progress where embedded throughout the learning management system used for the course (see Figure 2). These checklists were carefully designed to quickly convey key information. Open source icons from www.thenounproject.com were used to help students quickly identify the nature of the checklist item in terms of the needed actions of the student. Time estimates were also provided to help students in planning and managing their time. Most importantly, students could mark off completion of individual tasks, which could be monitored by the teachers to identify students who may be struggling and falling behind.

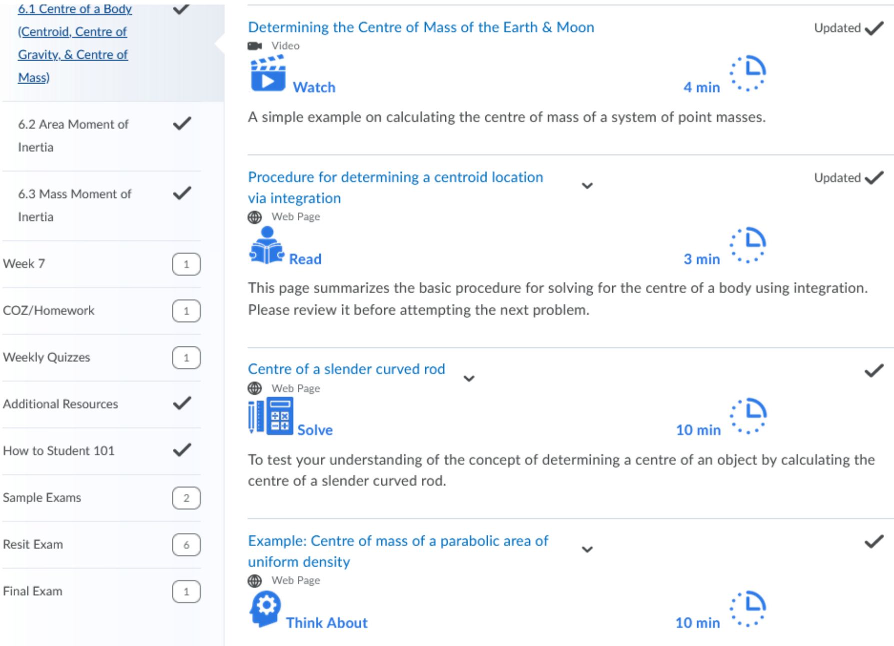


Figure 2: Lecture preparation checklist for a livestream lecture.

Although the concept of a checklist in a learning management system is not new, using the analogy of a human space mission helped convey the importance of using this feature to both the teaching staff and the students. Students greatly appreciated the ability to look forward into the course and see an overview of activities, time requirements, and get a sense of expectations. This was particularly appreciated during this period of pandemic education where uncertainty and ever-changing education conditions provided added stress to students.

4.3 Isolation and Loneliness

One of the largest concerns for long duration human space flights is the effects of prolong isolation on the mental well-being of the astronaut [2]. This was a major concern for all students during the period of pandemic education; however, it was expected to be particularly difficult for the incoming cohort of first year students who had not had the benefit of being on-campus, establishing peer groups, and adjusting to university life prior to the lockdown situation. This was further exacerbated by the fact that approximately half of the incoming students were international and experiencing a new country and culture while being isolated in lockdown.

In combating this, it was recognized that more contact with a teacher would not be the solution. Students would be missing the contact and interaction with peers and the normalcy of traditional campus education. This is analogous to an astronaut missing friends, family, and their terrestrial life back on Earth. More contact with mission control does not effectively alleviate this, which is why it is important for astronauts to be able to send and receive recorded communications to friends and family back on Earth.

To replicate this within the course, the lecturers tasked the teaching assistants to be creative in creating a recorded weekly communication to the students. The lecturers only provided the teaching assistance with three high-level objectives:

1. Provide a student's perspective on the relevant context for course material
2. Help students feel connected to the campus and faculty
3. Give study tips and advice from a student's perspective

Beyond this, the lecturers stepped back and allowed the teaching assistants to run with the concept without interference. An example weekly message from the students (which they entitled How To Student 101) can be accessed through the QR code below.

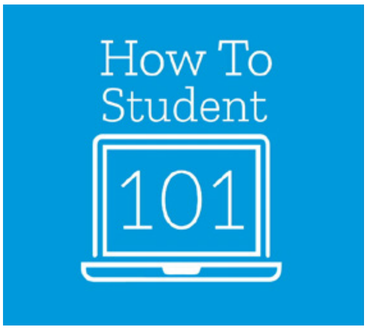


Figure 3: QR code link to example video message to the students

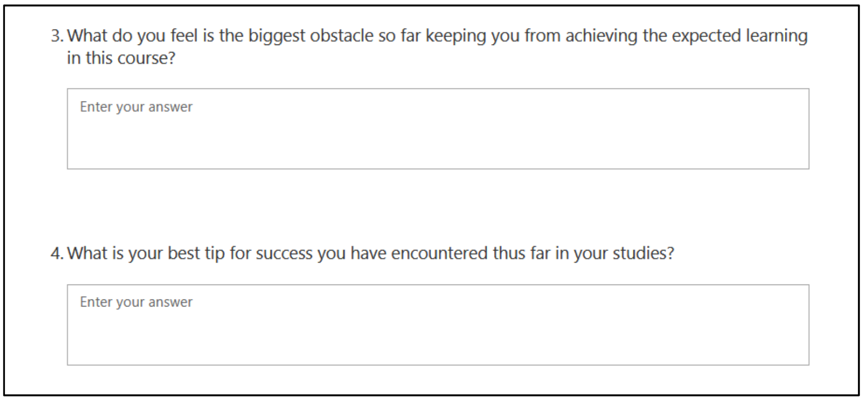
This element of the course was found to be an overwhelming success. Students reported to their teaching assistants that these videos made them more willing to turn on their cameras and interact during the weekly instructions sessions. Seeing the teaching assistants care about their well-being and open up with their own experiences lowered the barrier for students to also share. This also influenced the format of these weekly instructions where the first half hour of the sessions became dedicated to allowing students simply to talk about how they were doing and sharing their experiances.

4.4 Confronting Unexpected Issues

Astronauts are often confronted with unexpected issues that they have to solve with a limited set of resources. This is is best exemplified with one of many challenges on the Apollo 13 mission where astronauts were confronted with making a cube-shaped air filter from the lunar module compatible with the crew module's air filtration system that required cylindrical-shaped air filters, using only the items available onboard. Rather than expending energy complaining and being upset about problems that arise, astronauts have to be disciplined and creative in coming up with real solutions. It is this attitude we wanted to tap into within our students given the high likelihood for difficulties arising during the course.

To instill this attitude, the approach was two-fold. First, it was important to frame the role of students and staff in the course. The elite astronaut analogy served this purpose well. We reminded students of the significant challenges they already overcame to get accepted into such a competitive programme and that their acceptance was a sign that we believed they had what it took to succeed. Conversely, the teaching staff were compared to mission control. There to direct, assist, and help in ways that they could, but ultimately not able to see first hand the challenges the astronauts were experiencing along their journey. Second, with this framing in place, the importance of transparency and communication was explained. Students were given the opportunity to provide feedback throughout the quarter with open polls each week focusing on study success, student well-being, and providing an opportunity to communicate tips and strategies in addition to challenges. The teaching staff took class time to reflect on the results of these polls during class time. Major challenges the students were facing were acknowledged. Strategies to cope with or overcome the difficulties were discussed. The anonymous responses to the polls were open published in the learning management system so that students could see the responses of the other students and find some solace in discovering they were not alone in their struggles. This was further reinforced by the teaching staff also being open during lectures about their own struggles and challenges being faced on their side of the situation.

An example of one of the weekly open polls given to students is shown in Figure 4. The response rate on such polls was unexpectedly high. The students seemed to enjoy the opportunity to share their thoughts and appreciated the time taken by the staff to reflect on them. Engagement between students in the course discussion boards was also higher than in previous years.


3. What do you feel is the biggest obstacle so far keeping you from achieving the expected learning in this course?

Enter your answer

4. What is your best tip for success you have encountered thus far in your studies?

Enter your answer

Figure 4: Example open poll for students

The success of this strategy in the course is best exemplified by one of the biggest challenges faced in the course. During the final exam for the course, which was administered online using the *ANS* digital exam/assignment environment, the exam server unexpectedly crashed in the last halfhour of the exam. Understandably, students initially panicked. The course team had organized an Microsoft Teams channel that could be used in case difficulties were encountered during an exam. The channel was initially flooded with panicked messages from students. After making an initial announcement that the staff were aware of the issue and investigating it, we were happy to see several students step in and help manage the channel to make sure our announcements and the important information within them were not lost in a flood of panicked messages. They reminded other students to keep calm and to trust that the teaching staff would be fair in how they dealt with this mishap. The server was restored after 15 minutes, and students were allowed to resume their exam with an extra 20 minutes added to their exam time. In the course reviews, we were pleasantly surprised to see students identifying that indeed this event caused a lot of stress for the students, but that they were satisfied with how the teaching staff dealt with it.

4.5 Having Fun with the Theme

One of the main reasons for making an analogy between a human space mission to Mars and the pandemic online education was student motivation. One factor that should not be overlooked in this is the role of fun in motivation (both for the teachers and the students)! In line with this, the course team added two elements to the course simply to add some fun to the situation.

The first element was the use of storytelling in presenting relevant problems to the students. The analogy of a mission to Mars created a great storyline in which relevant problems for the course could be embedded in a playful manner. The role of the students as elite astronauts on their way to Mars was personified by animated characters that encountered problems that had to be solved to save their mission (see video links in Figure 5). The backstories to these problems was setup in a way that personified the attitude described in the previous section and included several Easter Eggs in terms of subtle references to various aspects of university life. The response to the problems was overwhelming. Rather than simply solving the calculation set out for them in the videos, students engaged with the context and discussed other structural alternatives that could possibly meet the context of the problem.

Figure 5: Computer decal mission patch (left) and example spaced-themed statics problem (right).

The second element included in the course for fun was a physical mission patch, in the form of a sticker, that was sent to each of the students (see Figure 5). These stickers captured the analogy of the human spaceflight to Mars and the challenge of remote learning in the form of a badge that students could place on their laptop computers.

5 CRITICAL REFLECTION AND CONCLUSIONS

The authors wanted to share their experiences and efforts with teaching and introductory mechanics course to first year students during the COVID-19 pandemic. However, it should be recognized that what is presented is not a thoroughly planned out academic study. Indeed, although the overall concept of the human mission to Mars analogy was conceived before the course began, many of the elements described evolved over the duration of the course or were completely serendipidous. For example, the story-based Engineering in Space problems previously presented were not planned. They were born out of one of the teachers simply experimenting with a creative outlet to cope with his own stress and anxiety brought about by the pandemic situation. As a result, it does not feel appropriate to over-analyze course statistics or treat any of the outcomes as if it was a planned academic study.

That being said, the authors would like to highlight two key points of reflection. First, is on the importance of empathy and cooperation in the learning process. The major difference between teaching this course before and during the pandemic was not the remote learning aspect, but the added focus on well-being and how students were getting on. This reflection may be biased by the fact that both teachers had had significant online teaching experience prior to the pandemic; however the outcome remains true. Despite the greater distance between students and teachers, a greater awareness of students as people rather than student numbers permeated the entire course. It is hoped that this element of teaching during the pandemic can be maintained after this period of remote teaching ends. Secondly, placing time and energy into these aspects of the learning process seem to pay off. Despite the greater set of challenges students were faced with in remote learning, the performance by the students did not suffer. The passing rate was on par with past years the course was delivered on-campus. Feedback from students on the course was also more positive and/or constructive than typically received in previous years.

It is the authors' hope that other teachers have had similar experiences over this period of pandemic education and that it will have a transformative effect on the delivery of education following the pandemic. Education more focused on student well-being, empathy, and student-teacher cooperation.

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MUPIC: MULTIDISCIPLINARY PROJECT IN AN INTERNATIONAL CONTEXT

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***Conference Key Areas**: Internationalisation, joint programs, Lab courses and projects in online/blended learning*
***Keywords**: international project, engineering, English as lingua franca*

ABSTRACT

MUPIC (multidisciplinary project in an international context) is an international engineering project blending students from several universities (UWB, UMONS, Florida universitaria and Turku University of Applied Sciences) having different backgrounds (mechanical engineering, project planning, business and marketing, industrial design). Students from the partner universities work together on an assignment from a private company. Their task is to improve an existing product according to the company/customer needs.

In parallel, the project developed an online course to support students work in multidisciplinary international project teams. It contains modules on intercultural communication, language skills necessary for effective work in an international team, engineering design guidelines, project management, working in virtual teams as well as online communication. It is accompanied by a glossary of industrial design terminology. A teacher's guide will be developed to provide all the necessary information and instructions for the use of the online course after the project lifetime.

A kickoff week is organized to allow team building prior to the development of the work which is performed online. Three checkpoints are organized during the project to get feedback from experts in the different fields. The presentation of the projects at the end of the course is intended to be face to face, including a participation of the companies that have submitted the assignments.

Unfortunately, COVID crisis prevented most of the face to face interaction for both pilot sessions of the project (in 2020 and 2021). Nevertheless, students succeeded in providing all deliverables at the end of the project.

1 INTRODUCTION

The development of engineering projects needs the collaboration of members in teams having various backgrounds. Project teams consisting of members with diverse professional backgrounds are expected to make better decisions and lead to more innovative project results [3]. Moreover, in the current context of globalisation, cultural aspects need to be considered. Like professional diversity, also cultural diversity can bring new ideas to solve problems but may also lead to challenges regarding team dynamics and integration [1]. In addition, the development of international projects is more and more linked to virtual communication and using English as a lingua franca in online meetings which becomes an important factor in working life projects and higher education [2]. Diversity, whether it is disciplinary, cultural or linguistic enriches teamwork by bringing different viewpoints into team discussions. On the other hand, diversity can also set some challenges for communicating these viewpoints [5]. COVID crisis stressed even more on that aspect. It is therefore crucial to allow master level students to develop in real life experiments competences such as understanding cultures, virtual communication in English as a lingua franca, choice of media, collaborating in virtual teams, managing virtual projects.

In this context, MUPIC (multidisciplinary project in an international context) project has been developed by joining four European universities: University of West Bohemia (CZ), Turku University of Applied Sciences (FI), University of Mons (BE) and Florida universitaria (SP). MUPIC is an ERASMUS+ project (2018-1-CZ01-KA203-048151) that aims to develop student projects joining students having different backgrounds (mechanical engineering, design engineering, business and marketing and project management). The project aims to let the students work on a real-life engineering project submitted to a company mostly remotely.

2 Methodology

2.1 Course organisation

Prior to the beginning of the project, course material has been developed (see 2.2) allowing students to have resources supporting them either on technical aspects (mechanical engineering, project management,…) or on soft skills (intercultural communication, online meetings,…).

A kick-off week is organised face-to-face to ease the start of the project. During this week, the rules of the project are exposed to the students who are invited to form the teams (composed of students from all participating universities). Team building activities are organised to increase adhesion to the project. The experts that developed the online classes have then the opportunity to introduce the available material to the teams.

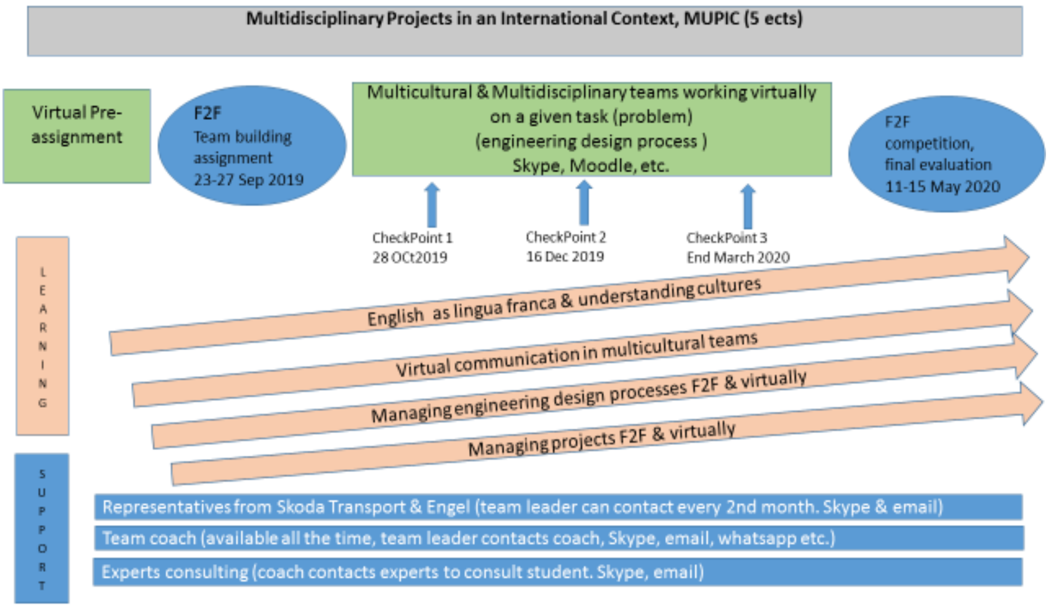

Fig. 1. MUPIC project organisation of the first intake

At the end of the week, the companies supporting the project are invited to present the assignment that all teams will solve along the project and define the way communication will be organised during the rest of the project.

After the kick-off week, all teams collaborate remotely to develop a solution to the problem stated by the industrial partner. The course was created to facilitate innovation in teams. Problem based, self-directed and working-life oriented learning in teams were emphasized. The students were given two tasks: an individual task to reflect learning in their own diaries and a project team task given by the partner companies. In all fields covered by the project, a panel of experts attached to the project can be contacted using an online platform; all teams also have a coach helping with the organisational issues. Along the project, three checkpoint reports are provided by the teams and assessed by the experts to check if the work is on proper track and provide appropriate feedback.

At the end of the project, each team provides a summary report and performs a presentation in front of the experts and the company representatives to close the evaluation of the project.

2.2 Online courses

Online courses have been created from the various aspects of the project.

Language skills & multicultural virtual teamwork

One of the main goals is to give students an authentic experience of multicultural teamwork. Intercultural communication issues were addressed by asking the students to start by completing individual culture profiles and the development of their intercultural communication skills was monitored through the reflective learning diaries students kept throughout the course. Student teams´ virtual communication and collaboration was supported by encouraging the teams to discuss and reflect how they share and create knowledge with others through digital communication technologies. How diversity of the team members affect virtual communication and choice of media [7] ? Moreover, the students were asked to discuss and create communication rules and netiquette for their own MUPIC project team to facilitate teamwork work (time/free time). In addition, this module had activities that aimed to support creating trust and leading a virtual project team through various stages of a project [6]. Moreover, all students are asked to take the Oxford English placement test to estimate the students level of English at the beginning and at the end of the course.

Engineering design

The course is divided according to the main phases of the project: general framework of engineering design, writing of specification, evaluation of the state of the art, creativity in the design process. The systematic approach proposed by Eder and Hosnedl [8] is proposed as a framework for this part of the project.

Project management

The students form teams, and one team member is nominated as Project Manager (PM). Principles of project life-cycle model by PMI PMBoK [9] is followed which is giving structure for the project execution and teamwork. In the beginning of the project emphasize is on project definition, target, stakeholder analysis, requirements and risks identification. Team's working methods such as team meetings, communication tools and practices are important to agree early.

When the project Charter is mature and reviewed in the first check-point, detailed project planning with WBS (Work Breakdown Structure), time schedule and resource allocation is finalised by the team. During the project execution phase, PM is monitoring and managing project scope and schedule, reporting progress and possible changes. Project communication and stakeholder management has proven to be important factors in a project's success.

Finally, when the project is reaching closing phase, the focus is on final deliverables for the customer (the company). The Final Weeks student team's presentation is an important part of the project outcome as well as the detailed technical, industrial design and business development customer reports. Project management point of view, before the team adjourns, it is important to discuss and collect lessons learned knowledge material from all the team members.

2.3 Glossary

To ensure that all participants understand each other while discussing technical or managerial aspects, it is crucial that they can translate the concepts from their mother language to English which is the lingua franca of the project. For that purpose, a glossary has been constructed for the five languages of the project, i.e. Czech, English, Finnish, French and Spanish. Inside the glossary, each input gathers the words in the five languages designing the same object or concept but also the most usual verbs, or adjectives. For a more complete definition of the word, links are provided to online tools and references. To avoid possible confusion, the inputs are also assigned a domain. Presently, there are seven general domains (engineering and industrial design, project management, strength of materials, general mechanics, CAD, machine elements and mechanical transmissions) and four specific domains, which were added according to the topics proposed by the companies (railway, metallurgy, thermodynamics and robotics). For the sake of efficiency, the glossary was constructed through a shared Google sheet. For a more user-friendly access by the students, the glossary will be transferred into the MUPIC Moodle course in the form of a database. The use of other applications is open.

2.4 Teacher guide

During the life of MUPIC, an Action Plan for Sustainability has been developed to ensure the expected impact of the project results at the end of community funding.

The project proposes several mechanisms to sustain the project results and impacting of practices other than the ones of the consortium such as the sustainability plan ensuring that the resources (handbooks, glossaries, learning materials) can be used, duplicated and reproduced at European level also after the project end (from project's website). MUPIC Project will also provide a Teachers' Guide with the objective to develop a best-practice guide to teachers' evaluation, aligned to the intent of the European Curriculum. The Teachers' Guide will be launched at the end of MUPIC Project and will include the results of both pilots (Pilsen and Mons), providing a good source of information and lessons learned. The teacher guide will include an introduction, the methodology for launching and implementing the project and the evaluation of the global results.

2.5. Assessment Grid

MUPIC project final scores are unique for each student. Scores reflect the fulfilment of MUPIC general objective and the acquisition of specific and transversal competences. Final scores consist of the sum of the partial scores obtained as a team and on individual basis.

- A: Assignments: 20%. Evaluation to be carried out by team coaches of the project and experts based on the Rubric of Written Work.
- FR: Final Report: 35%. Evaluation carried out by team coaches, experts and representatives of partner companies based on the Rubric of Written Work.
- PP: Project Presentation: 15%. Evaluation made by team coaches and representatives of partner companies based on Rubric of Presentation and Oral Communication.
- ILPE: Individual Learning Process Evaluation: 20%. Evaluation based on all the evidence gathered in the project development process (attendance to training, meeting minutes, attendance and participation in virtual classes, attendance and participation of virtual sessions and interaction with partner companies) and the self-reflective learning diaries.

CE: Cross Evaluation among students: 10%. Evaluation carried out by the members of each team based on the Cross-Evaluation Rubric.

With all the objectives, competences and learning objectives in mind, the evaluation of MUPIC Project will be holistic; scores will be calculated at the end of the project to get the *5 ECTS* involved and will be obtained by adding the following items.

MUPIC project score is computed according to this formula:

$$score = (A \cdot 0{,}2 + FR \cdot 0{,}35 + PP \cdot 0{,}15) + (ILPE \cdot 0{,}2 + CE \cdot 0{,}1) \quad (1)$$

In some cases, where team coaches consider it appropriate, a correction factor may be applied to the team score to compensate for differences in the performance of its members.

2.5 Course Curriculum

A course curriculum was developed so the course could be prepared for future accreditation by the partner institution to give students the opportunity to receive credits. The developed course curriculum follows the ECTS and EQF 7 standards.

The multimodal four module course focuses on the core skills the students should achieve, i.e. improve their language skills in order to communicate effectively in the working environment; improve or gain intercultural competences; learn how to communicate online properly using formal language in synchronous as well as asynchronous learning and working environments; learn how to work in virtual teams effectively. English B2 according to Common European Framework of Reference for Languages (CEFR) is required from the students.

3 RESULTS

3.1 First pilot (2019-2020)

For the academic year 2019-2020, 4 teams of 5 students were involved in the project, with the following distribution

- 8 in Engineering, 5 in project management, 3 in business/marketing and 4 in art&design;
- 3 students from UMONS, 5 students from TUAS, 5 students from FLORIDA and 7 students from UWB.

The teams were constructed with, on average, 1 manager, 2 engineers, 1 economist and 1 designer. Only 17 students completed the experience, the abandonment being the most often due to personal situations (e.g. a pregnant student).

Fig. 2. Kick-off week in September 2019

Two teams were assigned a project submitted by the company Engel with the purpose of reviewing the design of an industrial conveyor. The other 2 teams had to take up a challenge proposed by SKODA Transportation, consisting in rethinking the so-called front underpass barrier which prevents objects and people from getting under a tramway. In both cases, companies defined requirements, objectives and economical, regulatory or economical constraints.

The project started with the welcome week from 23rd to 27th September at the university of West Bohemia in Pilsen (CZ). Teams had to provide intermediary reports for October 28 2020, December 16 2020 and March 27 2021. The final week was organized from 11th to 15th May 2021, strictly online through Zoom due to the CoViD pandemy.

All teams produced reports on time, the quality increasing after each checkpoint. For the first checkpoint, the reports rather look as the assembly of independent contributions but final reports (typically between 150 and 200 pages long) have a uniform style, a global structure (table of contents, bibliography, …), and connections between the different fields. The organization of feedback to students after each checkpoint was continuously improved. For the last checkpoints, the comments and evaluations of all partners were aggregated by the coaches to provide a consistent and clear feedback.

Various communication tools are used by the students: chat and video-communication tools (WhatsApp, Google Chat/Meet, Microsoft Teams,…) and e-mails. Teams adopt a file sharing system, usually included in messaging tools. Most often, teams organize a weekly interactive meeting and a bi-weekly meeting with the company, with only the leader in general. Regular interactive meetings appear necessary for the efficiency of project management and team building. The teams met challenges with issues related to so called power distance and management style. In addition, there have been differences in time management skills. Time management has been emphasized during the second pilot partly because it was implemented totally online due to Covid19 pandemic.

Both companies acknowledged the quality and the volume of the work completed by the students and were satisfied to contribute to the education system. In all cases, teams and the companies were able to find an efficient and convenient way to communicate with a mix of synchronous and asynchronous interactions. Companies are motivated by the multidisciplinary nature of the teams, are interested in new approaches and hope original and innovative ideas. Of course, the MUPIC project is also an opportunity to give a positive idea of the company.

Concerning the benefits brought by the project, students are 100% satisfied with respect to oral and written English, and multicultural and online communication, which was the objective of the project and the main motivation of the students for participating in MUPIC. According to the results of the Oxford English Placement Test the average level of English increased from 63,5 points to 70,3 points, i.e. from low B2 to B2 according to CEFR. Which means students entering the course with A2 and B1 levels moved to B1 or B2 by the end of the course. The level of satisfaction is a bit lower in terms of team working or skills in their own field (engineering, business, design,…). It turned out that the specification of the task did not sufficiently incorporate the role of the business and business members, to the detriment of the team spirit. Generally speaking, students appreciate the support provided by the online modules, the experts, the coaches and the industrial partners. An unexpected return is that it appears more difficult to mix people from different fields (business, engineering, art) than people from different cultures (limited to European countries in this case).

3.2 Second pilot (2020-2021)

The second pilot was organized on the same basis as the first one with a notable difference: due to the CoViD pandemy, no face to face meeting was possible. The feedback of the previous year allowed performing the following improvements were brought

- the expectations of each checkpoint were completed to be as clear as possible as well as the instructions for completing the reflection diaries;

- more team activities were included in the kick-off week in order to develop the team spirit;
- a particular attention was paid in the definition of the tasks so as to ensure relevant contributions of all members (business/marketing and design namely);
- a reorganization of the structure of the Moodle course to make it more efficient.
- a feedback on intercultural communication, virtual communication and common language mistakes in written reports was introduced.

The kick-off week took place fully online from 2nd to 9th October. The deadlines for checkpoints were scheduled on November 9, 2020, December 18, 2020, and March 29, 2021. The kick-off week will take place online from 17th to 21st May 2021.

The teams were built in the same way as for the first pilot, with the following distribution of the 19 students

- 7 in Engineering, 4 in project management, 6 in business/marketing and 2 in art & design;
- 5 students from UMONS, 5 students from TUAS, 5 students from FLORIDA and 4 students from UWB.

Tasks were proposed by companies with plants in Belgium: Vesuvius and Desimone. Vesuvius task consists in designing and automating a mortar setting machine for refractory components used in a proportional valve for molten steel. The project submitted by Desimone is related to a machine implementing cold storage expected to be coupled to a cold room with the purpose of decreasing the electricity costs.

At the moment of writing this paper, the project is still running. Teams operate efficiently despite the fact that they never physically met, and managed to submit high quality reports up to the 3rd checkpoint. The interaction with the companies is running smoothly after the settling time necessary to find a formula convenient for both parts.

4 SUMMARY AND CONCLUSION

Being confronted with projects including diversity in background and culture is crucial for engineering education because more and more real projects are carried out in that context. MUPIC project allows students to discover at a small scale the challenges they may face in their career and develop new skills to solve these issues. The course had a blended approach mixing face-to-face kick-off and closing meeting with virtual meeting between team members and written feedback from experts. The quality of the work produced by all teams show that they can adapt to changing situations, even in the context of COVID crisis. However, the survey among students stresses the fact that communication issues may be more important between people having different backgrounds than different cultures (but the sample was limited to European countries). The course material is available for institutions willing to try the concept, an extension to a more global network of participants (including countries outside Europe) may be worth a try.

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The value of interdisciplinary presentations for engineering students

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ABSTRACT

The engineer of the future is not only able to find innovative solutions to big problems, but also continues to learn about new topics that are relevant to these problems. They have a can-do mentality, are system thinkers, and are able to link their engineering background to relevant societal challenges. And most importantly, they work in multidisciplinary teams with engineers with diverse backgrounds. One aspect crucial to success is the engineer's ability to communicate with engineers with different backgrounds. Time and time again, projects get delayed or even fail because, for example, the software engineer did not fully understand the architect. In order to prevent this, students should be able to discuss and present their work in interdisciplinary settings. A project was run which had the main objective to create an environment in which students communicate about their (research) findings to peers with different backgrounds. The project was split into four phases: an exploration phase to gather information on how communication between students can be deployed in an interdisciplinary approach; a development phase in which a training for students and teachers was created; an intervention phase in which the training was applied and feedback from students was collected; and an evaluation phase designed to evaluate the intervention and provide recommendations to other departments and/or universities. This paper describes the steps of the project and ends with recommendations on how to apply the lessons learned in practice.

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1 INTRODUCTION

An important element that was introduced in many Bachelor programs globally are the so-called Professional Skills. These skills are intended to enable students to develop professional competencies that will help them in their future career. However, surveys consistently show that these skills are not sufficiently integrated in the educational programs. Bachelor students consistently rate such skills as insufficient. Alumni indicate that these skills are an important component of their jobs, but that they are insufficiently incorporated in their educational programs. Employees of alumni indicate a lack of communication and other skills, which manifests itself by the notion that a programmer and a designer working on the same project have difficulties communicating about this project. The Dutch minister of education indicated in an interview in Trouw on October 25 2019 that students experience a high pressure to perform, while the job market asks for very different qualities such as the ability to work in groups and to connect to others.

At the same time, intensive, challenge-based and project-based education is introduced in a multitude of educational programs [1–3]. This way of learning will prepare students better for their life after University, as it requires that students learn to give constructive feedback, work together in (interdisciplinary) teams, learn to communicate on an academic level, and learn how to plan for longer projects at an early stage in their educational programs. Efforts that allow students to work together with peers from different programs are successful, indicated by the high amount of attention towards [department]. At [department], students from different departments work together on projects with an applied focus. This approach allows students to learn how to communicate with those who have different backgrounds. The number of students who can participate in such programs is however limited, as most students will continue doing their final Bachelor projects in their own departments. If universities want to manifest themselves as enablers of interdisciplinary communication between students, other innovative solutions should be considered.

The notion that Professional Skills in general, and especially the ability to link different disciplines, should be a crucial element of higher education is also highlighted by Bert van der Zwaan [4], who argues that soft skills applied to a multidisciplinary context will play a defining role in teaching in higher education in 2040. This prediction fits well with the so-called T-shaped skills [5], which refers to the notion that engineers need to have both in-depth knowledge and expertise in their own domain (i.e. the vertical bar of the T) and the ability to collaborate across disciplines (i.e. the horizontal bar of the T). When it comes to the learning of new skills, students are more likely to learn when new ideas are presented. This helps them to have a fresh look on their own work as well [6], implying that that interdisciplinary presentations and discussions help students expand their knowledge and perspectives on their own topic. As such, providing the option for students to present in multidisciplinary settings enables them to learn more, and simultaneously it better prepares them for our future society.

In order to achieve this, students need to be given the right tools and support that helps them developing this new skill. This concept paper describes the steps that were taken to reach that goal. A project was defined and split into four phases. The first phase (exploration) was designed to gather information on how the existing communication skill can be adjusted into an interdisciplinary approach. The second phase (development) was designed to apply the knowledge gained in the first phase into a training program for students and teachers. The third phase (intervention) was designed to gain experience with the training program and collect some feedback from students that would help the further development. The fourth and final phase (evaluation) was designed to mainly evaluate how students experienced the intervention, and how we could further develop it in the near future.

2 EXPLORATION PHASE

The main goal of this phase was to gather information on how the existing communication skill could be adjusted into an interdisciplinary approach. To achieve this, two types of data were used: (1) Students who recently finished their Bachelor End Project were asked to complete a survey that tapped into their experiences with the final presentations, and how they could be altered to be given to an interdisciplinary audience, and (2) a co-design session was organized in which teaching support staff, experts from Education and Student Affairs, and students worked towards a description of the training program that had to be developed.

2.1 Survey responses

A total of 32 students (20 males, 12 females, age ranging from 20 to 26) completed the survey. The main outcome of the survey was that students do not necessarily feel that understanding of their domain knowledge is crucial for their presentation. This finding indicates that domain knowledge is not perceived as a very important criterion for giving a good presentation. This is an interesting finding, as we believe that communicating about the results one obtains in their domain to an interdisciplinary audience deepens their understanding of their own work. It could be seen as a way of active learning, which is shown to increase academic performance [7–9].

Important to note here is that the survey answers represent student perceptions of presentations that are given to an audience of peers who followed the same educational program. When asked what students would need from us to help them prepare for an interdisciplinary presentation, some provided very useful insights that can be categorized in three topics; (1) knowledge on what information is domain-specific and what is general knowledge, (2) balancing general and in-depth information such that people can follow the talk, and (3) a basic level of understanding of other disciplines. These three topics were further explored in a co-design session in which teaching support staff, educational experts, and students worked towards a description of the training program that had to be developed.

2.2 Co-design session

The co-design session took place on March 9 2020. The goal of the session was to collaboratively come up with some crucial points to make interdisciplinary presentations a success. When first asked to provide some points of improvement that could be taken into account when developing a training program for interdisciplinary presentations, two elements that were mentioned stood out: (1) there seems to be limited interaction with the audience in an average presentation, and (2) students are not concerned with doing an audience analysis and the target group is often unclear. From this we learned that this concept of an audience analysis may be key to the success of interdisciplinary presentations.

In terms of assessment, all attendees agreed that presentations should be assessed on both content and form, and separate assessors should be present for those two elements. A key factor in this is the question who will assess the content. This usually is an expert of the domain in which the student has done their work, but for multidisciplinary presentations this may require a different type of expertise. Both assessors should make use of their own rubric, where one focuses on the form of the presentation (e.g., language, posture, gestures, clarity, structure) and one on content (e.g., depth of the work, relation between the disciplines, original contribution).

The assessment of the audience analysis should be part of at least one of those rubrics. The participants of the session did not agree which of the rubrics that should be though. When doing a proper audience analysis, students should be capable of separating main and sub topics, provide sufficient depth for all audience members to understand the topic, while still not being boring for domain experts. This connects best to the content of the presentation. On the other hand, a proper audience analysis also gives all audience members the feeling that they are being addressed properly, prevents extensive use of jargon, and makes the presentation come across as well-prepared. These elements fit better to the form of the presentation. This gave us the idea that an audience analysis should not be a separate part of any rubric, but should instead be incorporated in various elements in the rubrics for both content and form of presentations.

3 DEVELOPMENT PHASE

The main outcome of the exploration phase was that students could benefit from doing an audience analysis. We decided to develop and test a tool for this in a course in which students would already be presenting in front of an interdisciplinary audience. The audience analysis was presented to students as an a-priory inquiry of the kind of people who would be in the audience of their presentation, to help tailoring the presentation to those people. We decided to make students think about this topic by asking them to answer the following three questions: (i) what are the backgrounds of people in the audience for the upcoming presentation?, (ii) what are the roles of people in the audience?, and (iii) who are the three or so people that are most important for you to either convince about the quality of your work or to receive some feedback/input from and how will you achieve this?

We noticed that students struggled a bit with the third question, especially the last part of it. As they had never really thought about their presentations in this way, writing down how they would achieve their goals turned out to be difficult for them. Based on this, we decided to put some extra emphasis on this element during a workshop in which we zoomed in on their preparations for an interdisciplinary audience.

In this workshop, various topics related to giving a presentation in front of an audience with differing backgrounds were discussed. We decided to include three components in the workshop. The first was a short overview of the desired achievements in this project; giving students experience with interdisciplinary presentations, as this would prepare them better for the job market. The second was an overview of criteria that are included in all presentations, focused on the form of those presentations. Students should be familiar with these criteria, and giving them an overview would help refresh their memory. The third was the most important component; the additional audience analysis that would help students prepare for their interdisciplinary presentation.

4 INTERVENTION PHASE

This chapter describes our experiences with the workshop which was provided on 2 October 2020. The workshop had three main components: (i) background information on giving interdisciplinary presentations, (ii) a discussion on current criteria for presentations, and (iii) a discussion on extra criteria that play a role when presenting for a multidisciplinary audience.

4.1 Background information

We started by explaining the general aims of the current project. That is, we presented the notion that students tend to work in multidisciplinary teams after their graduation, that they also often need to present their work to various stakeholders, and that these presentations call for a different skill-set than the presentations they are used to giving. This part of the workshop is meant as an eye-opener and to attract the attention of students to the topic. Students were made to understand that a presentation in front of an audience of people with various backgrounds is conceptually different from any presentation they had given so far in their program. Even though they did understand the importance of the topic, students did not yet fully grasp how they would go about preparing for an interdisciplinary presentation.

4.2 Discussion on current criteria

After this, we checked to what extent students were aware of the criteria that were used for evaluating the form of presentations. Students were able to mention most of them, although not in their official classification:

1. Quality of work delivered; focuses on content and explanations
2. Structure; focuses on primary versus secondary topics and goals
3. Interaction with audience; focuses on engagement of audience members
4. Non-verbal behavior; focuses on eye-contact, posture, and gesturing
5. Verbal behavior; focuses on fluency, language, volume, and pronunciation
6. Visual aids; focuses on balance between text and visuals

When asked to reflect on how well they scored on these criteria, students were mostly positive about their abilities, with an occasional exception. One observation was that students felt comfortable sharing their strong and weak points on these criteria. We believe this was enhanced by creating an informal atmosphere in which these elements were discussed, and that the workshop had a small-scale character as only 12 students participated in the course. We did not perform this workshop with a bigger group or on another (online) platform (yet), so it is hard to predict what will happen with such a bigger group.

4.3 Discussion on extra criteria

The discussion on extra criteria focused on elements that make a presentation for a multidisciplinary audience more complex than a regular presentation. Two distinct elements were highlighted. The first was that such a presentation requires the student to obtain knowledge that reaches further than that of their own discipline. It is important for students to understand the work their team members are doing if they want to present this to a multidisciplinary audience. Students indicated that a group project could not be performed if members of the group are not informed about what the others are doing. As these others were students with different backgrounds, this basic understanding of each others' work was perceived as more complicated compared to regular group projects with students from the same educational program.

The second element that was highlighted was the importance of doing an audience analysis. After doing an exercise on this, students indicated that they found it useful to think about who would be at the presentations, as this would also help them seeing the presentations from a different perspective than they had before. The exercise itself was not performed very well, though. Students had difficulties putting themselves in the perspective of different audience members, or trying to understand what those audience members would like to hear from them. Students were mostly wondering what to do to make members in their audience satisfied with their presentation. An important part of this discussion revolved around the question: if you would be [audience member], what would you expect to hear and see in this presentation? From this it easily became apparent that audience members could be categorized into clusters. People in the different clusters would expect different levels of complexity, detail, and background information from a presentation. Seeing this realization take place in the group of students was a good moment in the workshop, as this would help them prepare for their presentation.

We had expected that moderating the discussion between the students would be sufficient to help them reach this conclusion, but a bit of nudging was needed to step away from seeing the audience as separate people but more as clusters that could be addressed separately. From this we learned that the assignment connected to the workshop could maybe do this nudging next time, and we would have to change the description of it in such a way that the roles that are mentioned with the second question more explicitly steer towards a classification of those roles, with specific criteria for the categories in which audience members can be clustered.

5 EVALUATION PHASE

This chapter presents the main outcomes of the student evaluation related to the interdisciplinary presentations throughout the project. It should be noted that in the student evaluations that were collected after the course, no specific questions were asked about the workshop on interdisciplinary presentations. Students of the course indicated that in general they enjoy learning from other disciplines, thinking about how to make their disciplinary knowledge valuable for the interdisciplinary projects, and working on open ended challenges. Even though these elements are positive, they do not necessarily provide clear information about how the specific activity in the course was experienced by the students. It is therefore important to include questions that are connected to specific activities in future instances of the course.

Nevertheless, many discussions have taken place between the coaches and the students shortly after the activity, and throughout those meetings, the following issues were raised by the students:

- Students asked many questions about levels of detail that should be included in their final presentations. This shows that they had internalized the notion of presenting for people with varying backgrounds, and wanted to verify whether the decisions they were making were the right ones.
- Students expressed concerns that the audience analysis made them drop too many details of the individual parts of the project, and that their academic coach would therefore not hear anything new in the presentations. This shows that they were trying to involve all members of the audience equally, and that they had difficulties doing so. This in turn is not unexpected, as it is the first time that students are involved in interdisciplinary presentations.
- Students indicated that they wanted to discuss details of their individual projects with their academic coaches before the final presentations. This would help them find out which elements were crucial to include in their presentations, and which details could be omitted. This shows that students understood that not all technical details should be included when presenting for a multidisciplinary audience, but a certain level of expertise was still expected to be shown.
- Students were more keen to perform stakeholder analyses prior to other presentations. This shows that they were working out what the goals and ambitions of different stakeholders in the projects were while they were preparing for further presentations. This in turn could be interpreted as a way for students to try to understand their audience and tailor their presentations to that audience.

6 CONCLUDING REMARKS

The outcomes of the project are promising, as it has given us clear insights on how to create an environment in which students can communicate about their (research) findings to peers with different backgrounds. The main three takeaways from the project are described below:

1. When students are to present their work in front of an interdisciplinary audience, the

best way to prepare them for this is making them perform an audience analysis. Making them think about who will be in the audience, clustering the different roles that the audience members have, and tailoring the story to people in those different clusters, enables students to present their story in an understandable manner to all members of the audience.

2. Assessment of presentations that students give in front of an interdisciplinary audience should focus on both form and content, and the audience analysis element should not be a separate element of the assessment forms (rubrics). Instead, the outcomes of a successful audience analysis should show in the other components, as for example the structure of the presentation (a form element) will become better when a proper audience analysis has been performed. At the same time, students will show a better understanding of their own work, due to the meta-cognitive skills that are acquired while preparing for the presentation.
3. These outcomes link to an essential skill of learning. When students present about their work in front of an audience of their peers, they stay within their little box. The knowledge they obtain throughout their educational however, career needs to be fitted in a larger network. Analyzing an interdisciplinary audience and connecting ones own disciplinary work to that audience provides opportunities for doing exactly that, showing the value of interdisciplinary presentations for engineering students.

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SIMPLE HOME-LAB EXPERIMENTS WITH DIGITAL DISCUSSIONS - AND THE WORLD OF PHYSICS BEHIND

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ABSTRACT

During the Covid-19 pandemic home-lab experiments were suggested to substitute for closed laboratories and experimental classes. Based on a competition among students in the 2nd semester of the Bachelor of Physics to determine the mass of a fly with home-lab experiments we present the approach of the winner experiment that allows to explore a broad range of physics touching the fields of mechanics, electronics, thermodynamics and statistics.The winner team chose an approach to measure the time that an empty sphere which has nearly the density of liquid water, needs to overcome a fixed distance in a water filled zylindrical tube under gravity. The approach allows for an analytical solution of the problem which can be proven and measured with high accuracy. The small effect of the weight change of the sphere by adding the mass of a fly (0.1 %) is nicely transferred to a macroscopic change of the time needed to sink down to the ground. Further improvements of the experiments are suggested by using different liquids, electronic timers or photsensors for more accurate measurements of time. An interesting approach works with a gradient of the sugar concentration in a zylindrical tube that results in a specific height in the gravitational field that depends on the small weight of the fly inside the sphere.
The experiments were discussed online with the students supporting their engagement with additional digital materials and constant supervision.

1 INTRODUCTION

Experiments that have to be performed as a competition are highly motivating for students [1]. The experiment to determine the weight of a fly has to be performed in the home lab based on own experimental concepts. Everything is allowed that the kitchen and the study room provide. The ideas of the students range from self built scales up to changes in the buoyancy of a plastic capsule. Two awards, small book prizes, will be awarded to the best idea and the most precise result determining the weight of an unknown fly (about 30 mg). In addition the natural link between home lab experiments and digital sensors available on the own smartphone gives rise to a motivating character of the home lab study as naturally any rather simple problem can be solved via a large range of different experimental approaches [2]. In that sense the students realize that a project turns out to have an infinite number of possible solutions involving the sensors and apps available on the smartphone [2].

Digital tools that support data acquisition and analysis as well as further possibilities for information and literature research including teaching videos suitable to explain important aspects of the theory and the configuration of complex experimental setups allow and enable students for self studies necessary to conduct home lab experiments [3, 4].

A pure problem based competition as the suggestion to determine the weight of a fly follows the concept of research-based learning (RBL) with free choice of of the experimental approach which is motivating [1, 5, 6]. Freely chosen learning topics rise motivation and promote interest in sustainability research and environmentally sustainable attitudes and behavior [7, 8].

RBL trains skills such as the ability to independently formulate questions and conceive research plans and to take responsibility for the outcome of projects [8, 9]. RBL is additionally well suited for online support and new technologies as part of blended learning concepts [10, 11, 12, 13, 14]. We experienced results of a competition to determine the weight of a fly in a simple home lab experiment that were rather astonishing and gave a glance how a single home lab experiment can in principle touch many concepts in physics ranging from meachnics to electronics and from statistics to thermodynamics.

2 CONCEPT OF THE EXPERIMENTS

2.1 Example concepts

In principle the most simple approach to measure the weight of a fly is a sensitive scale, however especially that simple approach turns out to be rather complicated because neither sensitivity nor reproducibility can be easily obtained if tools and techniques of precision engineering are missing.

Therefore the students ideas to overcome these limitations are generally focussed on mechanical approaches that use light materials and an easy construction promising the necessary accuracy. Some students indeed have built a pair of scales from straws and/or paper. Even if the mass of the scale itself is small there is a general problem with friction and the observed effect always scales only linearly with the fly mass.

Other students constructed a reversible free swinging pendulum (Kater’s pendulum), which consisted of a small piece of wire. The frequency of Kater’s pendelum is dependent on the center of mass. The students fixed the fly at different positions on the filament and measured the frequency, however it turned out that again the friction was a serious problem for an accurate measurement.

One approach used a very light car rolling down an incline transferring it´s momentum towards a razor blade that was filmed when indicating the maximal displacement indeed showing the mass of the fly with high accuracy. This approach finally also won the price for the experiment with the best result.

However the project which won the price for the most interesting approach (as judged by a jury) has put the fly into an empty plastics sphere which was swimming on water. Then the students added screw-nuts of known weight and small tablets of artificial sweetener which had a known weight of 60 mg each because a package of 2000 tablets measures 120 g (according to the producers information).
In such way the weight of the plastics sphere could be adjusted until it reached the density of liquid water. The experiment can be conducted in such way, that the sphere still rises slowly in water and suddenly starts to sink just when the fly is added. Then the small weight of the fly leads to a phase transition of the observed dynamics. However the best results were obtained when accurately measuring the kinetics of a sinking sphere with and without the fly and comparing the results with theory. The sphere needs to overcome a fixed distance in a water filled zylindrical tube under gravity. The approach allows for an analytical solution of the problem. The small effect of the weight change of the sphere by adding the mass of a fly (about 0.1 %) is transferred to a macroscopic change of the time needed to sink down.

2.2 The winner project

If a sphere with mass m is accelerated along the z-axis by gravitational force $F_G = mg$ while buoyancy F_A and friction F_{R1} point into the opposite direction (See Fig. 1) the forces calculate as denoted in eq. 1 and define the equation of motion.

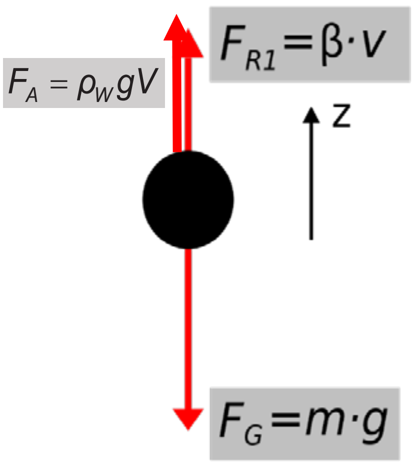

Fig. 1. *Forces on the sphere in liquid*

$$\vec{F} = m\ddot{\vec{z}} = -\left(\vec{F}_g + \vec{F}_A\right) + \vec{F}_{R1}$$
$$\vec{F}_g + \vec{F}_A = \left(m - m_W\right)\vec{g} = \Delta m\vec{g}$$
$$\vec{F}_{R1} = -6\pi\eta r\dot{\vec{z}} := \beta\dot{\vec{z}} \qquad (1).$$

Interestingly the driving force for acceleration of the sphere scales with the difference (Δm) of it´s mass and the mass of the discplaced water m_W. This diference can be positive (sphere sinks), zero (sphere floats) or negative (sphere rises and swims). When the velocity of the sphere along the z-axis rises the contribution of the laminar (Stokes) friction F_{R1} starts to rise proportionally to the velocity, viscosity of the medium η and the radius of the sphere r following Stoke´s law. These values except the dynamical variable z are summarized as a factor β in eq. 1. With this simplification eq. 1 can be rewritten as a simplified linear ordinary inhomogeneous differential equation of 1st order for the velocity of the sphere v (eq. 2).

$$m\ddot{z} = -\Delta mg - \beta\dot{z}$$
$$\ddot{z} = \dot{v}$$
$$m\dot{v} = -\Delta mg - \beta v \qquad (2).$$

Eq. 2 is solved by first solving the homogeneous system, variation of the constant and integration of the velocity $v(t)$ to obtain the trajectory $s(t)$:

$$v(t) = \frac{\Delta mg}{\beta}\left(e^{-\frac{\beta}{m}t} - 1\right) + v_0$$
$$s(t) = \frac{-\Delta mg}{\beta}\left(\frac{m}{\beta}e^{-\frac{\beta}{m}t} - \frac{m}{\beta} + t\right) + v_0 t + s_0 \qquad (3).$$

If the sphere starts with zero velocity at $z_0 = s_0 = 0$ then the trajectory is driven by the mass difference Δm of the sphere and the displaced water while the inert mass m is much larger. This leads to a very slow movement and a large difference between two trajectories proportional to the mass difference between the sphere and the replaced water mass (see Fig. 2).

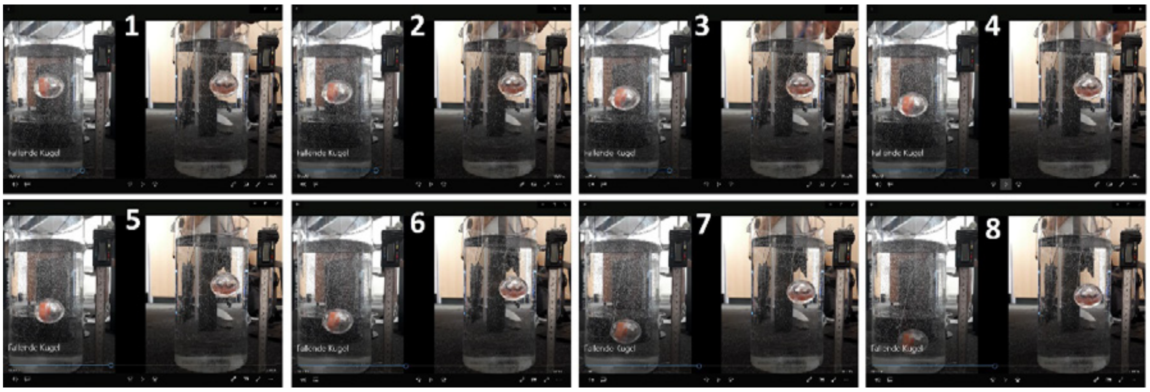

Fig. 2. *Trajectory of two spheres with a mass difference of 75 mg as plotted in Fig. 4*

This becomes evident when looking at the theoretical plots of the depth of the sphere when sinking in water at 21°C for a sphere with radius r=2.1 cm and a mass of 25 g accelerated by 50 mg mass difference (Fig. 3, right side, black curve) and 25 mg mass difference (Fig. 3, right side, red curve). From these plots it also becomes evident that the approach is more complicated than initially assumed. At the beginning of the experiment the students were focussed on the equilibrium condition

$$v(t) = \frac{-\Delta mg}{\beta} \qquad (4).$$

Eq. 4 is a general aproach to analyse the maximal velocity a free falling object can reach under Stokes friction. However as it can easily be seen from the plot of the velocity in Fig. 3, left side, the equilibrium is reached after more than 150 sec. in a depth of 40 m for a mass difference of 25 mg only and therefore the experimenters can not assume to reach the equilibrium condition under laboratory conditions.

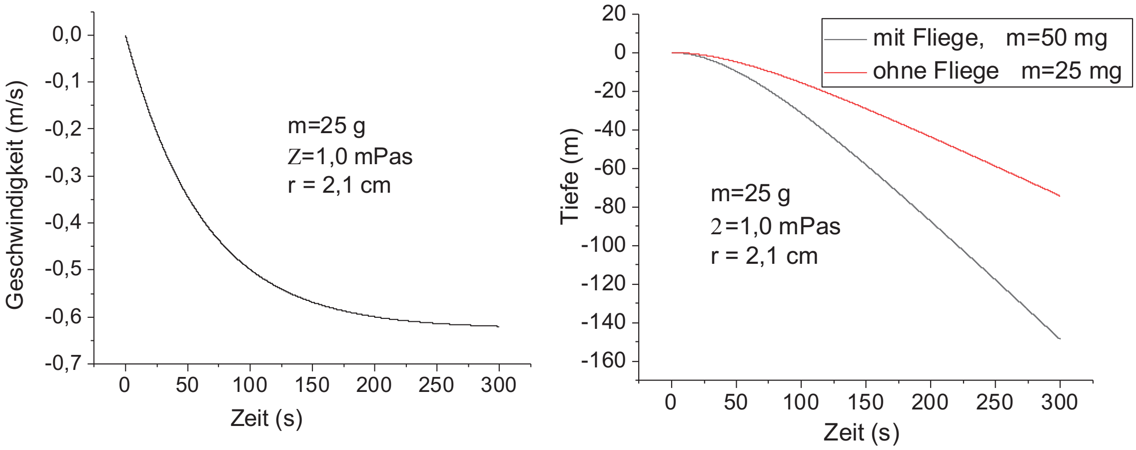

Fig. 3. *Theoretical plots of the velocity according to eq. 3 (left side) and it´s depth when sinking in water at 21°C (right side) for a sphere with radius r=2.1 cm and a mass of 25 g when accelerated by 50 mg mass difference (black curve) and 25 mg mass difference (red curve).*

3 PROJECT RESULTS

3.1 The weight of the fly

During their first tries the students aimed in determining the mass of the fly by stopping the time the sphere needs to sink down to the ground. However it turned out that their numbers were rather random and did not at all fullfill the achieved precision which was initially expected.
It turned out that the start of the free fall of the sphere was a crucial point and was not easily overcome by just releasing the sphere from the free hand.
So several approaches were tested and improved to gain reproducible initial conditions. One was the fixation of the sphere with a thin filament that was burnt at the moment the experiment was started. Especially when spheres are used which have quite exact the mass of the density of water even the weight of the falling filament and it´s interaction with the liquid surface tension seems to disturb the measurement. Another approach used a magnet holding the sphere on the ground of the vessel which had slightly less density than water. The sphere was released by quickly removing the magnet. It is also tricky not to disturb the rising sphere in the initial point when the magnet is released.
Fig. 4 shows 2 trajectories of falling spheres after burning the filament in a vessel with only 10 cm of free fall range. As especially the initial point and the first few centimeteres of the free fall are the crucial data the students quickly learned that a search for a long tube with long free fall time is quite unnecessary but the repetition of a short free fall and accurate averaging of the results is much more constructive.

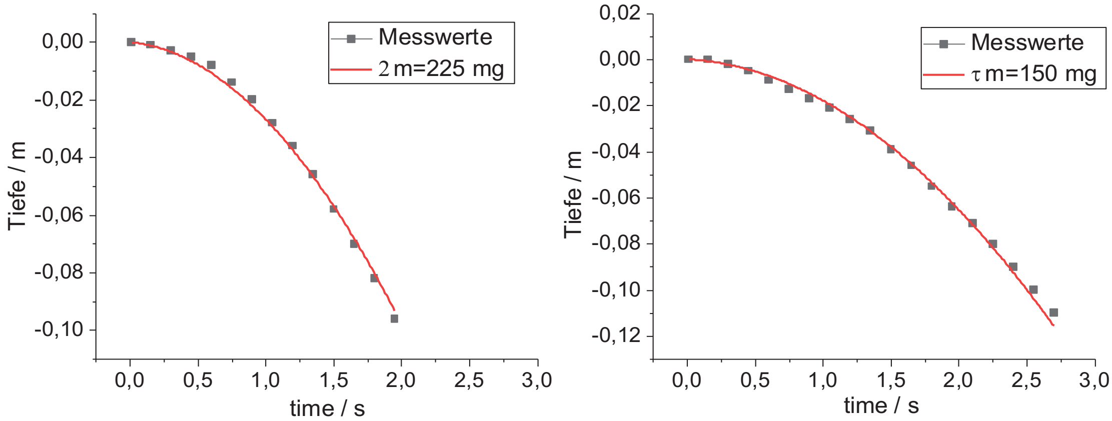

Fig. 4. *Measurement (black squares) and data fit of two trajectories of falling spheres with a weight difference to the displaced water of 225 mg (left side) and 150 mg (right side)*

As seen in Fig. 4 the free falling sphere which was filmed during sinking and the trajectory (black squares in Fig. 4) later evaluated from the movie can be well described by eq. 3 (solid red line in Fig. 4). The fit of the measurement data resulted in a weight of the fly of 75 mg after it had been added to the sphere (Fig. 4, left side) in comparison to the sphere without fly (Fig. 4, right side)

3.2 Fit Curves and statistical errors.

A fit on the measurement data resulted in much better values than just stopping the free fall time. The fit curve shows a much better match with the expected outcome than just a series of stopped time points for the moment when the sphere hits the ground of the vessel. Finally the students determined the weight of the fly to 59 +/- 38 mg which still has somehow a large deviation and needs to be further investigated.

3.3 Systematic deviations

With the possibility to change the weight inside the sphere with small screw-nuts weighting 200 mg and sweetener tablets weighting 60 mg the students additionally could check for possible systematic deviations of their experimental outcome and they could indeed identify a quite long list:

1. It is rather difficult to exactly close the plastic sphere in such way that it perfectly measures the same volume as before. This deviation is the most critical one. Finally the students chose a solid plastic sphere with small interior space that was closed by oiling the surface of the cut and press both halfs together.
2. When the water is freshly filled from the tap it does not have 20°C. Therefore the viscosity is not 1 mPas and it deviates strongly as water at 25°C reduces to 0.9 mPas. Therefore the students quickly understood how important it is to control the exact temperature of the water in the vessel.
3. When releasing the sphere still disturbance occurs which might even shortly drag the sphere a little bit upwards. This was especially the case when the students initially used a filament that contracts shortly when heated and turned out to be unsuitable as the curves deviated from the expected results.
4. In water the sphere covered with bubbles that were stuck on the sphere surface and practically led to a virtual increase of the sphere´s surface and volume therefore increasing the buoyancy.
5. When not closing the plastic sphere perfectly a drop of water appeared inside and the experiment was completely wrong as the water might be heavier than the fly itself.

The students quantified their systematic deviation finally by a Gaussian error propagation and estimated possible systematic errors of 45 mg which is quite much. When checking with an exact lab scale the fly was determined to only weight 28 mg. However the students were able to separate their statistical errors from systematic errors which is quite helpful for research to understand the role of both, statistical and systematic deviations.

4 CONTINUOUS DIGITAL SUPERVISION

It turned out that quick, regular and flexible supervision of the students via a video conference, both on demand as during a jour fixe, where they shared their experimental results and even presented the procedure on camera was of high value to identify and judge all the errors mentioned and being able to suggest and discuss improvements of the experiments.
Therefore the homelab experiments should always be acompagnied by a regular discussion of each experiment. There is not necessarily a need to do such a discussion with each group separately however at least for each experiment with the groups of all students involved.

5 DISCUSSION AND SUGGESTIONS FOR IMPROVEMENTS

During the discussion with the students after they had finished the experiments and presented their results a lot of suggestions had been made how to improve the setup or explore different effects and directions. Some of them are shortly outlined here.

5.1 Mechanical variations of the experiment

The most logical approach is to modify the mechanical setup itself. As mentioned above the release of the sphere was either done by a thin fiber that is burned at the beginning of the experiment or by a magnet that realeases the sphere. One could also think how else to construct a “smooth” release and compare the quality of the results. Also the variation of the liquid itself and substitution by oil or other liquids with higher viscosity could be promising to further prolongate the duration of the trajectory. Also a promising approach might be the start of the time measurement at a given height with an initial velocity to get rid of the initial disturbance when the sphere is started and measure just a later part of the curve during the free fall.

5.2 Thermodynamic variations of this experiment

The identification of the strong sensitivity of our results on the water temperature as it changes the viscosity made us think about the influence of further thermodynamic effects on the systematic deviations in our experiment. When considering the opportunity to slow down the process by changing the viscosity of the surrounding medium the students came up with an interesting approach that works with a gradient of the sugar concentration in a zylindrical tube that allows for an equilibrium height in the gravitational field that depends on the small weight of the fly inside the sphere. As the gradient of the sugar concentration can be adjusted infinitesimally one can build a scale where a single mg of weight difference shifts the equilibrium positions by several centimeters. In that sense the sugar gradient scale as shown in Fig. 5 was constructed where the sphere has about 15 cm difference in height when the weight rises by 60 mg.

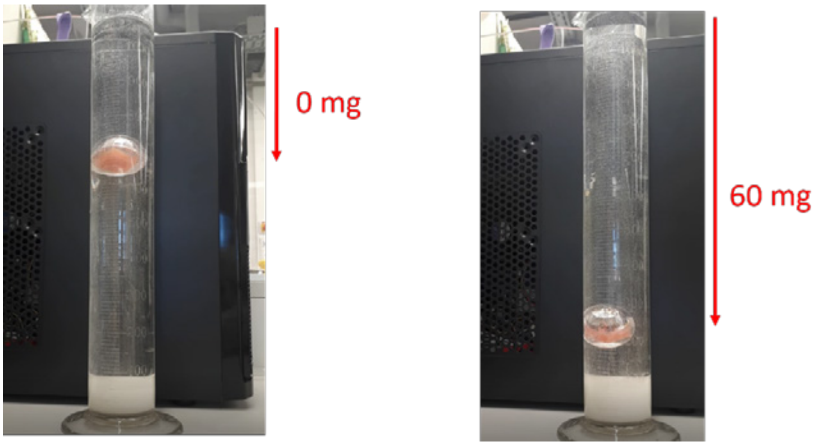

Fig. 5. *Different equilibrium positions of the sphere in dependency on the weight when the sphere falls into a gradient of sugar concentration*

Further improvements or different approaches could use a hot air ballon or helium filled balloon which is in a similar equilibrium position in a rooms natural air gradient. Such a construction might find it´s equilibrium positions with meters difference if the weight just changes by few mg.

5.3 Optics and electronics

The best values were obtained when taking a video with subsequent evaluation of the trajectory. However improved measurements could also track the object optically or at least install photosensors for better and reproducible time measurements.
For an accurate determination of the weight in the sugar gradient scale (see Fig. 5) one has to adjust the sugar gradient with high accuracy and also know the local sugar concentration. As the sugar mixes with time this also needs to be measured continuously and could for example be done with refractometry, i.e. the bending of a laser beam when crossing the solution in different height.

6 CONCLUSION

All in all the students were surprisingly engaged to achieve the best results which was most probable driven by the competition that was connected with the experiment. From meeting to meeting the discussed ideas were subsequently investigated by the students and they started to dig deeper and deeper into the teaching matter. We recognized the importance of continuous digital interaction when doing home-lab experiments. Finally when we collected the outcome it was astonishing to understand how deep you can dig into physics with just one single home-lab experiment that is appropriately exploited in all directions and touches all fields of physics.
In that sense we encourage to motivate students (e.g. by competitions) and ask them to use very simple tools which are available at home and invest the available time into steady discussions of results and further improvements.

Acknowledgements

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Appendix: Solution of the differential equation of motion for the sphere in liquid

$$\begin{aligned}
\vec{F} &= m\ddot{\vec{z}} = -\left(\vec{F}_g + \vec{F}_A\right) + \vec{F}_{R1} \\
\vec{F}_g + \vec{F}_A &= \left(m - m_W\right)\vec{g} = \Delta m\vec{g} \\
\vec{F}_{R1} &= -6\pi\eta r\dot{\vec{z}} := \beta\dot{\vec{z}}
\end{aligned} \tag{5}$$

$$\begin{aligned}
m\ddot{z} &= -\Delta mg - \beta\dot{z} \\
\ddot{z} &= \dot{v} \\
m\dot{v} &= -\Delta mg - \beta v
\end{aligned} \tag{6}$$

Solving the homogeneous system:

$$\begin{aligned}
&\dot{v} = -\frac{\beta}{m}v \Rightarrow \frac{dv}{v} = -\frac{\beta}{m}dt \\
&\Rightarrow \int_{v_0}^{v(t)} \frac{dv}{v} = \int_0^t -\frac{\beta}{m}dt \\
&\Rightarrow \ln\left(\frac{v(t)}{v_0}\right) = -\frac{\beta}{m}t \\
&\Rightarrow v(t) = v_0 e^{-\frac{\beta}{m}t}
\end{aligned} \tag{7}$$

Variation of the constant:

$$
\begin{aligned}
&v(t)=c(t)e^{-\frac{\beta}{m}t}\\
&m\dot{c}(t)e^{-\frac{\beta}{m}t}-\beta c(t)e^{-\frac{\beta}{m}t}=-\Delta mg-\beta c(t)e^{-\frac{\beta}{m}t}\\
&\dot{c}(t)=\frac{dc(t)}{dt}=\frac{-\Delta m}{m}ge^{\frac{\beta}{m}t}\\
&\int_{c_0}^{c(t)}dc(t)=\int_0^t\frac{-\Delta m}{m}ge^{\frac{\beta}{m}t}dt=\left[\frac{-\Delta m}{\beta}ge^{\frac{\beta}{m}t}\right]_0^t\\
&\Rightarrow c(t)=\frac{\Delta mg}{\beta}-\frac{\Delta mg}{\beta}e^{\frac{\beta}{m}t}+c_0
\end{aligned}
\tag{8}
$$

General solution for the velocitiy (with initial condictions) and integration:

$$
\begin{aligned}
&v(t)=c(t)e^{-\frac{\beta}{m}t}\\
&c(t)=1-\frac{\Delta mg}{\beta}e^{\frac{\beta}{m}t}+c_0\\
&\Rightarrow v(t)=\frac{\Delta mg}{\beta}\left(e^{-\frac{\beta}{m}t}-1\right)+c_0e^{-\frac{\beta}{m}t}+v_0=\frac{ds}{dt}\\
&c_0=0\\
&\Rightarrow\int_{s_0}^{s(t)}ds=\int_0^t\left(\frac{\Delta mg}{\beta}\left(e^{-\frac{\beta}{m}t}-1\right)+v_0\right)dt\\
&\Rightarrow s(t)-s_0=\left[\frac{-\Delta mmg}{\beta^2}e^{-\frac{\beta}{m}t}-\frac{\Delta mg}{\beta}t+v_0t\right]_0^t=\frac{-\Delta mmg}{\beta^2}\left(e^{-\frac{\beta}{m}t}-1\right)-\frac{\Delta mg}{\beta}t+v_0t
\end{aligned}
\tag{9}
$$

Solution for *v(t)* and *s(t)*

$$
\begin{aligned}
&v(t)=\frac{\Delta mg}{\beta}\left(e^{-\frac{\beta}{m}t}-1\right)+v_0\\
&s(t)=\frac{-\Delta mg}{\beta}\left(\frac{m}{\beta}e^{-\frac{\beta}{m}t}-\frac{m}{\beta}+t\right)+v_0t+s_0
\end{aligned}
\tag{10}
$$

THE FLUID COMPETENCE LEVEL-ORIENTED ADVANCED PROJECT LABORATORY (FCLPL) IN PHYSICS

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Keywords: *projects • project laboratory • competence level-orientation • physics • practical courses*

ABSTRACT

The fluid competence level-oriented project laboratory in the advanced practical courses of our Bachelor and Master programs of physics with up to 50 students per semester enables students to gradually grow into self-developed experiments. The students formulate a project idea and while conducting their project the students continuously proceed with the project development in close contact to their supervisors. If the students develop convincing ideas they can continue with projects XL or XXL and expand their initial ideas. The basic experiments of the practical course which had originally been assigned to the students at the beginning of the semester are gradually omitted and are replaced by a project XL or XXL. The students improve their initial project idea and write proposals and documentation. Research, experiments and documentation alternate successively and thus enable the ongoing improvement of the projects and the constant documentation and evaluation. The practical courses profit from a steady refinement as new experiments are continuously developed by the students themselves.

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1 INTRODUCTION

An extremely important question which needs to be addressed by universities is how to educate young students enabling them to solve future large-scale problems. We believe that a competence level-oriented advanced student laboratory contributes to the development of such skills and we developed such a teaching format for the advanced practical courses in the Bachelor of Physics and the Master of Physics at Martin-Luther-Universität Halle-Wittenberg. The competence levels of Bloom's taxonomy [1] are achieved in a consecutive and hierarchical sequence. The creation of something new requires remembering, understanding and critical reflection of the content of previous teaching levels to set the stage for further progress. Each level requires exercise and self-reflection combined with the phantasy to drive creative processes. Knowledge and competence emerge from a steady development process, as psychological studies [2, 3] and error research [4, 5] show.

Research-based project courses provide a chance to reshape teaching, endowing students with the capability to master problems occurring later in their professional life [6, 7]. These problem-related competences need higher priority in universities. For this purpose, new didactic strategies have to be developed. This applies both to theoretical topics [8, 9, 10] and experimental modules (e.g. practical courses) [9, 11] and is strongly linked to project-based and research-based learning [11-16].

Project work is not necessarily a sure-fire success at universities. A big problem is a certain fear among the students to devote themselves to the challenges of a project. The basic teaching modules are often found important enough to deserve all attention. This means that often only a few students volunteer for a project. Integrating mandatory projects with high complexity into the curricula may not do justice to the heterogeneity and diversity of the students. That is why we suggest a learning format in which the students can grow individually with their projects.

The evaluations of our students' interests show [11,14,15] that they want motivation and orientation in their studies in two ways. On the one hand, students want to develop specialist skills and decide on their master's thesis or doctorate. On the other hand, many students are also interested in the acquisition of interdisciplinary skills to deal with complex problems, especially questions of sustainable development. They want to see meaning in their work. Project teaching is rated as helpful for both.

The projects in the fluid competence level-oriented advanced project laboratory in physics (FCLPL) are deliberately not limited to physics alone. We motivate students to think in an interdisciplinary manner and also to go beyond the questions of classical physics. Particularly good students can develop their potential freely by expanding their projects successively.

2 CONCEPT AND METHODS OF THE FLUID COMPETENCE LEVEL-ORIENTED ADVANCED PROJECT LABORATORY IN PHYSICS (FCLPL)

2.1 Formal requirements

The advanced practical courses in the Bachelor of Physics and the practical courses in the Master of Physics measure 6 credit points (i.e. 180 hours of student engagement) for the Bachelor and 10 credit points (i.e. 300 hours) for Master´s laboratory course. The full Bachelor practical course has to be passed by about 50 students in the Bachelor of Physics, Bachelor in Medical Physics and Teaching degree in the summer semester, the Master course by generally less than 20 students of physics only during the winter term. So especially in summer the students are composed heterogeneously. Usually students conduct 5 basic experiments in groups of two students. The idea of the FCLPL is to implement projects into both practical courses (Bachelor and Master) without changing the structure of both modules.

In the FCLPL the students have to formulate an obligatory project idea at the beginning of the semester. This idea is discussed together with the teachers and the students can develop it to a project experiment. In the Bachelor program such project experiments are facultative and can be executed voluntarily while at least one project experiment is mandatory for the practical physics course in the Master´s program that can be expanded to a project XL or project XXL.

In such case the basic experiments of the internship assigned at the beginning of the semester are gradually omitted as long as the project grows to XL or XXL (See Fig. 1). Therefore the teaching load for both, students and the involved staff, stays constant. The students finally carry out a total of 2-5 advanced experiments in the practical courses of both, Bachelor and Master of Physics, as gradual and fluid access to research-based learning can be exploited to varying degrees.

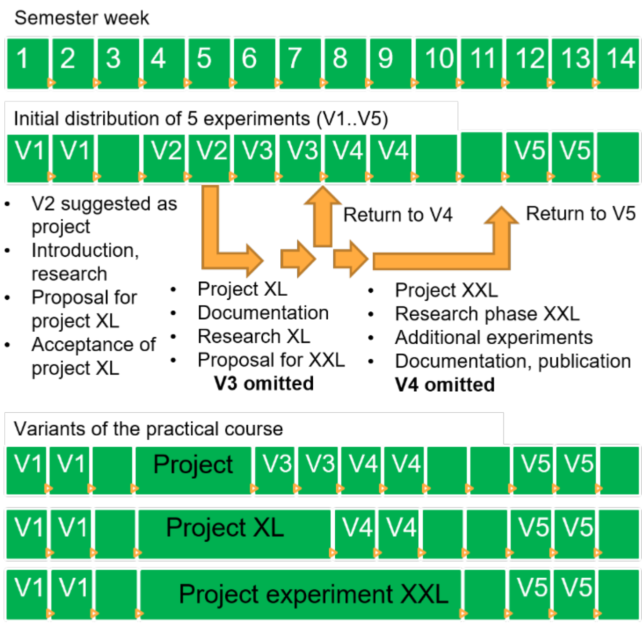

Fig. 1. *Project experiments, projects XL and projects XXL in the practical courses.*

2.2 Implementation of a project, project XL or project XXL

At the beginning we suggest possible research topics suitable for projects XL or XXL, but with an open outcome, since the projects are refined and redesigned in an evolutionary process. Publications of current research topics are discussed so that the students are motivated to recognize the current state of science but already try to think beyond – not necessarily with the focus on a deep scientific approach but in a broader sense of how to transfer recent scientific findings to their project.

Once a topic has been chosen, the students formulate a hypothesis and a proposal for research, a realistic goal and concrete research methods. The students perform the necessary literature research and present their ideas to the supervisors who agree with the students' suggestions. The important construction of the FCLPL is done in such way that the module can run as initially planned without a change of the lab structure allowing student projects to be implemented on the fly, while the practical course is running. This is achieved as outlined in Fig. 1.

Five standard experiments are suggested at the beginning of the semester. For the experiment which is suggested to be substituted by a project, an extended research question, an extension of the methodological approach and a possible further experimental approach may be proposed. The feasibility of the project proposal is discussed with the supervisors during the lab course which takes place weekly for 5 SWS (teaching hours).

If the students succeed in carrying out the proposed part of the project, they apply with new ideas for the continuation of the project on an enlarged project experiment XL, which can expand the ongoing research or touch a new question. It replaces a (second) standard experiment if the recent results of the project and the proposal for the continuation of the project experiment XL are convincing. The decision to continue the project is discussed between students and advisors. If the XL project is also successful and a concept for an XXL project is presented, it can be expanded to replace another (third) standard experiment. If the students lose interest in their project work, they can always return to the initially suggested basic experiments that were assigned to them at the beginning of the semester.

The FCLPL is conceptually a hybrid module that combines a physical project module with a normal experimental course in the practical courses.

An XL or XXL project attempt is not only submitted as an ordinary protocol but preferably concluded with a seminar talk, a poster presentation or even a small publication or as a blog article in the internet, ideally in combination with public events such as the Long Night of the Sciences. For that purpose the practical course combines 5 hours of laboratory work per week (5 SWS) with 1 hour weekly seminar per week (1 SWS). It involves 6 teachers with a workload of 4 – 8 SWS each for 50 students in the same way as the practical course in the standard format (without projects). All experiments are conducted within the rooms of the practical courses on the setups available there however the extension of single experiments can also be perfomed in collaboration with and within the rooms of the working groups of the University.

2.3 Achieved Competences in the FCLPL, seminar and poster presentation

In detail, the following interdisciplinary skills are taught to the students in the FCLPL:

• Working out the theoretical and experimental basics of self-selected questions (literature and information research)

• Acquiring performative skills by imitating a real problem without a fixed solution (in the sense of research-based learning)

• Planning, implementation, evaluation and documentation of a scientific project

• Understanding failure as a learning path

• Assessment and critical reflection on one's own work

• Critical error analysis as a basis for innovative further development and improvement

• Basics of multimedia documentation

• Seminar Talks

• Scientific writing and publication

• Poster Presentations

• Writing of project proposals

• Convincing argumentation and discussion of your own results in front of a group

The work in the FCLPLP is carried out in close contact between lecturers and students, who conduct regular meetings or video conferences. This ensures that the students' problems are communicated promptly and solved by the advisors during ongoing operations (ambulatory assessment).

The FCLPL offers students and teachers more flexibility. Seminars, poster presentations, meetings and the implementation of the experiments are supported online and the time for experiments can be freely planned in agreement between teachers and students. The presence during the internship is concentrated on a limited number of intensive days (typically 1-2 days per experiment and/or project level).

2.4 Elements of digital teaching

Digitalization plays a major role in communication and science including the acquisition of and the search for knowledge. It enables a quick literature search, the administration and sharing of information and the collaborative evaluation and documentation including the recording of actions and progress. Secondly, digitalization can support self-directed learning as it makes students independent from the university as extensively elaborated during the Covid-19 lockdowns. Thirdly, digitalization offers transfer possibilities between disciplines and institutions as well as towards the public when research outcome and learning content is shared in social networks, on blogs or via videos. It is useful to record the students' current experiences and behavior in a timely manner, and, if necessary, to intervene in a controlling manner (ambulatory assessment) [17,18]. Such recording can be achieved simply by establishing a digital laboratory documentation system (lab book) or project planning tools (we used Trello®, GitLab® and Slack®) that allow for collaborative work,documentation, tracking and the steady review of the outcomes.

We offer the students a digital environment, in which they can transform their already acquired knowledge from different disciplines as well as their own digital skills, habits and ideas for the application of digital tools into a concrete project.

2.5 Example projects and their integration into the general syllabus

To give an example project that was extended to a project XXL we want to refer to "SEM and EBIC", where the students had initially proposed the combined scanning electron microscopy (SEM) with simultaneous measurement of electron beam induced current (EBIC). The poject took place in winter 2020/21 (See Fig. 2) and the students developed both, experimental approach and technical implementation of EBIC microscopy into a standard SEM and the theory to evaluate EBIC images. The finally resulting project XXL was of such interest that the students' efforts were used to completely overwork the standard experiment as it is usually offered in both Bachlor advanced practical courses and Masters' practical courses. In such way the students not only developed their own project but they contributed to the steady development of the whole teaching module.

It is foreseen that this approach will therefore be continued in such way that good projects are implemented into the practical courses as regular experiments.

Further example experiments that have already been conducted and contributed to the development of the practical courses are

• Physics of the photosynthesis – time resolved fluorescence spectroscopy to describe energy and electron transfer processes in living photosynthetic cells (project XL)

• Optical and electronic properties of semiconductors investigated by spectroscopy, temperature dependent conductivity, magnetoresistance and Hall-effekt (Project XL)

• Temperature- und frequency dependent permittivity of water and polymers during phase transitions (Project XL)

• Combined scanning electron microscopy and electron beam induced current (Project XXL)

• Characterization of a novel setup for the tension dependent viscosity of complex fluids (Project XXL)

• Establishment of an x-ray diffraction setup for structure analysis by Laue-spectroscopy (Project XL)

• Photvoltaics and Solar Cells (Project XL)

• Environmental radioactivity, Gamma-spectroscopy and self built Geiger-Müller counters (Project XXL)

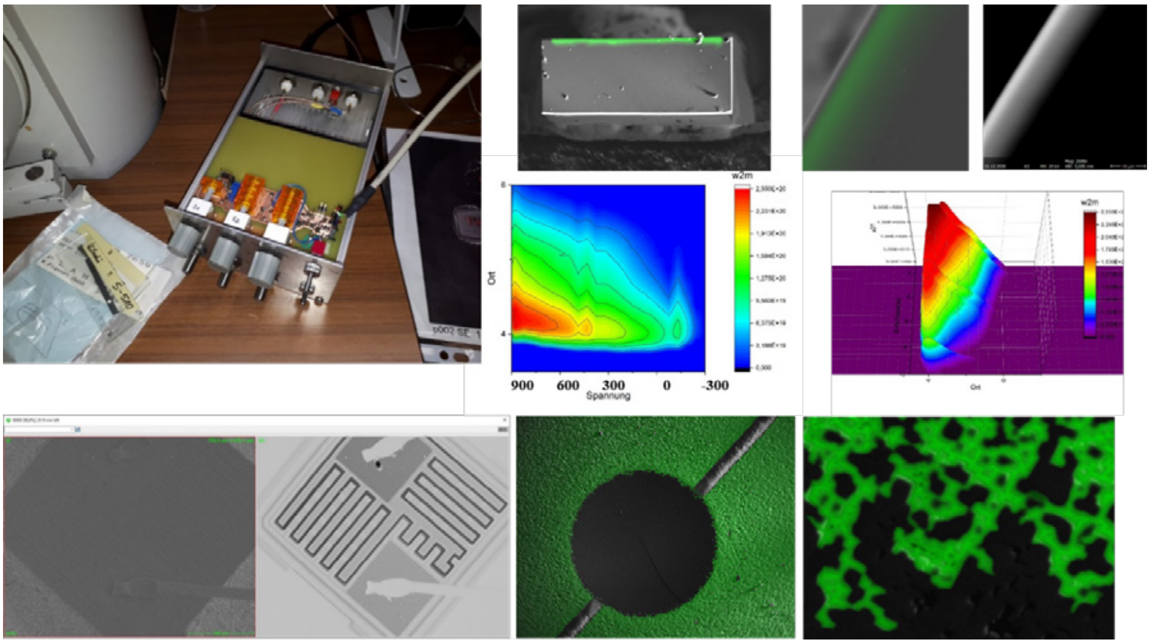

Fig. 2. *Elements of the project "SEM and EBIC"*

3 POSSIBLE TRANSFER TO OTHER CURRICULA

The FCLPL is now implemented into the advanced physics laboratory of the Bachelor and the practical courses of the Masters of physics at Martin-Luther-Universität Halle-Wittenberg. It is a tool for a steady development of the curricula and it is a compulsory module for the Bachelor and Master in Physics and Medical Physics as well as for ongoing physics teachers.

The FCLPL is therefore already designed as part of 4 different modules for the different subjects. From next year also the students of Physics and Digital Technology and students of "Physics Plus" will participate in the FCLPL.

The idea of a project experiment, into which the students can grow, can be transferred to all curricula without principal restrictions. The idea takes into account the concerns that students could be overwhelmed with projects and at the same time targets the need that especially very good students should be challenged by particularly extensive projects. The heterogeneity of the educational access is thus taken into account through a fluid adaptation to the learning behavior and the motivation of individual students.

4 EVALUATION RESULTS AND QUALITY OF SEMINAR TALKS AND POSTER PRESENTATIONS

The FCLPL was evaluated several times by the central evaluation of the MLU with special attention to the project experiments. Further interviews with the students of the physics department gave insights into the students' interests and wishes.

In this way, it was possible to improve the course during ongoing operations and thus make conceptual risks visible early enough to react. For example the Masters students rated the project experiments very good and turned out to be highly motivated to undergo projects. The Bachelor students, possibly overwhelmed by large workload, were not easily activated to participate in projects. Therefore the suggested structure with voluntary projects in the Bachelor and mandatory projects in the Master was developed.

The general aspect to be able to conduct project experiments was judged very positively during the evaluations and the students declared themselves as highly comfortable with the structure of the modules.

As supervisors we judged the quality of the seminar talks and poster presentations that were given on the project experiments. The projects were found to have highest quality with all marks ranging between 1.0 and 2.0 with an average of 1.3.

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RAPID SWITCH FROM FACE-TO-FACE WORKSHOPS TO ONLINE WORKSHOPS

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ABSTRACT

During 2020, the COVID-19 pandemic required many higher education institutes, including engineering education, to quickly switch all face-to-face lessons and meetings to remote meetings and teaching sessions. This situation forced us all to rapidly create new ways to interact, work and study remotely.

We had planned to organize five face-to-face multiprofessional ideation workshops in spring 2020 to create unbiased and innovative ideas related to smart clothing. COVID-19 forced us to replace the planned face-to-face workshops with five online workshops. We chose one video meeting platform for that purpose.

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Overall, online workshops proved to be an effective way to gather diverse ideas. The work went smoothly, although the video meeting platform was new to some participants. Online workshops are an easy way to bring together people regardless of geographical distances. Even though the organized workshops were for research purposes, we think similar workshops are very suitable for online teaching as well. We believe online workshops will be here to stay after COVID-19, as they are a great option when hybrid teaching and working take place.

1 INTRODUCTION

During 2020, the COVID-19 situation placed many higher education institutions, including engineering education, in a situation where all face-to-face lessons and meetings had to be switched to their online counterparts almost immediately. The change from on-campus working and teaching to online equivalents had to be done literally in one night at Tampere University.

Efficient working and learning incorporate bodily, physical, and social aspects [1] in addition to subject matter. These aspects are harder to establish in online working and learning than in face-to-face sessions. When rapidly changing all working and teaching to online, one big question was how to engage, activate and ensure interaction in online work, especially in a case where the participants do not know each other beforehand.

Many new ways to conduct remote and online teaching as well as research have been established during COVID-19, including, for example, broad utilization of different technical tools for online meetings, teaching sessions, and synchronous, as well as asynchronous, communication. Many of these tools have proven very suitable to multiple purposes. However, teachers need proper equipment and skills to use the technical tools for efficient online teaching [2] that facilitates students' intensive online learning. These equipment and skills can be very different than the ones used in teaching before COVID-19. Hence, teachers need time and training to adopt the new tools in an efficient way. Furthermore, the technical tools are developing continuously, hence teacher training is a continuous phenomenon [2]. The most important part of the teacher training with these tools is not know-how for their own use, but rather how to utilize the digital tools to enhance students' learning [2].

The COVID-19 pandemic provided a great opportunity to try different online teaching methods and to see their effects on students' learning, teachers' workload and costs of teaching. The COVID-19 situation has been a strong accelerator of teaching's digitalization [1]. A lot of discussion is going on about post-COVID-19 teaching, and especially about hybrid teaching in which the benefits of face-to-face and online teaching are combined. We believe that hybrid teaching is going to dramatically increase its popularity in higher education institutions after COVID-19. The online workshop is one distance teaching and working method. It suits the idea of hybrid teaching in the future very well.

2 HYBRID TEACHING AND WORKING

The hybrid teaching method utilizes technical tools to broaden the ways of teaching, learning, and working [3]. The hybrid method, whether it is connected to teaching or working in general, takes advantage of face-to-face, remote, and online working. Our definitions for those can be seen in *Table 1.*

Table 1. Definitions for face-to-face, remote, and online working and teaching

	Meeting in a physical room	Fully implemented with digital tools	Specific time slot
Face-to-face	Yes	No	Yes
Remote	No	Yes	No
Online	No	Yes	Yes

In a higher education institution setting, hybrid teaching means that a course has face-to-face sessions on campus, online sessions via an online platform, and/or remote study not depending on time, place, or pace. Additionally, in the hybrid method, the face-to-face sessions often contain parts that utilize technical tools, and the online sessions have more intense guidance for students, compared to traditional face-to-face and online lessons [3]. This encourages students to more intense active learning [3]. Hybrid teaching requires the students to take more responsibility for their learning. The hybrid model moves from the traditional teacher-centred classroom to an experience where the teacher is a learning facilitator [4].

Hybrid teaching has been shown to improve students' results in achieving learning outcomes [4]. As in all teaching, the goal in hybrid teaching is to help students learn the subject matter. The partial independence of geographical location saves teachers' and students' time. Furthermore, it enables, for example, video meetings and discussions with professionals all over the globe.

3 WORKSHOP AS A LEARNING AND WORKING METHOD

A workshop is an intentionally planned, facilitated, and scheduled session [5]. As such, it removes the participants from their normal daily context [5], which boosts their creativity. A workshop can be established either face-to-face or online [5]. In a workshop, a group of people is working on a task, such as studying and learning, solving problems, creating and developing ideas, and obtaining knowledge [5]. Today workshops can involve almost any number of participants due to the efficient online video conferencing tools. However, if the workshop involves a huge number of participants, it can be argued whether it is a workshop or a presentation, because not all the participants can interact efficiently towards a common goal. In a workshopthe number of participants should be kept small to ensure all an equal possibility to participate in the task at hand [5].

Workshops require firm engagement among participants, facilitators' true enthusiasm for interaction, and active and open communication during the workshop to succeed [6]. Workshops are often used for educational purposes in professional development programs [6], even though they also suit normal teaching purposes in higher education. The method has been found very effective in boosting communication between different groups in courses requiring tasks to be done in small groups [7]. Involving all students in the workshops facilitates interteam discussion [7]. Without workshops, project teams in a course would work in isolation from other teams [7], and important ideas and knowledge would not have been shared. Workshops have been found to aid students in achieving learning outcomes [7].

4 RAPID SWITCH FROM FACE-TO-FACE TO ONLINE WORKSHOPS

Our initial plan, before COVID-19, was to organize face-to-face workshops to create new ideas for our research questions related to smart clothing. The duration of the workshops was planned to be two to three hours. Each workshop was designed for a group of five to seven participants, in addition to the five to six researchers who were supposed to take part to the workshops. We had planned to use Post-it notes for the idea creation process. The participants would have written their ideas on Post-it notes and attached them to posters on walls. Each poster would have had its own title in coordination with our research questions. However, due to the COVID-19 pandemic, we had to change our plan on very short notice. We moved the workshops online.

The number of participants in a single online workshop varied from five to fifteen, and five to six researchers participated in the workshops. We used a video meeting platform (VMP) for our online workshops. The online platform enables a larger participant group, as the physical environment or geographical distance creates no limitations. This is a clear benefit of online implementation. In addition, scheduling of online workshops is easier because there is no need for room reservations, and the participants do not have to reserve time for travelling to the workshop location.

The online workshops lasted two to three hours. We realized the idea creation process in VMP by sharing a screen with a ready-made whiteboard including titles, and each participant had their own section. The planned idea creation phase in face-to-face workshops and the realized idea creation phase in the online workshops are clarified in *Fig.* 1. This phase worked well in online workshops, for example, the written text is easy to read, and more text can be written on a small area, compared to face-to-face workshops.

Fig. 1. The idea creation phase in face-to-face workshops (left) and online workshops (right).

The online workshops required more thorough instructions to the participants than the face-to-face workshops would have needed. Even though the participants would have used the VMP before, not all were familiar with all the tools in VMP. To ensure smooth working in the idea creation phase, the participants were all given a chance to try typing on the shared screen and to use the stamp feature from the VMP's annotate bar. In addition, everyone was instructed on the use of VMP chat. Some of the participants used a browser version of the VMP, which meant that they did not have the annotate feature. Those participants were instructed to use the chat for writing their ideas. Two of the researchers transferred the messages from the chat to the screen when needed. One of the researchers was the host of the video meeting, and the rest of the researchers had cohost rights.

The initial idea was to record the face-to-face workshops with a video camera. This idea was directly moved to the online world by recording the online workshops in the VMP. Not all the participants kept their cameras on in the online workshops, hence not everyone was able to see everyone else's face. This is a clear disadvantage of online workshops compared to face-to-face ones. Even though the participants in online workshops would have the cameras on, screen sharing can hinder seeing the participants' images, depending on the computer equipment they are using. We noticed that the communication and the feeling of presence benefit from seeing each other's faces on-screen. However, the feeling of presence would probably be even better in face-to-face workshops, especially in cases where the participants do not know each other beforehand.

A coffee break was included in the original plan for the workshops. Coffee breaks are very good for getting acquainted with others; they have a very important role in many kinds of meetings and teaching sessions, even though their importance is seldom discussed. Some of the online workshops had a break around the middle. However, the break did not create informal chatting among workshop participants; instead, all were taking the break by themselves. Informal chatting with participants creates a feeling of community spirit and creates a friendly atmosphere among participants. This is unfortunately much harder to establish in online work.

The general flow of the workshops is presented in *Fig.* 2. Regardless of whether face-to-face or online implementation, the basic idea in the workshops was the same. Every workshop opened with a short welcoming speech, followed by introducing the research group and all the participants. All were informed that the entire workshop would be recorded and screenshots taken. The participants were encouraged to have their cameras on, but they were not obligated. Researchers had their cameras on during the workshops. Next one of the researchers gave a brief presentation about the subject matter, and after that, the participants were instructed in the use of the VMP.

The workshop ideation phase of every research question began with a ten-minute silent session, in which the participants could write their ideas with the VMP's annotation tool on the shared screen. After silently working, participants were asked to discuss freely the ideas they had created. Two or three researchers elicited discussion, and simultaneously one to three researchers grouped the written ideas in different themes. The purpose of this grouping was to promote ideation and increase discussion. Each of the questions was processed in a similar manner, as seen in *Fig.* 2. The aim was to form as many ideas as possible to answer the research questions without any limitation. The discussion in the online workshops was very active and rich. However, some participants were very silent. The researchers had to pay special attention to them so that their ideas would also be written on the screen and discussed. Based on our previous experience, communication among participants who are not familiar with each other is much easier in face-to-face than online meetings. To succeed in bringing all participants into lively discussion in online workshops requires more effort from the facilitators than in the case of face-to-face workshops.

After the ideation phase, every participant was asked to mark their favourite idea, the most innovative idea, and the idea that is very good but has many challenges. This was done in the VMP with the annotation tool's stamps. This was a new feature in our workshop implementation plan; we did not have this planned for the face-to-face workshops. The VMP we used made this possible, and this phase worked very well in online implementations.

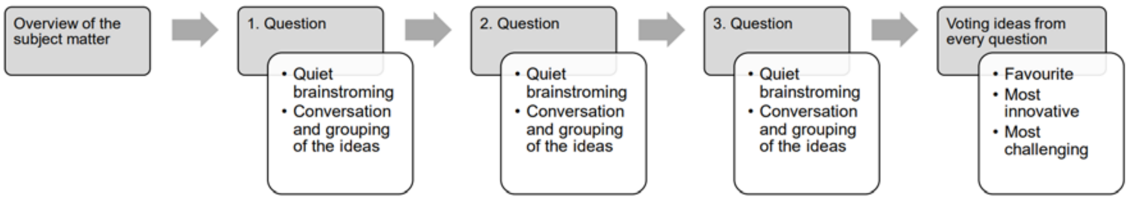

Fig. 2. The flow of the online workshops

Even though nowadays technical tools are mainly working well, some participants faced technical problems during the workshops. These kinds of challenges do not appear in face-to-face implementations. A technical facilitator and problem solver is needed in online workshops. Thus, one organizer needs to pay special attention to these issues.

5 SUMMARY AND ACKNOWLEDGMENTS

Overall, online workshops proved to be an effective way to gather and create diverse ideas, and the work went smoothly in all groups, although the VMP was new to some of the participants. Our thoughts on the benefits and disadvantages of face-to-face and online workshops are presented in *Table 2*, in which we have bolded the most important issues, in our opinion.

Table 2. Comparing face-to-face and online workshops

	Face-to-face	Online
Benefits	**Better feel of presence** Easier to activate all participants to take an equal part in task at hand Easier unofficial communication Participants don't necessarily need computers Low probability of technical problems	**Independence of geographical place** Easier scheduling Easy recording with video meeting platform Huge number of participants possible Helps in achieving sustainable development goals Clear text, possibility to use various fonts and colors Lack of travelling saves time and money
Disadvantages	**Dependency of geographical place** More difficult scheduling Time and money spent on travelling Recording needs special equipment in the room Number of participants is limited according to the room	**Poorer feel of presence** Challenges in activating all participants to take an equal part in task at hand Lack of unofficial communication Participants need computers Probability of technical problems Know-how of the VMP needed More instruction for participants needed

As seen in *Table 2*, both workshop implementation ways have their pros and cons. However, the biggest advantage to online workshops we noticed is the independence from being in the same physical place as other participants. Online workshops are an easy way to bring together people without restrictions on geographical distance. This is truly a great thing; people from all over the globe can participate in the same workshop. In the international field of higher education, where students are in different countries, this enables them to work and study together. We believe that in the future, teaching cooperation will be easier among different institutes of higher education.

Furthermore, the lack of travelling and easier access to education aid in achieving the United Nation's sustainable development goals, such as climate action, sustainable cities and communities, responsible consumption and production, and quality education. Hence, hybrid teaching and working methods, where online workshops are one possibility, have far-reaching effects on life in many sectors.

The feel of presence is much harder to establish in online workshops than in face-to-face workshops. That is the biggest challenge in online workshops, in our opinion. Online workshop organizers have to work hard to intensely activate the participants, and in this way to create a better sense of presence.

Our experience of online workshops is definitely positive. They suited our purposes very well. Even though they have disadvantages, in many cases the benefits surpass the disadvantages. Online workshops prove to be a teaching method that adapts very well to a future utilizing hybrid teaching in higher education institutes.

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DESIGNING FLIPPED LEARNING IMPLEMENTATIONS FOR ELECTRONICS COURSES

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ABSTRACT

Due to the COVID-19 pandemic during year 2020 many higher education institutes were forced to switch to remote teaching on a very short notice. The rapid change from on-campus to remote teaching showed us that effective remote teaching needs totally new forms of course implementations. The idea that one just moves the on-campus teaching to a distance learning platform without changing anything else was found to be inefficient and passivating for students.

Flipped Learning Method (FLM) has been successfully utilized in many fields, including engineering education. The students' learning is enhanced and deepened when they study the basic concepts of a subject remotely in the place and time that suits them, and the face-to-face time is reserved for issues on the higher levels of Bloom's taxonomy. In engineering studies, the possibility to utilize technology and technological tools are important. Nowadays the technological tools, such as the internet, simulation devices and various pieces of software, are widely available to students thus enabling and supporting the FLM.

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The FLM has been taken into use during couple of recent years in Tampere University. The COVID-19 situation gave us a trigger to adopt FLM in our courses. We believe that FLM is very suitable to hybrid teaching, where remote and on-campus teaching are combined in the same course implementation. In this paper, we will report our experiences on the rapid change to remote teaching on year 2020, the reasons for taking FLM into use, and the FLM planning and designing process of our courses.

1 INTRODUCTION

The COVID-19 epidemic meant a huge leap into remote teaching for educational institutes. Even after the COVID-19 many institutes are going to offer an increasing number of courses that utilise hybrid teaching. The hybrid teaching or learning can be defined in multiple ways: In one definition the hybrid teaching means that students attend syncronously the same session either physically in a classroom or online [1]; In other definition the hybrid pedagogical method means that face-to-face activities in classroom are combined with technology-mediated activities outside classroom [2, 3]. In this article we use the latter definition. Many times the terms hybrid and blended learning can be used interchangeably [3].

In hybrid teaching some of the seat time in a classroom is replaced with, for example, video lectures [2]. This type of hybrid teaching and learning offers many benefits, such as increased student engagement, increased active learning in class, custom-tailored learning activities for diverse student groups and the possibility to study at a self-paced rate [2]. We believe that hybrid teaching can be designed and implemented using the Flipped Learning Method (FLM).

During year 2020 we have been forced to think our teaching in a totally new way, and we have found that effective remote learning needs new tools and methods. The methods used in traditional face-to-face classroom teaching are not working in remote teaching, we have found them passivating and inefficient for students' learning. One very potential method for efficient hybrid teaching is FLM, and we believe it is going to increase its popularity also after COVID-19. FLM is a learner-centred approach to teaching and studying [4]. The basic idea of it is not new, already dialogues used by Socrates were learner-centred [4]. Research results on FLM to students' academic achievements are varied, some do not show significant improvement, while some do show it [4]. FLM can, for example, help students to learn, increase interactivity in class, and enhance active learning. [5]. Thus, we think that when the FLM is utilized so that it suits well to the course and the subject matter, it will enhance students' learning and helps them to better achieve the learning outcomes.

An academic project has been ongoing for a couple of years for taking FLM into use in the engineering education in Tampere University. The first courses involved in this project were large basic courses in natural sciences. Succeeding those, also other courses have been accepted to the project. The rapid change to remote teaching due to the COVID-19 pandemic on spring 2020 gave us a trigger to apply to this FLM project with bachelor level electronics courses. Furthermore, the project gave us an extremely good framework to try FLM. The FLM project provides the participating teachers equipment needed in doing short videos, and most importantly, allows the participants to use one month of working time to the course design with FLM.

The change to FLM is not as huge as it might be in our courses. We have already been using blended learning in many ways on our courses, including various activating learning events and assignments, and we have utilized various evaluation models, such as continuous assessment. With the adoption of FLM we are aiming to students' deeper understanding of the important concepts, better skills in problem solving and critical thinking, and better achievement of the learning outcomes.

2 THE FLIPPED LEARNING METHOD

FLM combines face-to-face and online sessions with different kinds of online tasks. The traditional teacher-centred, time, place and pace dependent, information transfer lecturing is moved online, very often in the form of pre-recorded videos or texts. The teaching strategy is moving towards learner-centred [4]. The face-to-face time with teacher is reserved for deepening the understanding of the subject matter, for example, by discussions with the teacher or doing problem-solving activities. FLM is very popular today, and it is increasing its popularity continuously. [6] As FLM requires students to take more responsibility of their learning, they must adopt active learning strategies instead of passive learning [4].

The basic idea in FLM can be found in Bloom's taxonomy, where the complexity of the subject matter increases from lower to higher levels [4]. The face-to-face time is reserved for higher levels in Bloom's taxonomy in FLM, on the contrary to traditional teaching, where it is consumed in the lower levels. This can be seen in *Fig.1*. The subject matter on the middle levels in Bloom's taxonomy can be dealt with both ways, in face-to-face sessions, or self-studying, depending on the case in hand. The students study the basics of the subject matter themselves in FLM, either alone or in groups, by reading, watching videos, or doing different kinds of assignments. The students' conception of the subject matter is deepened in classroom sessions and discussions with the teacher. The focus of the classroom sessions is to engage the students in higher-level thinking and application of the concepts in groups with teacher's support to promote deep and significant learning [7]. The Bloom's taxonomy helps teacher to design the course implementation properly while it aids in the classification of knowledge on the course [4]. It has been found that FLM has positive effect on the students' learning especially in higher levels of Bloom's taxonomy [4]. One big advantage of FLM is that students can utilize the learning methods and strategies that suit them best [6]. Another great advantage is that they can study the self-study parts independent of time, place, and pace.

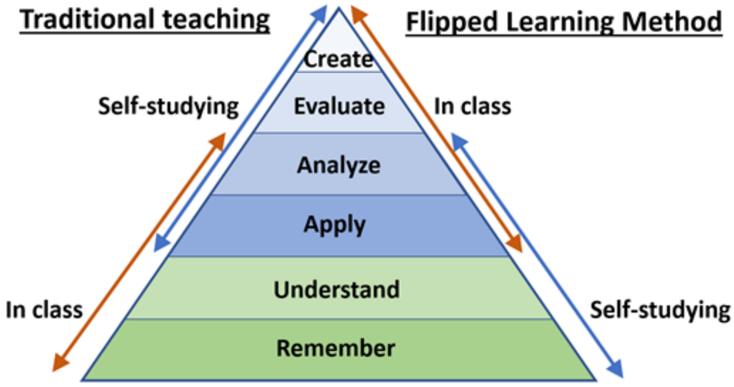

Fig. 1. Bloom's taxonomy with traditional teaching and FLM

3 PLANNING OUR COURSES ACCORDING TO THE FLM

The courses we are designing now according to FLM are implemented on autumn 2021. Some details of the two courses, which are now under design process, are presented in *Table 1*. The first course is a totally new course, that course has not existed before, and the second course is an old course which is now adopting FLM.

Table 1. The courses under FLM design work

Course	Target group	Estimated number of students	New course/ Old course	Duration
Electronics and Circuit Theory	BSc second year	25	New course	7 weeks
Product Design of Electronic Device	BSc third year	30	Old course	7 weeks

3.1 The basic idea and weekly schedule

The planned basic idea in both the courses is presented in *Fig. 2*. The courses last for one study period, i.e. 7 weeks. The course content is equally divided to the weeks keeping the workload constant throughout the course. Every week has basically the same structure consisting of pretasks, online assignments, face-to-face session, online activities, and small group meetings with teacher, as seen in *Fig. 2*. The basic structure can be modified according to the subject and recourses available, but so far, the idea is to follow this basic idea. The designing of the basic weekly schedule needs to be done carefully to accomplish the appointed learning outcomes, to keep the workload constant and to offer students meaningful and versatile learning opportunities.

The starting point of the design is a thorough definition of the learning outcomes and the core contents of the course. Learning outcomes are designed with the help of the Bloom's taxonomy. The core contents and their corresponding learning outcomes can then be divided into different flipping modules with the total duration of seven weeks. Based on the Bloom's taxonomy level of the learning outcome, it can be designed, whether this learning outcome will be accomplished via pretasks and online assessments, or via the face-to-face sessions.

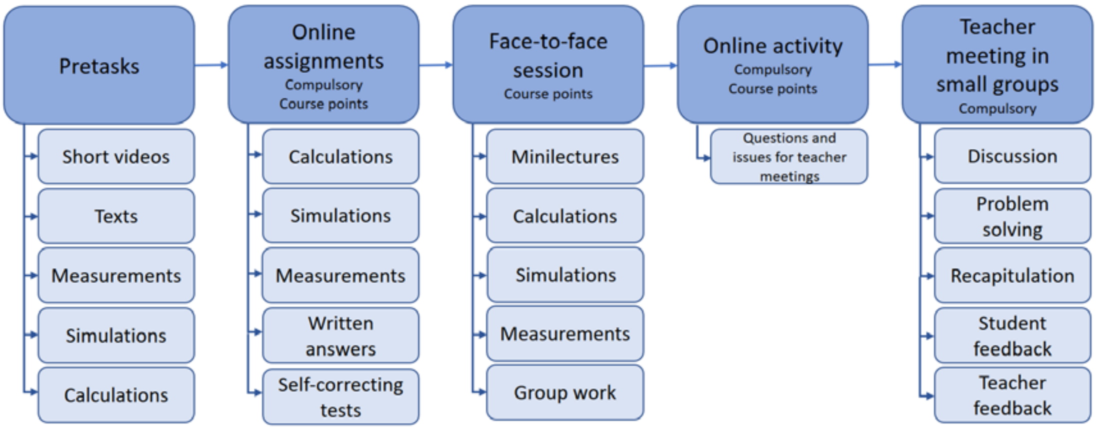

Fig. 2. The basic weekly schedule

The pretasks can be almost anything that helps students' learning on the topic. Potential choices for pretasks in our electronics courses are presented In *Fig. 2*. The student must have acquired the contents and concepts of the pretasks to accomplish online assignments. The main learning outcomes of the self-studying part can be e.g., that the student can describe, define, explain and classify the basic concepts of the subject at hand or to solve and simulate basic problems. Online assignment possibilities that suit well to our courses are presented in *Fig. 2*. In face-to-face sessions for example minilectures can be combined with different kinds of tasks that promote active learning. Examples of suitable task types can be seen in *Fig. 2*. The main emphasis in the face-to-face sessions is to deepen students' understanding of the subject matter. The learning outcomes of the face-to-face sessions can be e.g., that the student can compare, summarize, select, construct, measure and design concepts of the subject at hand. An important aspect of the face-to-face session is also to build a sense of community in learning. This can be accomplished by doing various group work assignments, or by doing measurements and problem solving in groups. Furthermore, in the face-to-face sessions important working life skills, such as teamwork, problem solving, creativity and critical thinking, can be enhanced. Online activity after the face-to-face session is mainly targeted to finding out issues that are the most difficult for each student, then they can be the baseline for teacher meetings. This way each student profits from the teacher meetings the most. Teacher meetings can handle issues in many ways, some suitable ways are presented in *Fig. 2*. The teacher meetings are very good situations for feedback both ways, from teacher to student and vice versa. Feedback for the students during the course helps them to capture their strengths and development areas, and feedback for the teacher helps the teacher in adjusting the course and its implementation to best enhance students' learning.

We provide the students with a bring-your-own-device (BYOD) in electronics courses in Tampere University. The BYOD contains, for example, a multimeter, an oscilloscope, a function generator and a power supply. Tampere University has a software licence required for the BYOD and students can download it to their own computers. This way every electronics student can do basic electronics measurements, simulations, and circuit construction outside campus. Thus, we can utilize the BYOD device when designing the tasks for our courses. This is a great advantage in a subject like electronics, in which different kinds of hands-on skills are essential.

3.2 The basic idea of course evaluation

Both the courses will have an evaluation system where the final course grade consists of multiple tasks done during the course, and perhaps also an exam. The exam can be a conventional exam done with pen and paper, an electronic exam, or both. The planning of the courses is still ongoing, and the final evaluation system is still not yet determined. Regardless of the possible end exam the students will collect course points during the course from different tasks. The planned arrangement for course points can be seen in the weekly schedule in *Fig. 2*. The course points will have a significant role in the final course grade. This encourages the students to work continuously throughout the course aiding their learning. The learning outcomes are important to define so that they are measurable. The course evaluation will be anchored to the learning outcomes so that it will advance learning.

3.3 Experiences on course planning using FLM

Even though the planning process for our courses utilizing FLM is still ongoing we have already noticed some important aspects. Perhaps the first to pay attention to is that the course planning, design and preparation tasks take really a lot of time, a significant amount of time must be reserved for these. This doesn't depend on whether the course is new or old, the time consumption is huge.

Furthermore, what and how much should be flipped needs to be carefully designed. Core content analysis and the learning outcomes play an important role in designing the course. The course design and especially task and video preparations are very time consuming. The short videos, for example, need to be carefully written and often they need to be subtitled also. At the beginning the video recordings might have to be done several times as well. In addition to making videos, different kinds of online tasks must be created. Depending on the learning management system (LMS) in use, for example, Moodle, whether automatic checking is used, and how it is used, the online task planning and making can be extremely time consuming.

Additionally, FLM requires new teaching equipment that must be taken into use. This takes time and creates costs. Videos of good enough quality and flowing learning sessions need something more than just a normal laptop and headset. Fortunately, the FLM project in Tampere University provides us new laptops with very good quality touch and drawing screen, and special microphones for video making.

Support from the institute, the possibility to ask guidance from experts, and peer support can help the teacher in utilizing the FLM. Furthermore, most of the work has to be done for the first implementation of a course, and only once. In the following years the teacher's workload will be significantly smaller.

3.4 Continuous course development

We are right now in the middle of the planning process, and only after the first implementation rounds on Autumn 2021 we know more: What were the things that worked well, what needs further development, how was the student motivation and engagement, and most importantly, how did the students reach the learning outcomes.

Feedback, both the student and colleague feedback, is an important tool to develop courses continuously. We are systematically collecting feedback from students in all our courses, and we use feedback to further develop all courses and study modules. Next Autumn we will design the feedback surveys so that we can find out relevant information of the FLM implementations from student perspective. In addition, we have an intense teacher community where we can discuss teachers' views on teaching related issues, and learn from each other. Furthermore, the LMS provides us useful information especially on the online tasks: We can have reports of, for example, how many times and how long the videos have been watched, and how long and how many attemps an online task required from students. Hence, even though the main planning of these courses utilizing FLM is now ongoing, the development work of these courses is continuous.

4 SUMMARY

The COVID-19 has done a favour to higher education, as well as to other education levels, by forcing the institutes to think about teaching and learning in totally new ways. Even though the change from face-to-face to online studying was done literally in one night on spring 2020, during the year 2020 we really had to rethink teaching and learning over again to increase students' learning and their engagement to their studies. This COVID-19 pandemic, and the support project from our university, triggered us to take FLM into use on our courses on autumn 2021.

Although the planning, design and preparation of courses utilizing FLM take really a lot of time, we believe it is worth it. We are expecting increased students' learning especially on the higher levels of Bloom's taxonomy. Furthermore, the partial independency of time, place and pace offers students possibilities to do their tasks with learning methods, time, place, and pace that suit each student the best. The social aspects of face-to-face sessions are extremely important, and the FLM also takes that into consideration.

We have found that the amount of work for a teacher is huge when taking FLM into use for the first time in a course. However, on the succeeding course implementations the teacher's workload will be stabilized to some much lower level. We assume that the workload after the first implementation will be about the same as in the case of a traditional course implementation. Hence, the benefit of the FLM is definitively not the saved teachers’ work time but the students’ enhanced learning results.

As a conclusion, we believe that FLM is a very good possibility for the higher education after the COVID-19. We think that the hybrid or blended teaching methods will be significantly utilized in future and FLM is a very potential method among those. However, the support from the higher education institute is essential in taking FLM into use. Efficient FLM needs special equipment, possibly some new software, resources for the planning work, peer support and guidance in the method itself. As a result, we can assume better student engagement, enhanced learning and learning skills, as well as more self-regulated and active students.

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HOW DO WOMEN EXPERIENCE AN ALTERNATIVE EDUCATIONAL MODEL IN IT?

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ABSTRACT

The advancement of technology, the need for life-long learning driven by the constantly emerging demands of contemporary economy, as well as the necessity for the educational organisations to address increasing competition and economy crises compel the transformation of education models; hence the emergence of alternative models of education. Such alternative models target different categories of learners and show various levels of success. This paper is an effort to contribute to the study of women's experience of an unconventional educational model recently launched in the field of Computer Science, namely at a franchisee of École 42 in Russia. The said model draws upon peer pedagogy, gamification, cross-generational and family friendly-learning. This study investigates the response of women participating in the program to the aforementioned methods. Recommendations produced based on the study may contribute to more efficient adaptation of the alternative model under study to women's needs and thus to female student retention.

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1. INTRODUCTION

Education systems and related organizations have always adapted to the developments and changes of economy and technologies; perhaps now these changes are more frequent and rapid, hence the demand of more often and quick responses from the side of those involved in education [1]-[3]. Alternative education models represent one way educators address the said demand. Contemporary alternative education models come in a variety of forms [4]-[6], aiming to effectively cater to the needs of both labor markets and learners, as well as to address organizational existential and economic crises of educational organizations. One of such recently emerged alternative forms of educational organization is École 42, launched in France in 2013 and now represented in over 20 countries [7], including Russia since 2018, where currently two branches operate – one in Moscow, and one in Kazan. The School trains manpower exclusively for IT industry, tuition free. The unique approach of the School is that it heavily relies on peer pedagogy, which is stated as studying without professors[1]. The School's methodology is also based on the principles and practices of gamification, cross-generational learning, and family friendly-learning.

Peer pedagogy used by École 42 draws upon *social constructivism* approach and the concept of *active learning*, e.g., [8], in particular. It implies that students learn from each other in formal and informal settings with various levels of supervision. This approach has long been used in higher education in general, e.g., [9]-[11], and in teaching Computer Science related subjects in particular, e.g., [12]-[14]. Findings on the effect of such practices on learning gain are generally positive, though the need for the instructors', course designers', and mentors' professional development is highlighted.

Gamification in education setups and *challenge-based education* have been a subject of multiple studies, e.g., [15]-[18], [19]-[21], respectively. Zahedi et al. in [22] have investigated gamification in education for computer science students. They concluded that 'gamification is a gender-neutral learning engagement strategy that improves female students' performance as much as male students'. Besides, the results show no or little positive effect on women's interest and engagement in the field of Computer Science. Jent and Janneck [23] have studied the influence of gender and age on motivation enhancement via gamification. They concluded that male users feel more motivated by gamification than female participants. Moreover, motivation through gamification decreases with age.

Further, Glebocki et al. in [24] discuss the value of *cross-generational* learning setup and argue that IT transmedia blend is supposed to bridge the gap between generations. Rubin et al. in [25] investigated how age and gender predict the deep learning ability and satisfaction at the university. They showed that age predicted deep learning ability more strongly among women than among men. Moreover, age positively predicted degree satisfaction among women but not among men, and deep learning mediated this moderation effect. Finally, to the best of our knowledge, *family-friendly learning environment* topic requires more intensive study, while the literature on workplace family-friendly policies is considerably large. The body of

[1] https://www.42.us.org/program/peer-to-peer-learning/

available literature, though limited, describes the examples of existing family-friendly learning environments and resources at the universities and investigates the challenges parenting students have to address; the results show the demand to acknowledge the need to develop and use official policies for this group of students [26]-[28].

Combining the aforementioned concepts, the novel approach of École 42 should clearly be investigated and understood for the benefit of learners, IT industry, and education research. In the current research effort, which is a part of an ongoing study of the said alternative model implementation by a franchisee of École 42 in Russia, we opted to investigate female students experiences and perceptions of the School's model. In particular, this research seeks to:

1. compare students' enrolment, learning progress, and dropout data by gender and age group to understand how much academic progress is related to the students' age, specifically for female students.
2. investigate how women perceive peer learning pedagogy, gamification, cross-generational learning practices and if family-friendly learning environment is important for the students of the educational model of the School under study.

The rest of the paper takes a form of two sections. Section Methodology briefly describes data collection methods, section Results and Discussion details and interprets the collected data.

2 METHODOLOGY

The data for this study were obtained from two sources in 2020 and 2021. First, the data on enrolment, academic progress, dropout rates, gender and age, as well as places of residence of the School's applicants and students for this study were provided by the School's administration. The data were anonymized. Specifically, the data were provided on the pass/fail results and gender for the selection activities for 6099 program applicants in Moscow branch and 1979 program applicants in Kazan branch (both are cities in Russia) . Academic achievements, dropouts, gender and the place of residence for the enrolled students were available for both Moscow and Kazan branches. Kazan branch administration also provided the data on the students' age. In addition, in spring 2021 all female students of the School were invited to participate in an online in-house designed survey. The survey responses were anonymous. We obtained 208 unique responses by this survey, which is around 29% of current female student body of the School.

3 RESULTS AND DISCUSSION

3.1 Composition of the School's students population

In this subsection we present the relevant data and compare

- the selection results in Moscow and Kazan branches for women and men (Table 1)
- dropout results for men and women, by enrolment batch (Table 2)
- the distribution of students in Kazan branch by gender and age group (Fig. 1)

- dropout results in Kazan branch by gender and age group (Fig. 2)
- the distribution of the students in Moscow and Kazan branches by gender and the geographical distance to the place of students' residence (Fig. 3)
- the relation of the geographical distance and student retention in Moscow office (Fig. 4)

To begin with, the School employs a comprehensive process for the students selection. Table 1 shows that during the selection process, on average, female applicants perform slightly better than their male peers.

Table 1. Shares of enrolled applicants by gender, %.

Branch	women	men
Moscow	45%	41%
Kazan	32%	29%

It is important to note though, that men tend to perform better than women during studies: the highest Level that can be achieved in the program is 21; and, while the highest achieved Level in men is Level 20, for women it is significantly lower - Level 15. To date, the highest achieved levels belong to the students if the first enrollment batch and the results can alter with time. To date, men systematically demonstrate higher achieved levels: in all enrollment batches without exception their average scores are higher, including when calculated on a sample truncated by 5%. At the same time, the median performance values form women and men are identical in all enrollment waves (except for wave 3, where the difference is 1 point: Level 7 for men and Level 6 for women).

Further, for the enrolled students the average dropout rates for women and men are almost similar - 37% and 33% respectively, and the tendency of dropouts of women being slightly higher than those of men holds for individual batches, with the only significant difference of the said rates for batch 1 and a reverse result for batch 6 in Moscow (Table 2). Batches 6 and 7 are recent, hence lower dropout rates to date in general.

Table 2. Students' dropout by gender and enrolment batches, %.

Batch	Women	Men
1 Moscow	44%	28%
2 Moscow	38%	35%
3 Moscow	52%	48%
4 Moscow	38%	35%
5 Kazan	36%	35%
6 Moscow	15%	16%
7 Kazan	17%	11%

Figs. 1 and 2 show the distribution of female and male students in Kazan branch by age group and their dropout rates, respectively. Students' age in this branch currently vary from 19 to 61. However, around half of both male and female students belong to the age group of 20 to 25 years old; the second biggest age group for both sexes is 26-30 years old. Notably, the shares of women in the age groups of 26-30 and 31-35 years old are bigger than the shares of men of these age groups. This might mean that women more than men perceive this program as an option of career change. As for the comparison of dropout rates of women and men (Fig. 2), in the largest age groups women tend to drop out more frequently than men. Interestingly, so far older female students show more persistence. Thus, it could be worthwhile for the School to test this hypothesis and focus mor women 35+ years.

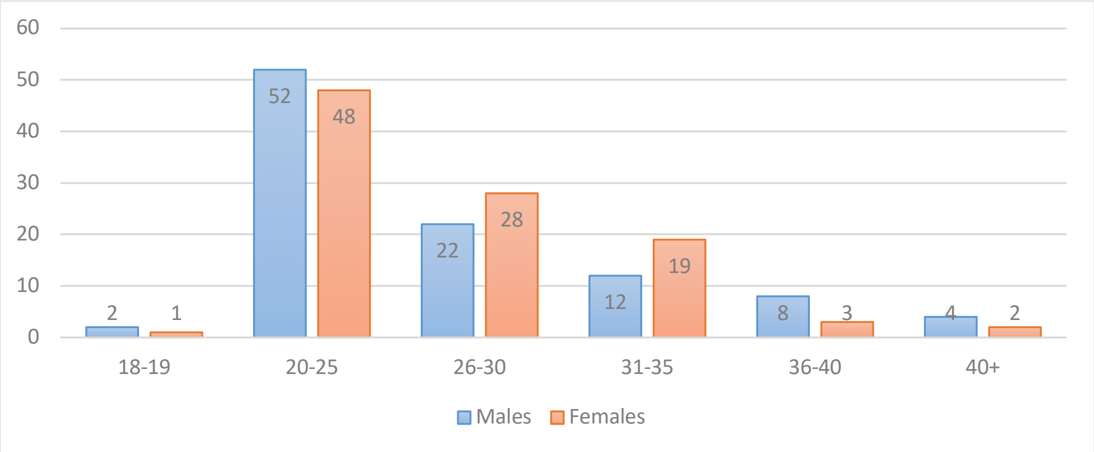

Fig. 1. Shares of women and men in student population of Kazan branch by age group, %

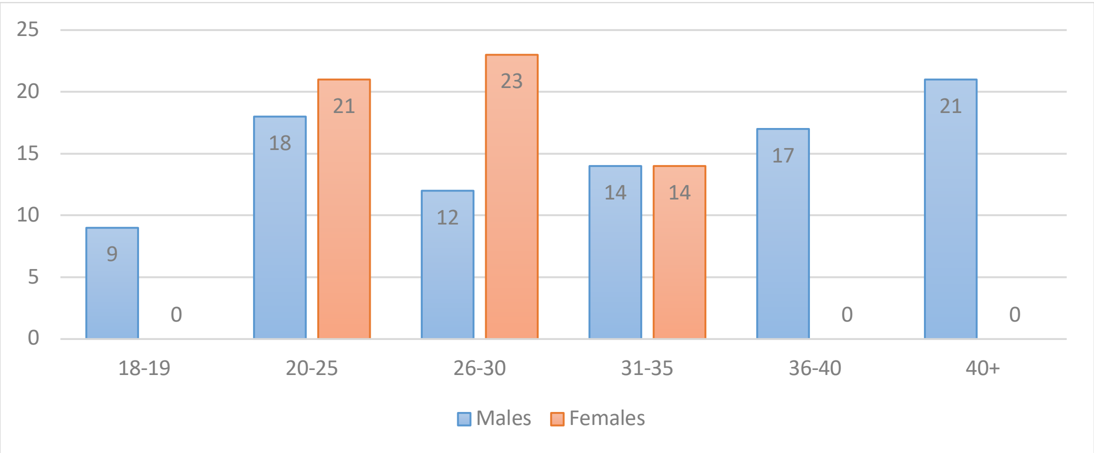

Fig. 2. Students' dropout rates in Kazan branch by gender and age groups, %.

Fig. 3 compares student bodies in Moscow and Kazan in terms of geographical distance of their place of residence from the study site. Notably, whereas the student body in Moscow is mostly represented by the locals, Kazan branch welcomes significantly more students who come from quite remote places. This might be due to Kazan being more affordable to reside while studying or due to more options of remote learning in this branch. Notably, the share of women arriving from the distance over 500km is larger than that of men for both locations: 33% vs 27% in

Moscow, and 51% vs 37% in Kazan. This may indicate a higher motivation of female students to study.

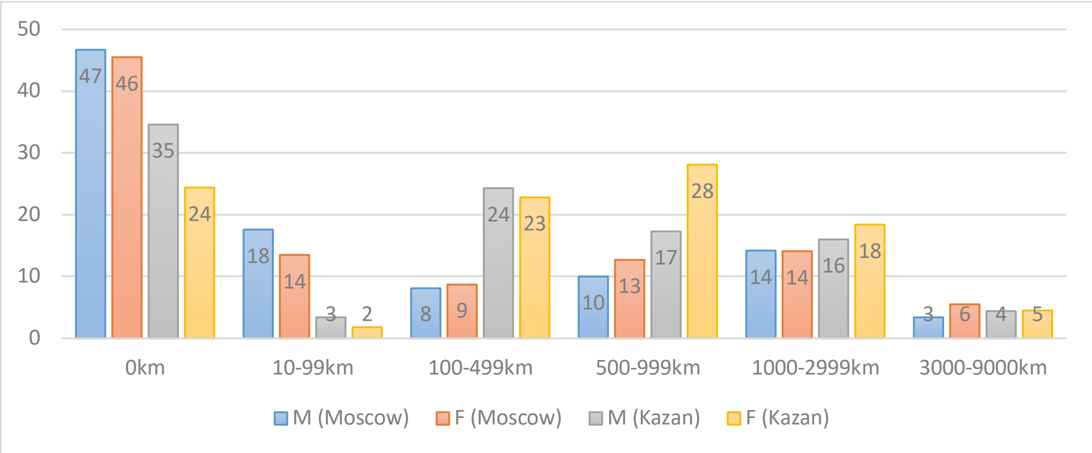

Fig. 3. Shares of male and female students in Moscow and Kazan branches by the distance to the location of residence from the study site, %.

Regarding the relation of student dropout rate and the distance from the original place of residence to the study site, on Moscow branch student population we observed (Fig. 4) that females who arrived from over 500-3000 km have lower dropout rate than their male peers, though overall dropout rate is higher for females. This may imply higher motivation of women arrived from long distance to study. Only few students arrived from 3000+km, hence the statistics for this group is not reliable.

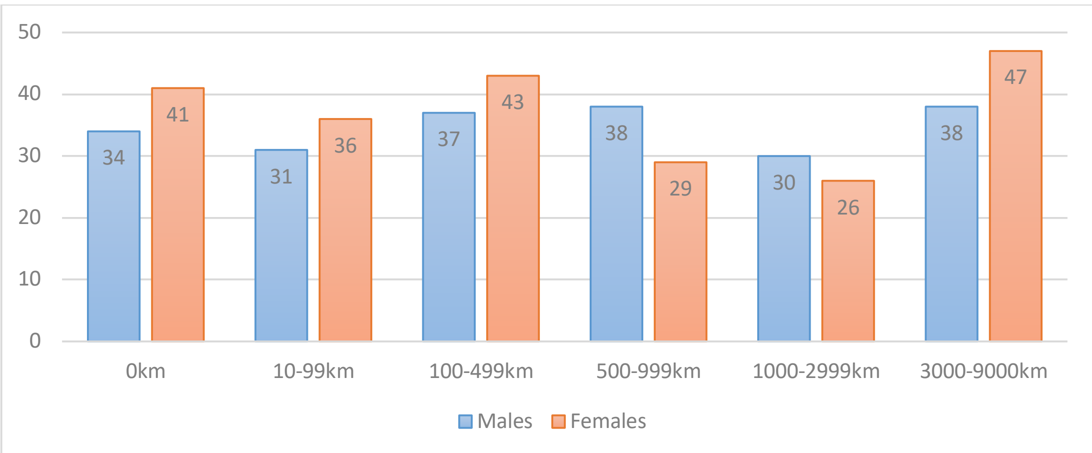

Fig. 4. Comparison of dropout rates of female and male students in Moscow branch by the distance to the location of residence from the study site, %.

To conclude, based on the obtained data, the School's model attracts a significant number of women, though so far women of the largest age groups of the target population tend to drop out more often than men. This tendency is, however, with the exception of women aged 35+ who at the moment of data collection showed zero dropout rate; clearly, such students are fewer, but, though generalizations might be premature at the moment, the hypothesis might be worth testing. In the following section, based on the survey data, we report the revealed perceptions of female students' of the School pedagogies and further discuss possible ways of their attraction and retention.

3.2 The effect of peer-pedagogy, gamification, cross-generation learning, family friendly-learning on female student retention.

The perception of the pedagogies employed by the School were studied by way of analyses of textual and numerical data collected via an in-house designed survey filled in only by female students (Appendix 1).

Peer pedagogy used by the School in practice means the absence of regular professors and scheduled classes. The majority of the students positively perceive a setup with no professors, though the share of this challenge with the students who dropped out reached almost 50% of the responses (Table 3). The results of our previous study (unpublished to date) revealed that female students having prior knowledge related to IT obtained in degree and non-degree programs experience no such a challenge.

Another theme, also observed in textual responses to the open question "*Are there any other downsides or anything that needs to be changed in School 21, in addition to those mentioned above?*", is that a noticeable number of women reported the need to moderate discussion forum, which is an essential part of peer pedagogy, because of unwanted sexist and offensive comments towards women. An example of a related comment:

> *There are some peers at our school who treat women badly, not just in IT, but women in general. They express dislike and doubt the abilities of girls online, it is very unpleasant to read, it is demoralizing. After these messages, you don't feel very safe when there are such inadequate people in the public space. I wish there was a way to block inadequate aggressive peers in Slack. Specifically the peer with the nickname **** -- who makes posts with messages against women.*

Table 3.Challenges of the program reported by those dropped out and currently studying.

Challenges	*Share of respondents*	
	Dropped out (N54)	*Currently studying(N154)*
Motivation loss	52%	27%
The projects are too complex, requiring higher level of prerequisite knowledge	48%	36%
The projects are too time-consuming	48%	45%
Absence of full time instructors/mentors	43%	30%
Strict Deadlines	35%	41%
Lack of interesing tracks	31%	21%
Separation from main job or family	31%	21%
Unfriendly treatment from other students or administraiton	30%	21%
Unclear grading system	22%	14%

Challenges	*Share of respondents*	
	Dropped out (N54)	*Currently studying(N154)*
Loss of interest to IT career	19%	1%
Accomodation issues	9%	19%
No support in internship search	7%	8%
No support during the internshop	2%	3%
Other	2%	7%
None	0%	2%

It looks like women consider these problems fixable and tend to disapprove the idea of women-only batches. Besides, a lot of textual responses appreciate peers and the opportunity to collaborate with them as they are perceived as a trigger of motivation:

> *Students working next to each other (peers) also motivate you to work hard, to find interesting and faster solutions together (although occasionally there was the opposite effect, when they distracted each other).*

Gamification practices at the School are manifested by sequencing the complexity and the progress by levels, by setting strict deadlines and assigning points for the quality and timely completion of the assignments. Naturally, we observed stronger dissatisfaction with the deadlines requirements and grading system with the dropped out students (Table 3).

Some students notice the limitations of deadlines:

> *… the level of cheating and superficially and unfairly executed projects, often caused by, excuse me, screwed up deadlines or the desire to score points ..*

However, other students highlighted the positive effect of deadlines on their learning:

> *Free schedule, but at the same time deadlines do not allow you to procrastinate long with projects... There is more freedom, but also more responsibility - we don't owe anything to anyone, and the future of our careers depends on ourselves, that's what I liked the most!*

> *[The School gives] an opportunity to become a more disciplined and organized person.*

One suggestion for modification of the deadlines system is:

> *Each participant should determine their own deadlines. If they are motivated, they will work towards their goal at a pace that is comfortable for them. If a person is not making progress, they are already punishing themselves by the lack of progress. Punitive deadlines are useless - demotivating.*

Besides, students suggest modification of the points system:

> *It would be cool if students could do different tasks, gaining experience and progress levels, well, as in the game with an open world. For example, someone can take three projects for 500 points and get 1500 points, while others can gain experience with 15 tasks worth of 100 points. Well, it would be more fair for those who really study. And it would increase motivation.*

We are reluctant to attribute motivation loss (Table 3) to the possible negative effect of gamification as this loss, based on the survey responses, can be due to a variety of reasons, e.g., an unwanted or unpopular programming language, the complexity of assignments, unfriendly treatment and the lack of professors.

We observed no evidence of negative attitudes towards cross-generation learning practices, instead, some students clearly value such a diverse learning environment:

> *… Plus the atmosphere, where the learning environment is heterogeneous both in terms of previous occupations and experiences and in terms of age, gives you the opportunity to interact with completely different people, which is also quite interesting and different from the university experience, where everyone is mostly your peers.*
>
> *You meet people of different ages, with different backgrounds - you can talk to people you would not normally meet.*

However, older student share fear on the career limitations due to old age of lack of knowledge:

> *In general I am happy with everything, only there is a fear that I will not be able to get a great internship because of my age and lack of higher education in IT (30 years).*

Regarding the need of family-friendly learning environment, according to the survey responses, 70% of the respondents said they are not married, and 92% of the respondents have no children under 18. “Family” as a challenge has been reported by 48 (23%) survey respondents, 7 (15%) of them have under-age children. Notably, those program participants who reported being married, tend to have lower dropout rates: 17% in married vs 29% in not married. Since the group represents around 30% of the School female population, it might be worth considering their special needs and suggestions. Those having children particularly indicated the need for adjustment to be able to handle family issues:

> *I wish those having families were given time off to go home (a week a month) (34 years old, 4 kids)*
>
> *More humane deadlines for moms (young children are often sick and not always with sick leave, and that needs to be taken into account!!!) (40 years old, 1 child)*
>
> *Softer deadlines for people like me, I have to both work and take care of my baby, and I'm not of the right age to sit up at night anymore (40 years old, 1 child)*

Thus, the investigated alternative model presents a viable solution to provide opportunity to enter IT career for more people and thus contribute to filling the gap in the labor market. Some particularities should be considered for attracting and retaining women in this alternative learning model.

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APPENDIX 1. Survey questions.

1. Specify your gender
2. Specify your intake (wave)
3. Please indicate the highest level of education you have received
4. Do you have any education (diplomas, certificates) in the field of IT?
5. What level of education (diplomas / certificates) do you have in the field of IT?
6. Do you have a higher or vocational secondary education in another education sector? If yes, please specify which one (not IT)?
7. Did you have any experience in the IT field before entering School 21?
8. How many years is your experience in the IT field?
9. Are you continuing your studies at School 21 now?
10. What level have you reached at School 21?
11. Evaluate how these characteristics correspond to the School 21 (Likert scale)
    i. Interesting program
    ii. Boosts hard skills
    iii. Boosts soft skills
    iv. Helps to establish connection with employers
    v. Promotes the development of contacts with fellow students
    vi. There is a creative atmosphere in the School
    vii. Gives significant career prospects
    viii. Allows you to solve real cases
12. Are there any other advantages in School 21 besides those mentioned above?
13. How much do you agree with the following statements about School 21? (Likert scale)
    i. The school lacks other areas of specialization (for example, UX, project management)
    ii. Only the female intake is needed
    iii. Internships in women's teams are required
    iv. More female mentors in IT are needed
    v. The school needs to improve its infrastructure
    vi. There is a lack of consulting on career opportunities in the Russian Federation and abroad
14. What are the greatest challenges for you at school (caused during training)?
15. Are there any other downsides or anything that needs to be changed in School 21, in addition to those mentioned above?
16. Specify the region of your permanent residence.
17. Specify the city of permanent residence.
18. How old are you?
19. What is your current marital status?
20. Do you have any minor children?
21. How many children do you have under the age of 18?
22. Write your suggestions and comments for the School 21.

FORMATIVE RESEARCH SUCCESSFUL ENVIRONMENTAL ENGINEERING EXPERIENCE

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Keywords: *Research, Engineering skills*

ABSTRACT

Research, in general, is one of the fundamental pillars of the formation of an environmental engineer, this is because the program obeys basic sciences and engineering that require the construction of investigative knowledge. In this reflective paper, the implementation of the pedagogical educational model of the faculty of environmental engineering of the Universidad Santo Tomas -Tunja is presented; it is based on a problem-solving approach that contains three axes: environmental planning, sustainable development, and innovation. It is framed in the guidelines of the Ministry of Science, Technology and Innovation, and the transversality of the knowledge that is imparted to students, which provide them with tools to forge competitiveness and social, ethical, pedagogical, and professional functions; through pedagogical strategies such as research hotbed, among others.

Keywords: applied research, educational model, science, environmental engineering.

1 INTRODUCTION

At present, the construction of investigative knowledge in higher education programs in Colombia is being worked on by guaranteeing spaces where the different actors of the educational system carry out dialogues that constitute the input for the construction of collaborative knowledge arising from the consensus discussion with the others, in which the combination of situations and social interactions contributes to personal and group learning. (Rodriguez-Pérez, 2019).

This collaborative dialogue among the different actors of the teaching-learning process, immersed in research, cannot be carried out without the mediation of technology, its natural use by new generations provides learning opportunities that can be taken advantage of in the development of investigative competencies. (Cosi et al., 2020).

Due to increasing competitiveness and a changing industrial environment, adaptability and creativity are even more crucial to learn how to *seize* opportunities that may arise especially in the context of research, technological development, and industrial participation. (Egan et al., 2017); (Juhl & Buch, 2019). Techniques and strategies should be developed in the classroom or academic groups by different actors to promote and facilitate access to knowledge, developing skills, habits, and attitudes, but most importantly, to feel the research spirit, that is the quality that conjugates the senses to find answers and solutions to the situations of the context in which the professional or trainee is located. (Landazábal Cuervo et al., 2010).

Based on the above, the Faculty of Environmental Engineering of the Universidad Santo Tomas Tunja, following the policies of the Ministry of Science, Technology, and Innovation, has established various strategies to ensure that the research processes achieve good academic experiences and results in accordance not only with the institutional guidelines but also with those established by the Ministry. The research processes of the Faculty are developed within the framework of the curriculum, which describes the importance of carrying out a problematizing education that involves students with the needs of the local, regional, national and international context. (Carlos Mario Alzate Montes et al., n. d.) The Faculty is integrated by graduate and undergraduate programs; the undergraduate program in Environmental Engineering and a master's degree in Environmental Management and Sustainability. The Environmental Engineering program, in coherence with the Curricular Policy and the Pedagogical Educational Model, is structured in three major training areas: Environmental Planning, Sustainable Development, and Innovation, these are reflected in the exercise of problematization of knowledge and construction of nuclei that make this an integral academic proposal.

2 DETAILED MATERIALS AND METHODS

On the follow article involves the kind investigation methodology participative action, which "allows the expansion of the knowledge, and generate concrete answers to problems to faced researchers and co-research when decided solve a query, interested topic or problematic situation and desire to give any change alternative or transformation" (Colmenares, 2012). This methodology relates the scientific knowledge with the actions on the society; have like a principal advantage, unlike others, the transformation of a reality, in this case educational and research. For the organization of this study document, was considered the approach of Kurt Lewin and the triangule of research-action-formation (Colmenares E., 2021), which present to us the development phases, so:

a.) Diagnostic

b.) Construction of an action plan

c) Plan formulation and execution

d.) Permanent discussion

The case study is the program of Ambiental Engineering of the University Santo Tomás - Seccional Tunja, which is explained shortly as follow:

The University Sant Tomás - Tunja, have a Direction of Research, which makes up a transversal element in the training of the professionals in different fields of knowledge in whom "research training is understood as a process articulated with professional training, for the purpose to sensitize students to discovery activities and innovation and give the basic tool for the design and development of projects" (USTA Tunja, 2017). The Faculty of Environmental Engineering of the University of Santo Tomas works in hand of the Research Direction through an Investigation Committee, which have in charge a Coordinator, who act like a facilitator and supervisor of process quality on the investigative processes of the facultity; trough the organization of investigative strategies like scientific events, Project Formulation, Students inclusion, and establishment of international agreements and interinstitutional and others. Is very important note that the Faculty of Environmental Engineering is a new program on the Boyacá region, starting in 2014 and graduating the first Environmental Engineers in 2019.

The pedagogical educational model established in the Environmental Engineering program has as its core the problem-solving approach, oriented to the search for solutions and concrete alternatives to solve regional and national problems and needs. Problematic education is seen as an institutional option that encompasses all levels of the pedagogical model, including the field of research (Balaguera Cepeda et al., 2010). Based on the problem-solving approach of USTA's educational pedagogical model, the research projects that are formulated are framed in the problematic nuclei, the problematic questions, the academic spaces are articulated consistently with the lines of research defined by the Faculty of Environmental Engineering and the strategic lines of social projection that have been used and respond to the needs of the context.

In this sense, the articulation of Teaching, Research, and Social Projection in the Environmental Engineering program of the Universidad Santo Tomás can be highlighted. This articulation allows responding to the needs of the context and the Institutional purposes. The appropriation of the problematic approach and the problematizing methodology, through which environmental problems are questioned and analyzed, is an added value of the Environmental Engineering program, which has leveraged research, innovation, and development projects. The confluence of teachers from different areas of knowledge and their research about a problem identified and treated by the subjects of the curriculum favors the analysis from different optics and disciplines, generating critical, analytical, and propositional thinking. (Universidad Santo Tomás, 2018).

For the case of Environmental Engineering, besides being a program in which different disciplines converge, which summons various professionals from Engineering, applied basic sciences, Earth Sciences and Economics in its teaching team, likewise it is supported by other programs, such as Business Administration, Law, Civil Engineering and Public Accounting and as support in academic units such as the Institute of Languages, the Department of Basic Sciences, and the Department of Humanities.

This interdisciplinary work allows the students of the Faculty of Environmental Engineering to integrate all the knowledge which lets the student guide the development of research competencies in an integral way, in which this interdisciplinary component is essential for the formation of the environmental engineer.

Following the guidelines established by the institutional system of research and innovation, the program has consolidated, since its creation in 2015, a culture of research and innovation, with human resources (students, teachers, administrative staff); structural resources (library, laboratories, physical plant) and relational resources (cooperation agreements, networks, etc.) that have facilitated the conditions for its generation and development with tangible products and cataloged within the classification established by MinCiencias.

The way the organizational structure of USTA Research is conceived allows the different actors of the academic environment to relate and exchange knowledge among them and with the environment, to make possible the missionary process of research and innovation at the University.

In this sense, it is necessary to recognize the difference between formative research and research training, to establish the importance of its use. Formative research can be understood as a pedagogical strategy to train students in research skills, oriented to their professional training. On the other hand, research training is understood as the exercise of research in the strict sense of the term. The knowledge acquired is put into practice to carry out a research project (Parra Moreno, 2004); however, it is important to point out that both concepts are not far from each other.

Due to the above, training on formative research begins in the program from the academic spaces with the structuring of classroom projects, where the competencies of the scientific method are developed, based on the competencies of the subject and within the framework of the research projects proposed and in development of the research groups. The teacher's guide the students to build their projects autonomously, deepening in specific topics according to their interests and with the definition of a particular problem, defined by the research groups.

The organization of the curricular structure based on training fields and problem areas allows the integration of research in all academic areas in an articulated manner, where the student works autonomously with the support of the teacher as a dynamic agent with tutoring, counseling, consultation, reinforcement, and other learning strategies. To facilitate the implementation of internship on formative research, the flexibility of the curriculum is necessary, it is recognized by the program as: "the characteristic of the curriculum that favors the autonomous development of the student, in attention to their needs, affinities, and interests, within the framework of the integral formation of the human person" (González Gil O.P., 2015).

It is for this reason that, in favor of the development of research products, the interaction between the curricular contents of the subjects, their problematic nucleus, facilitating the implementation of formative and investigative practices in pertinent products that affect the solution of environmental problems for the development and improvement of the quality of life of the communities is sought.

3 DISCUSSION AND RESULTS

From the strategies used in the different academic spaces for the design of final subject projects from the first semester until the final semester subjects, each one of them with its respective level of complexity; research workshops where students enter freely and spontaneously at any moment of their university career, where students show their skills in each of the topics worked on by the teachers who guide the workshop. In each of these strategies, it is understood as fundamental the existing relationships between the teacher, the student, and the knowledge, to ensure the development of the competencies established in the curriculum and the research process, in this description of the experiences in scientific initiation of the Faculty of Environmental Engineering, the different paths implemented in the program in the development of the research processes are presented.

As a strategy it has been defined that the teacher must create stimulating environments of experiences that facilitate the access of students to the different research mechanisms established, for this, the direct face-to-face accompaniment through group and individual meetings is fundamental for the achievement of the proposed objectives, the meetings with students can be individual or group face-to-face or virtual, through the use of the virtual campus or other means, such as telephone (mobile), email, chat, virtual discussion groups and forums and video conferencing. The number of hours dedicated to meetings depends on the nature of each project, which should be at least one (1) hour per week for each research group.

In addition to the hotbed meetings, it is required that the teacher in the classroom poses problematic situations for the development of the classroom projects so that students have the opportunity to make significant learning as they experiment and consult the available bibliography, analyzing the new information with the logic of the scientific method and elaborate their knowledge; this resource also allows the integration of some academic spaces, stimulates teamwork and favors the development of creativity and personal and collective ingenuity.

As a commitment of the student, the guided autonomous learning time, in which the student develops the activities designed by the teacher, for the development of the activities proposed in each of the research projects, in this individual space, the student performs complementary activities such as readings, consultations, reviews, bibliographical revisions, and essays.

An essential element within this formative research process is the evaluation that allows the student's self-regulation with a view to the development of his/her research competencies. The evaluative practice must reflect the fulfillment of the objectives set for the development of the research, it is necessary to check that the competencies outlined in the subjects of the curriculum are aligned with the research lines defined in the research groups.

The evaluation exercise must be coherent with the achievement of the students' research development: integrating the following functions: a social function, as it helps and guides students to advance in their formation; an ethical function, since it demands a critical and constant revision of the processes so that they respond to human values; a pedagogical function as a regulator of students' learning and their different interactions for a constant academic improvement; and finally a function that could be called professional function since it identifies students' abilities and skills and intervenes in the decision making that the teacher must carry out in his/her pedagogical relationship.

In this way, these guidelines of evaluation of the research process are translated into different evaluation strategies implemented both from the subjects with the development of classroom projects, active participation in the research hotbeds with projects endorsed by each call of the university and that respond to the products established by the main research projects.

4 CONCLUSIONS

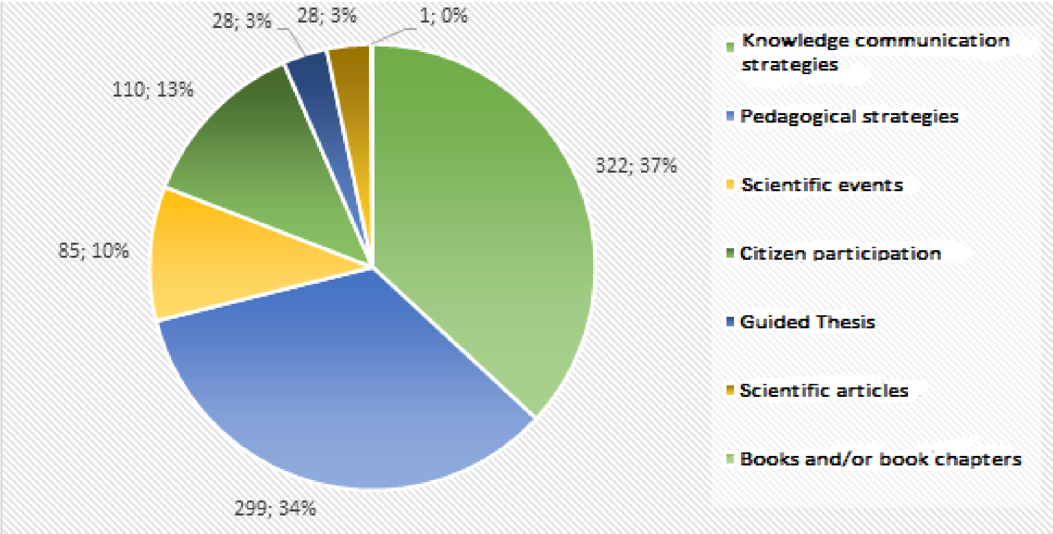
Since 2015, when the program was created, the teachers who are or have been linked to the environmental engineering program have made scientific products according to the Colciencias classification, which is quantified in the following relation:

Table 1. Relationship of scientific production teachers-Colciencias products

	Knowledge communication strategies	Pedagogical strategies	Scientific events	Citizen participation	Guided Thesis	Scientific articles	Books and/or book chapters
2015	1	0	11	1	4	6	
2016	0	1	10	3	1	2	
2017	10	51	17	20	1	5	
2018	153	103	33	86	4	7	1
2019	158	144	13	0	18	8	2

Source: Environmental Engineering Research Report 2019

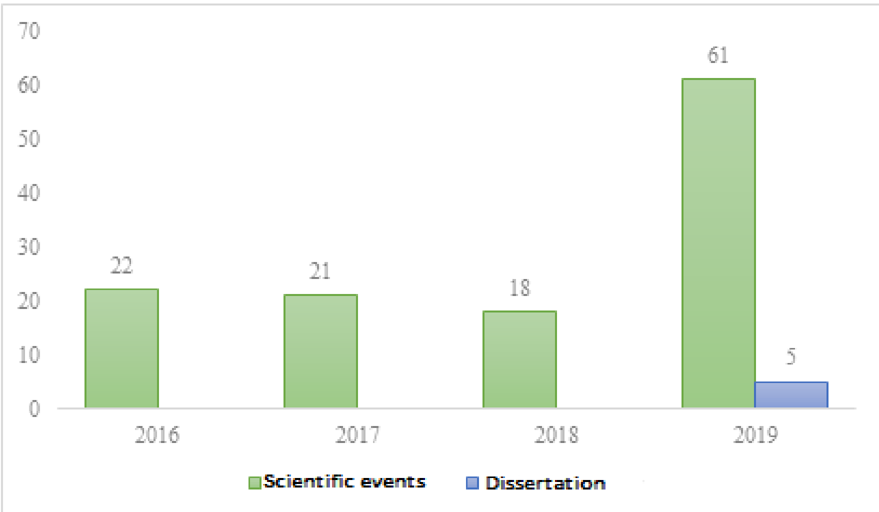
Graphic 1. Relationship of scientific production Environmental Engineering teachers USTA Tunja –Colciencias products



Source: Environmental Engineering Research Report 2019

The research represents an important axis within the development of academic spaces, this is how students participate in the dissemination of research processes through participation in scientific events. In addition, as a degree option, they develop research works.

Graphic 2. Relationship of scientific production Environmental Engineering students USTA Tunja



Source: Environmental Engineering Research Report 2019

This graph shows the scientific productivity reported in the research group of the Faculty of Environmental Engineering of the Universidad Santo Tomás Tunja. This graph shows that formative research and each of its activities are a fundamental part of the growth of productivity and encourages students to find the basis of research.

5 DISCUSSION AND CONCLUSIONS

The formative research process in the Faculty of Environmental Engineering of the Universidad Santo Tomás has been strengthening in recent years, thanks in large part to the increase in investment and the implementation of institutional policies in research. This is reflected in the perception of the improvement of the quality of the academic programs which, in the specific case of Environmental Engineering, is ratified by businessmen, teachers, students, and graduates of the program. In addition, there is a significant increase in the scientific production of the research groups.

In the same vein, Pin and López (2019) speak about the importance of the relationship between the university and its environment, given that the results of the educational process are expected to be effectively transferred to society, in such a way that both economic and human development is enhanced. Hence, the relationship between the university and business is vital to validate the training processes in higher education to the extent that they demonstrate their relevance. For Ferreira, Mena, Acosta, and Mena (2019) the company becomes a special context by becoming an extension of the classroom for an engineering student; companies validate the theoretical knowledge given by the academy, but in turn, contribute to the development of skills that are only possible to acquire in practice.

Classroom projects have become an appropriate tool to promote culture research in the institution. Their focus on the application of knowledge for the solution of specific environmental problems has made it possible to make learning something meaningful while improving the academic level. This strategy can be enhanced to the extent that the projects are made transversal within the curriculum so that the knowledge applied in each subject is directly related, and in the end, the product delivered can attest to the entire training process. This significant learning has allowed through the classroom projects has made the formative processes more relevant, since they are focused on the solution of society's problems.

There are still some aspects to improve in the formative research process within the institution. It is clear that the work with the research groups still needs to be consolidated and that the academic production can be greater, in addition, it is necessary to work on the construction of curricula and transversal and relevant micro curricula, aligned with the needs of the environment, in which research is a training strategy in the classroom and every teacher assumes the role of tutor, who not only transmits information but also assumes an active role as a trainer. In this sense, strategies such as classroom projects, research hotbeds, PBL methodology, case studies, have been very helpful and have allowed improving the training processes significantly, so as these good practices are generalized, better results can be obtained within the program.

Finally, it should be noted that among the difficulties that were evidenced by the students in the formative research process is their lack of reading and writing skills and logical-mathematical analysis. This situation is recurrent in higher education institutions in the country, which receive students who come from a deficient secondary education and must assume a process of knowledge placement that often is not successful. This, in turn, generates gaps in professional training. Because of this, Vargas, Hernández, and Aguilar (2019) analyze the importance of the integral formation of an engineer, which must be following the requirements of the productive sector, which not only refers to technical competencies, for which logical-mathematical analysis is essential in any engineering program, as well as reading, writing and soft skills.

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CONTINUOUS, VERSATILE AND FLEXIBLE ASSESSMENT METHOD ON ENGINEERING PHYSICS COURSES

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ABSTRACT

The global COVID-19 pandemic and lockdowns required many educators to redesign their courses for an online environment. Not only the delivery of contents needed to go online, but also assessments and socio-constructive learning elements, such as group work, discussions, and argumentation etc. This paper presents the continuous assessment arrangements and methods used in engineering physics courses at Tampere University of Applied Sciences during lockdowns and in online courses. Since physics is an empirical science, also the assessment contains elements of measurements and data handling - now in blended and online learning environments. The assessment is based on a basic level exam, week exams, measurement assignments and final exam. The basic level exam is an automatically assessed exam in Moodle with randomly generated initial values for calculus-based problems and with randomly chosen multiple choice problems. Students are able to try the basic level exam as many times as needed to pass it. It generates new values and randomizes questions for each try. The main idea is to make the course completion more flexible for the students and reduce teachers' workload in relation to assessment. By completing the basic level exam with sufficient points, the students pass the course with the lowest possible grade. Many students want a better grade and also accomplish the other elements of the online assessment: week exams, measurement assignments and final exam. This paper also presents data of how the students interacted with the different elements of the courses and how they used the basic level exam as a learning tool.

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1 INTRODUCTION

In engineering education, the assessment of learning outcomes typically consists of some or many of the following elements: 1) formative assessment during the course with the help of quizzes, forms or polling surveys etc.; 2) laboratory work with written or oral reports; 3) homework assignments; 4) summative assessment containing mid-term exams and/or final exam.

Usually the summative assessment is justified by the need for quality control of the education. It offers a controlled environment for assessing student learning gains and academic performance. However, the final exam session can be very stressful for the students, and sometimes students underperform during the final exams. Many university students have been found to report poor sleep due to academic stress, which in turn has a negative impact on for performance [1]. Stress levels typically increase during mid-term and final exams [2]. Based on own teaching experience, this unfortunately applies especially to those students, who already are in danger of failing the course.

The role of formative assessment is to offer feedback for the students of their learning, support their self-efficacy and self-regulated learning. By using formative assessment, it is possible to boost student learning and thus enhance learning outcomes [3-5].

The teacher's workload increases as more and more elements are included in the assessment repertoire. This is even more true for the past year during which the global COVID-19 pandemic and lockdowns required many educators to redesign their courses for an online environment – including assessment. Especially due to the pandemic situation, during the past year a significant part of teacher's workload come from arranging retake exams and considering students' requests for late handout of exercises. To ease teachers' workload, a versatile assessment method including CAA (Computer aided assessment) was utilized and its usage was piloted as part of physics courses' final assessment in Tampere University of Applies Sciences.

2 ASSESSMENT METHOD

2.1 Overview

In Tampere University of Applied Sciences, engineering physics contains separate theory and laboratory courses. It should be noted however, that conceptual understanding and perception of measurement data is essential also in theory courses. Therefore, the assessment method piloted in this study consists of a many different elements. Some of them are group assignments, some individual assignments. Both traditional, calculus-based problem-solving questions and hands-on -type of doing were used. The summary of all the assessment elements is presented in Figure 1 together with their relative weights. Basic level exam and measurement assignments form the basis of continuous assessment and they are described more in detail in the following chapters. Final exam and homework assignments are rather traditional and are thus not discussed any further.

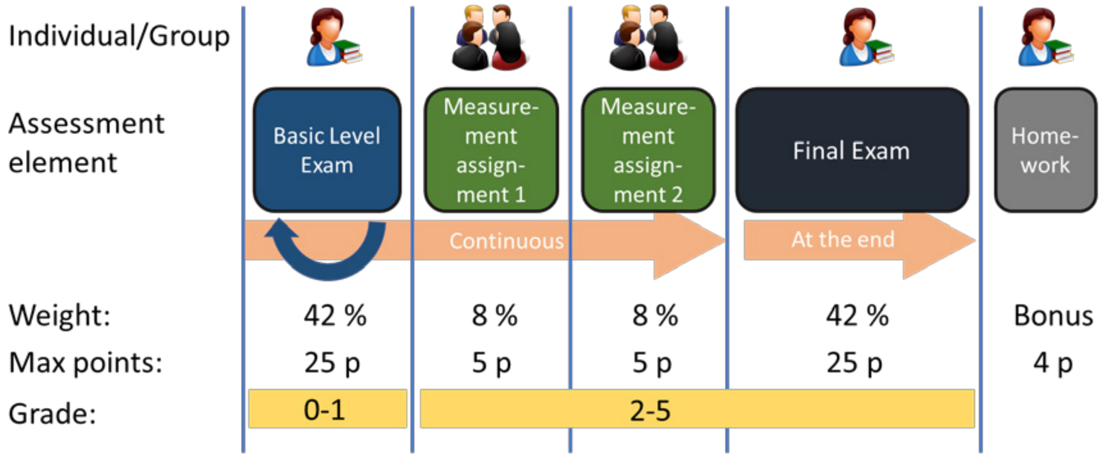

Fig. 1. Assessment method and its elements piloted in this study.

2.2 Measurement assignments

The basic idea in measurement assignments is to deepen the understanding of laws of physics by actually seeing and measuring different phenomena. This also brings an element of hands-on doing to online physics courses, which in turn activates the students. The measurement assignments are usually one-topic, relatively simple tasks, which doesn't need very complicated equipment. In online studies, the equipment should be easily available at home. The students are strongly encouraged to accomplish measurement assignments in small groups, but not forced to do so due to COVID-19 lockdowns. Students need to find the relevant laws of physics and the correct ways to implement them with the given problem. This they can best achieve by discussing, reasoning and considering different arguments and counter arguments together in the group. The emphasis is on the phenomenon and physics, not on the measurement skills. Measurement assignments have learning objectives beyond the topic itself: the students learn to argument their opinion, evaluate peers' opinions, evaluate if they themselves really know, based on laws of physics, or just have a certain "feeling". Moreover, an engineer needs to know (and admit it) when he/she doesn't know. Not to pretend knowing. And seek for support from colleagues. If the student group ends up to a wrong answer in measurement assignment, they then have opportunity to find where their own cognitive model was incorrect and rebuild it. These aspects make measurement assignments in theory courses a beneficial way to activate students. The two measurement assignments of thermodynamics and fluid dynamics course are presented in figures 2 and 3 as examples.

For the measurement assignment 1 students were provided with a video supplemented with data in Excel format (fig. 1). Based on the video and the data, the students were then asked to calculate the specific heat of copper. This was the simpler of the two assignments since the students didn't need to actually build or measure anything themselves. Instead, they needed to understand the phenomenon and the limitations of the method, choose a model for the calculation, pick values from the video and Excel-data and carry out the calculations. And as always in physics, conceptual understanding is also important and this was tested with open ended questions in addition to the calculations.

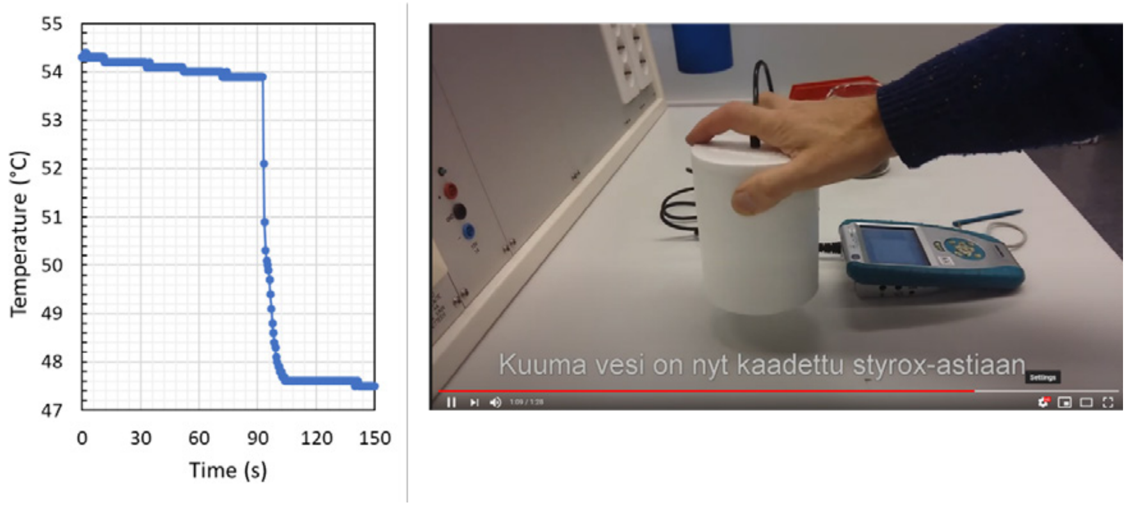

Fig.2. Example of a measurement assignment 1 from thermodynamics and fluid dynamics course: determining the specific heat of copper from video+ data set in Excel.

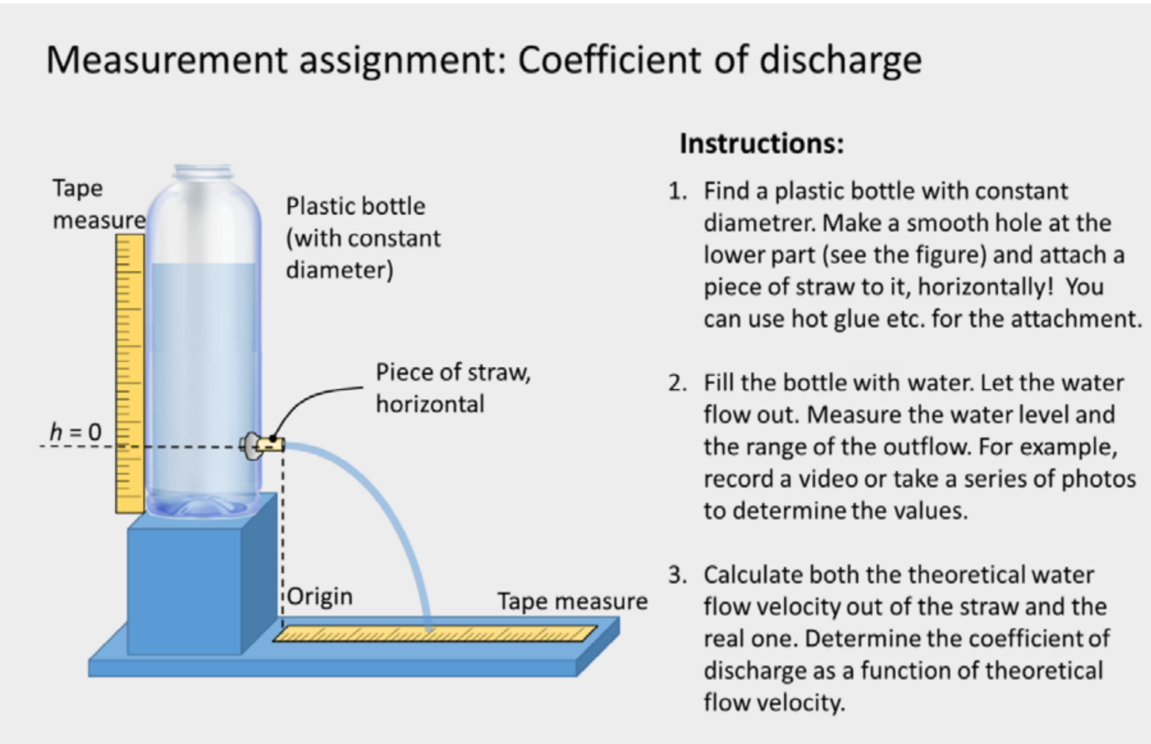

Fig.3. Example of a measurement assignment 2 from thermodynamics and fluid dynamics course: determining the coefficient of discharge with own measurement at home.

2.3 Basic level exam

The basic level exam is an automatically assessed exam in Moodle with randomly generated initial values for algebra-based problems and with randomly chosen multiple choice problems. Students are able to try the basic level exam as many times as needed to pass it. It generates new values and randomizes questions for each try. In our curriculum, the criteria for passing a course with the lowest possible grade state among other things: "…student is able to analyse physical phenomena qualitatively and solve simple problems that resemble those presented in course materials." In regard of this statement, the basic level exam doesn't have very complicated algebra-based problems and thus the problems are well suited for simple, dichotomous grading: correct/incorrect. The exam has seven algebra- based problems and six multiple choice problems which in turn have various number of questions.

3 ANALYTICS OF THE ASSESSEMENT

3.1 Measurement assignments

As described earlier, the measurement assignment 1 (MA1) was somewhat simpler than 2 (MA2). This is also visible in the points distributions for the two assignments presented in figure 4. The average score for MA1 was 2,71 and that of MA2 1,33. Even though students usually appreciate the possibility to learn hands-on, this do-it-yourself assignment didn't encourage all students to take action. Thus, approximately one third of them didn't hand it in at all, which drops the average score. It should be noted that this particular assignment was somewhat time consuming to do and this also might have influenced the accomplishment.

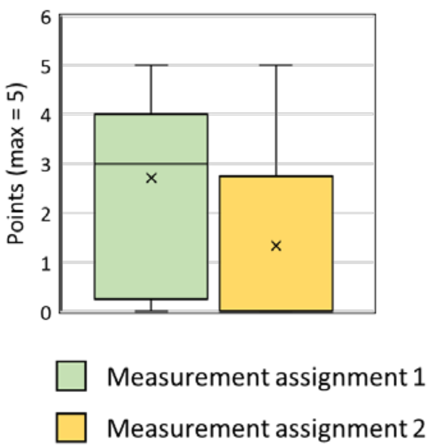

Fig. 4. Point distributions for the two measurement assignments. Maximum was 5 points.

3.2 Basic level exam

At the time of writing this article the physics courses implementing the basic level exam were still going on and therefore the data here is preliminary and limited to one thermodynamics and fluid dynamics course only. On thermodynamics and fluid dynamics course there were 42 attempts by 16 students. In the following data only serious attempts are included, since there were some attempts that had lasted only a minute or two. This is far from the needed time to accomplish the exam and these peeks to the exam are thus omitted. Figure 5 presents the results of basic level exam of one engineering physics course. Cumulative time students had spent accomplishing the exam is presented on the x-axis, and points they got on y-axis. Each data point represents one exam attempt and the lines connect attempts by the same student. Even though the data set is still small, it can be noted that students have spent significant amount of time in accomplishing the exam. Some students have tried to improve their score even ten times and the largest cumulative sum of time spent is more than 5 hours. In traditional paper exams those students who are in danger of failing or who are struggling with their studies usually spend just a few tens of minutes before giving up. In comparison to that, this automatically assessed, recurring basic level exam with all possible material available has encouraged the students to spend significantly more time in interaction with the exam. This is a remarkable finding.

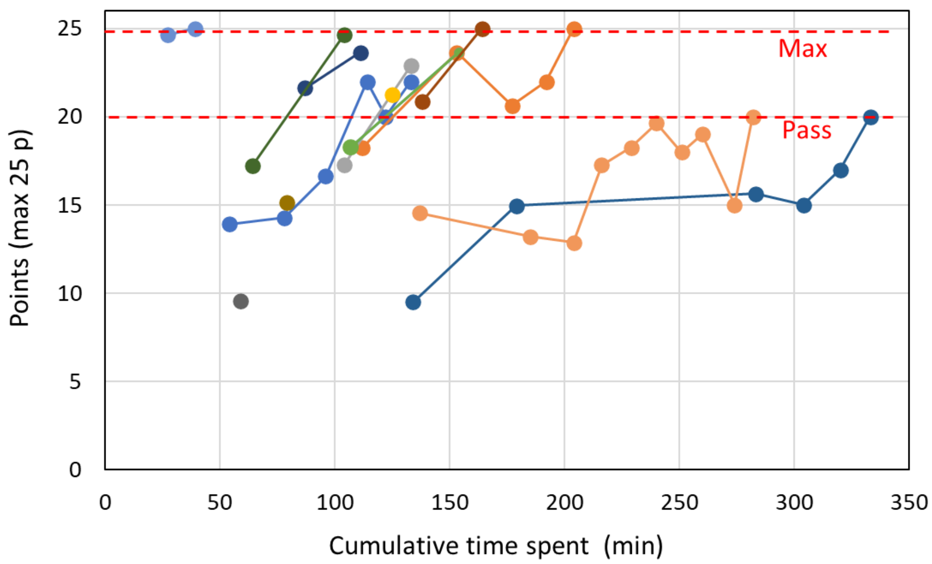

Fig. 5. Basic level exam points as a function of cumulative time attempting the exam. Each line represents one student and each point one attempt.

Another interesting question is how much time the students spent between the attempts. This is illustrated in figure 6 which shows that almost all the students and almost every time start a new try after only a short pause (0-5 min). Some of the pauses are a bit longer (6-30 min) but unfortunately almost nobody had a longer pause during which he could have studied further or had a rest. Instead of having a pause for resting or studying, it seems that students want to keep trying consecutively until they pass the exam. Or until they get the highest possible points, as some students seem to have aimed at, based on fig. 5. The results shown in figures 5 and 6 suggest that the students didn’t actually spend more time studying the course materials, but they used much more time with the exam than traditionally. Even though this seems like a kind of “trial and error” -approach, it should be noted that to pass the exam they needed to do a lot of calculations. Thus, they couldn't just randomly retry multiple choice questions but rather needed to get the principles and equations right for the numerical problems.

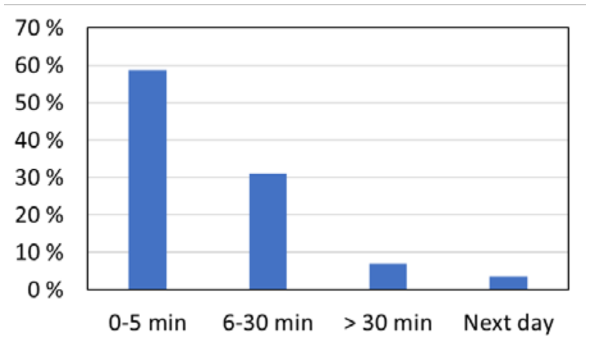

Fig. 6. Length of the pause between consecutive exam attempts.

4 CONCLUSIONS

The assessment method in engineering physics courses at Tampere University of Applied Sciences was presented. The aim was to bring hands-on doing to theory courses especially now during COVID-19 lockdowns and to online courses in general. The basic level exam was introduced as a method to decrease teacher's workload in arranging retake exams and to offer students a flexible way to accomplish the courses. Since the courses implementing these assessment methods are still going on at the time of writing this article, no student feedback is yet available. However, based on the results of student interaction with the assessment elements - measurement assignments and basic level exam - it seems that most of to goals are met: students spend considerably long time in attempting the basic level exam and actually pass it after a few or several attempts. The total exam time was found to be larger than normally in paper exams, even five hours. This suggests that the basic level exam works well as a learning tool, not only as an assessment method. Measurement assignments offer hands-on type of activity for the online course and they also have discriminating power from the assessment point of view since the point distributions were found to be spread out. The next step in this pilot is to gather more data and interview teachers and collect student feedback. Those results will then be used to further fine-tune the assessment method and the measurement assignments.

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ENGINEERING PHYSICS LABORATORY WORK DURING LOCKDOWN – HOW AND WHAT?

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Keywords: *Physics laboratory, remote laboratory, virtual laboratory, COVID-19*

ABSTRACT

During the past year, the global COVID-19 pandemic and the lockdowns required educators to redesign their courses for online instruction. Laboratory courses are much more difficult to convert into an online environment or offer for distant learners in comparison with theoretical courses. Typically, there are three different types of approaches for offering laboratory type of work online: virtual laboratories, which are based on simulation programs; remote laboratories, which allow access to physical equipment over the internet; and home-based laboratories, which utilize for example smart phone sensors. This paper presents three different methods for physics laboratory work during (partial) lockdown. The main purpose is to describe how a fast conversion to online access was accomplished within a couple of days with the existing laboratory setups and with minimal additional equipment. The piloted methods were: 1) using teacher as students' hands in the laboratory while students remained at home. 2) Only one student from each pair attended the laboratory and the other one stayed at home. WhatsApp video call was used between the students, the one at home collected the measurement results on a logbook, and the one in the lab worked as "an actuator". 3) Pre-recorded videos were used for presenting the measurement setup and the measurements. After the pilots, students and teachers were also surveyed of their experiences and of their suggestions for improvements. Naturally, the findings of this pilot study can be applied also to offering remote laboratory work in normal conditions, not only during COVID-19 lockdowns.

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1 INTRODUCTION

Engineering curriculum traditionally includes introductory physics laboratories. They are either own, separate courses or the laboratory work is integrated into theory courses. The learning objectives for the laboratory work typically include designing and implementing measurements and reporting their results in technically and scientifically proper way. The laboratory work can also be used to support theory courses. Laboratory work is often designed to deepen the conceptual understanding gathered in physics theory courses. According to Holmes and Wieman undergraduate laboratories that are designed to support theory courses, do not necessary improve students' grades. Instead, laboratory courses that focus on improving students' experimental and intellectual abilities offer great opportunities to learn experimentation, reasoning, and critical thinking skills. [1].

Global COVID-19 pandemic and lockdowns challenge educational institutes especially what comes to laboratory work. It is much more difficult to convert into distance learning mode than traditional lectures. Although, the situation was not completely new. Laboratories for geographically dispersed participants have been implemented either with simulations or remote laboratories for years. [2]. According to a previous study, remote labs can be seen as effective as hands on labs [3].

There are several ways to implement remote labs. Setups for remote labs can be very expensive including robotics that allow students to control real setup online and they may require weeks or months to set up. [4]. On the other end, there may be a possibility to design a laboratory work in a way that students can do the work at home, with the equipment that are easily available [5]. A combination of hands-on labs and individual work at home "Laboratory immersion" was also introduced. It was a combination of hands-on labs with students' individual work at home. [6] Using simulations instead of real equipment may also be a substitute of a lab work, but with simulation, the real phenomena are always available through media and therefore is always only a model of reality.

Due to the COVID-19 lockdowns, there was a need to rapidly change from hands-on laboratories to distance mode in a cost-effective way with easily available tools. Three different solutions to achieve this goa, are discussed in this paper.

2 LABORATORY ACCESS MEHTODS

Three different solutions to access physics laboratory equipment during the (partial) COVID-19 lockdown were piloted in Tampere University of Applies Sciences. Students from three different classes participated in this pilot and they were naturally informed about the non-conventional laboratory workdays beforehand. Each student participated in one of the pilot methods. To prepare for the labs they also needed to watch instructional videos. Students usually work in pairs on the physics laboratory courses. Now they were either asked to stay totally at home or to choose one person of the pair to stay at home meanwhile the other came to the laboratory, depending on the piloted method. The piloted methods are listed below and each of them is described in more detail in the chapters to follow:

A. Using teacher as students' hands in the laboratory while all students remained at home.
B. Only one student from each pair attended the laboratory and the other one stayed at home.
C. Pre-recorded videos were used for presenting the measurement setup and the measurements.

2.1 Teacher as students' hands, A

One solution to access laboratory equipment during COVID-19 lockdown was to use teacher as an actuator in the laboratory while the students remained at home. The students were asked to watch an instructional video about the principle of the measurement before the laboratory time. Then during the labs, they were able to instruct the teacher what to do though Zoom video conferencing. From the teacher's perspective, the hard part was to remain silent and not to tell how to proceed in the laboratory work and let the students to have the control of the experiment. There were four student pairs online and any of them could give instructions. If all remained silent, the teacher asked the contribution of each of them in turn. Figure 1 shows this method in action as an example. In this laboratory work IR-radiation is generated with Leslie's cube and the corresponding signal is shown as a thermopile voltage in a multimeter. Teacher joined the Zoom meeting both with a smart phone and a laptop to be able both to stream the video and to follow the happenings in the meeting.

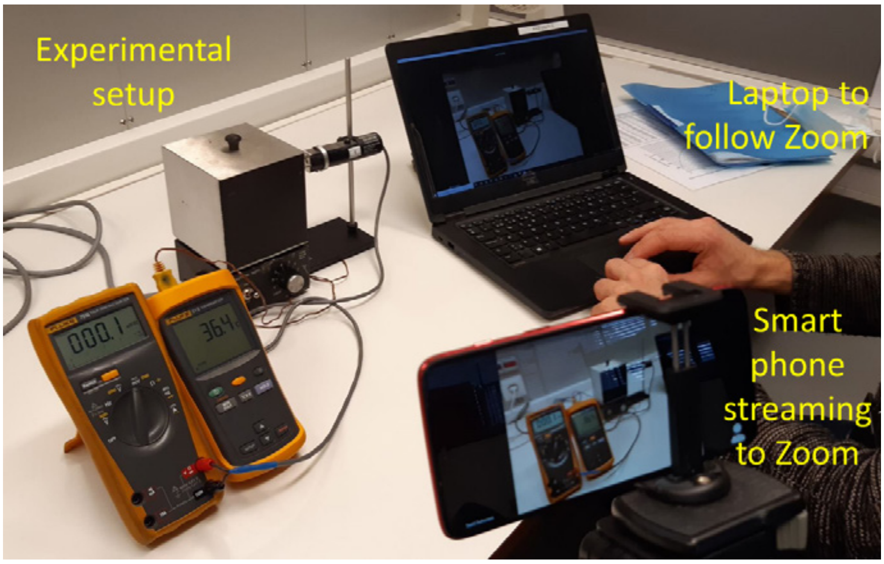

Fig. 1. The setup for streaming the laboratory work to Zoom. The students instructed the teacher in the Zoom meeting about what to do and what to measure. The multimeter readings are visible to distant students.

2.2 One student in the lab, other at home, B

In this method one student comes to the lab normally while his/her pair remains at home. The students were asked to bring their own headsets, preferably Bluetooth, with them so that they can communicate with the distant student. In the lab they were provided with a smart phone stands for easier video streaming. They were able to choose any video call software according to their liking. They needed to communicate with the remote participant in such a way that the principle, equipment, progression of the measurement and the measured values were transferred in a clear enough way. The remote participant was responsible for writing down the measurement logbook.

2.3 Pre-recorded videos, C

Using pre-recorded measurement videos (figure 2.) is an easy but not so engaging way to access the laboratory during lockdown. In this method the same video and the accompanying data is available to all students and thus no variation is expected in the reported results. The students have no influence on how the measurements are accomplished and they inherently don’t need to plan or discuss the details of the measurement. Therefore, after watching the measurement video the students are asked to ponder factors affecting accuracy, possible improvements in the method etc. and write their answer in Moodle. This way they are forced to think about measurement related aspects at least to some extent and it also brings some individual variance to the answers. On the other hand, same data for all students makes report checking somewhat easier.

	A	B	C	D
1				
2	**Veden massa: 4,15 kg**			
3	**Veden ominaislämpökapasiteetti: 4186 J/kg C**			
4				
5		Lämpötila (°C)	Lämpötila (°C)	Power (W)
6	Time	Kanava 1	Kanava 2	
7				
8	12:12:53	21,43	24,65	133,3
9	12:13:03	21,33	24,65	132,7
10	12:13:13	21,19	24,65	132,3
11	12:13:23	20,37	25,38	131,4
12	12:13:33	20,4	26,01	130,7
13	12:13:43	20,3	26,37	131,1
14	12:13:53	20,31	26,72	132,0
15	12:14:03	20,3	26,84	132,6
16	12:14:13	19,45	26,85	132,8
17	12:14:23	19,93	27,37	133,0
18	12:14:33	19,98	27,48	133,6
19	12:14:43	19,5	28,1	133,5
20	12:14:53	19,44	28,3	134,1
21	12:15:03	19,21	28,53	134,8

Fig. 2. An example of laboratory measurement video delivered in YouTube and link provided in Moodle https://youtu.be/LEmeRnqFwaA. The data was available for downloading in Moodle.

3 SURVEY RESULTS

After the laboratory work, the students were surveyed to collect their experiences and development ideas about the piloted methods. There were 38 answers to the survey and 27 of the answered students participated from home and 11 were present in the lab during the piloting. The instructional pre-lab videos were watched quite well (91% of the students) and the pilot consisted of six different laboratory work assignments.

Figure 3 shows the summary of survey results for all three different methods (A, B and C) concerning students who participated from home. Answer choices were from "1 = Not at all" to "7 = very well". Answers to question "*How well did you manage to grasp the idea of the measurement?"* are mostly on the better side of the scale and the overall average was 5.2. This divides between different piloted methods as follows:

- Teacher as students' hands average: 5.6
- One student in the lab, other at home average: 5.0
- Pre-recorded videos average: 5.3

It seems that it was possible to communicate the main idea to remote participants adequately with all piloted methods. The student sample and the differences between method averages are small, and not any strong conclusions about the superiority of any method above the other can be made. However, the "teacher as students' hands" method seems to have slightly highest average. In this method the student knew that they need to give instructions to the teacher. Possibly, due to teacher's constant presence, they might have watched the instruction video beforehand more carefully and might have been more alert during the laboratory work.

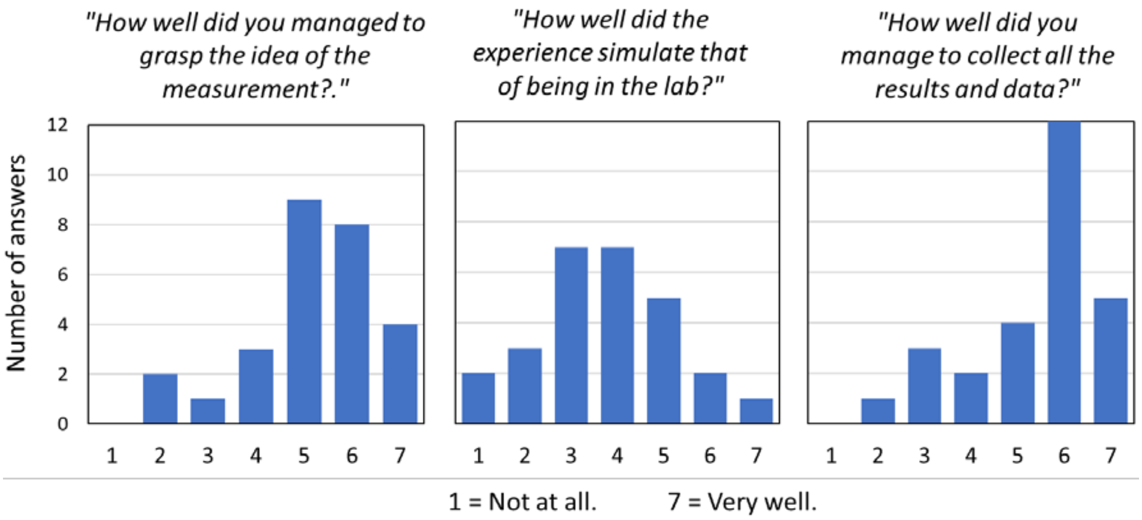

Fig. 3. Home participants' answers to survey questions.

Answers to "*How well did the experience simulate that of being in the lab"* got a lower average: 3.7. This is no wonder, since remote participation naturally can't generate exactly the same feeling as being in the lab. Nevertheless, the answers to question *"How well did you Manage to collect all results and data?"* show that all methods succeeded well enough in getting the measurement results the average of all answers was 5.4.

Figure 4 represents the summary of answers for those students who were present in the laboratory during the pilots for all three different methods (A, B, and C). Their responses seem to be in line with those of home participants concerning the transfer of the general laboratory work idea: the answer average is 4.7 which is close to that of home participants of the same method, 5.0. The same observation can be made with the transfer of measurement data. Both home participants and laboratory participants agreed that the collection of data and results succeeded well. The averages of the answers were:

- laboratory participants average: 5.8
- home participants: 5.4

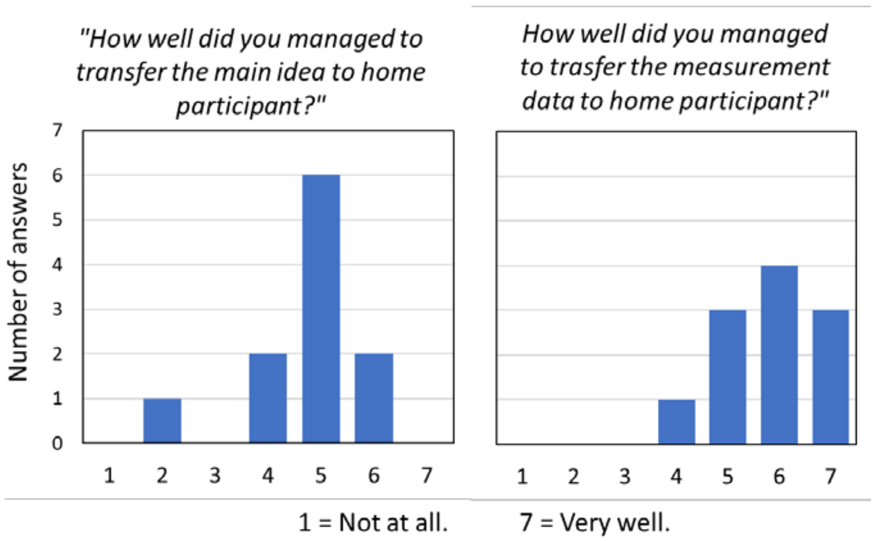

Fig. 4. Laboratory participants' answers to survey questions.

Student answers to survey's open-ended question *"Comments and feedback?"* were categorized into positive, neutral, and negative. Below are the corresponding percentages and a few picks from the comments (translated from Finnish).

- Positive 39 %
- Neutral 50 %
- Negative 11 %

> *"Videos, which show the measurement principle, make it a lot easier to start the measurements. They give a good preconception of what we need to do. Also, the participant at home gets a good view what the laboratory participant needs to do."*

"If there was a better way to arrange the video stream from the lab showing what is going on, the task would get easier. This kind of situation requires that the instructions to be clear. For the home participant, it is difficult to help, if there are problems in the measurement."

"The experience was good. Of course, it is best to learn in the lab, and the connections are not always good. This method requires a lot of own activity from the students."

4 SUMMARY

Three different methods for physics laboratory work during (partial) lockdown were piloted. A fast conversion to online access was accomplished within a couple of days with the existing laboratory setups and with minimal additional equipment. The piloted methods were: 1) using teacher as students' hands in the laboratory while students remained at home. 2) Only one student from each pair attended the laboratory and the other one stayed at home. Student in the lab worked as "an actuator" and the one at home recorded the measurement data. 3) Pre-recorded videos were used for presenting the measurement setup and the measurement results and data. It was possible to communicate the main idea of the measurements to remote participants adequately with all piloted methods. Both home participants and laboratory participants agreed that the collection of data and results succeeded rather well in all methods. Student comments of the piloted methods were mostly positive or neutral and only 11% of the answers to survey were negative. Naturally, the findings of this pilot study can be applied also to offering remote laboratory work in normal conditions, not only during COVID-19 lockdowns.

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CDIO OPERATION EDUCATION THROUGH REGIONAL COLLABORATION

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Conference Key Areas: *Challenge-based Education, Maker Projects, Engineering in Schools*
Keywords: *CDIO, Operation, Regional collaboration, Bus location system*

ABSTRACT

CDIO, a concept devised by the Massachusetts Institute of Technology (MIT) and three universities from Sweden, stands for “conceive, design, implement, and operate.” The goal of CDIO education is to enable students to lead in the creation and operation of new products, processes, and systems. Several studies have been conducted on CDIO education, but there is little discussion on operation education. Therefore, here we focused on the operation education method and explaine CDIO operation education through regional collaboration using a bus location system through a Web application. In addition, we explain its results and educational significance.

In CDIO education, operation is defined as the lifecycle support and evolution. During this phase, the system is managed so that it can be operated without troubles, finding and improving system problems, and considering the next expansion. In our study, students learned the system operation and maintenance by operating a bus location system. In addition, they learned how to operate the system steadily by responding to accidents such as bus breakdowns and replacement by new bus purchases.

Operation education faces the issue of how to deal with sudden problems. It is not suitable for a curricular course because it is impossible to predict troubles, and it is impossible to create a plan. However, with this trouble, there is also an opportunity to teach the important parts of a system. It can be said that this is the most important part of education that enables students to create a system to earn money.

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1 INTRODUCTION

1.1 CDIO education in regular classes

There is a growing mismatch between universities on one side and society and industry on the other. Furthermore, there is a need for human resources that could flexibly respond to changes and create a new value. CDIO is a concept devised by the Massachusetts Institute of Technology (MIT) and three universities from Sweden to respond to this reform of engineering education. CDIO stands for “conceive, design, implement, and operate,” and it is called the “CDIO Initiative,” which consists of the CDIO syllabus and the CDIO standard. It aims for high-quality education through the framework using real-world systems and products [1].

Our school has implemented CDIO education since 2010. At first, it was introduced in the Design Project course (PD), which are regular classes [2, 3]. Figure 1 shows the educational curriculum. Our school identifies five stages of engineering design processes. PD1 is a curriculum intended for learning problem discovery, problem clarification, and idea creation; and PD2 is a curriculum intended for learning idea creation, idea evaluation and careful selection, and concrete implementation of ideas. By evaluating PD education at our school from a CDIO perspective, we found that it corresponds to C (conceive) and D (design).

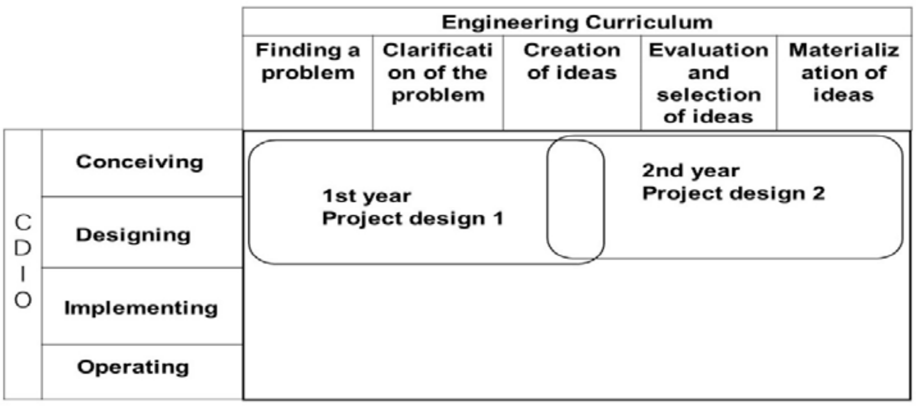

Fig. 1. Relationship between the Engineering Curriculum and CDIO Education

1.2 CDIO education in extracurricular classes

In the regular curriculum, it is difficult to have appropriate project activities and meaningful experiences due to the limited class time and the obligation to evaluate academic ability. For example, students need to understand practical requirements analysis, system design, architecture design, and system construction to build an information and communication technology system. These concepts can be learned in regular classes, but this alone does not make them capable of creating a system. To learn how to design a highly useful system, students actually need to perform requirement analysis and system design. For example, students must experience failure due to many omissions in requirement analysis and inability to create a system design. Otherwise, students were able to build the system, but when users tried to use it, the system did not work properly, and students had to recreate it. It is impossible to create a system without accumulating the kind of experience mentioned above. It is difficult to reflect these experiences in the syllabus and grade evaluation, and it is difficult to adopt them as regular classes. Therefore, International College of Technology (ICT) and Kanazawa Institute of Technology (KIT) have given this role to extracurricular activities. Extracurricular classes play an important role in strengthening interdisciplinary education in marketing, sales, electric/electronic circuits, programming, security, art, and so forth through the process of problem solving [4, 5, 6].

Figure 2 shows the processes of setting goals for activities to attract tourists to Ishikawa Prefecture, which was carried out by a group of students as an extracurricular class. Education through extracurricular classes is effective because students can set and execute their own goals using ideas freely without being restricted by time. It also provides the advantage of being able to perform all phases of CDIO education. However, these activities did not include long-term operations.

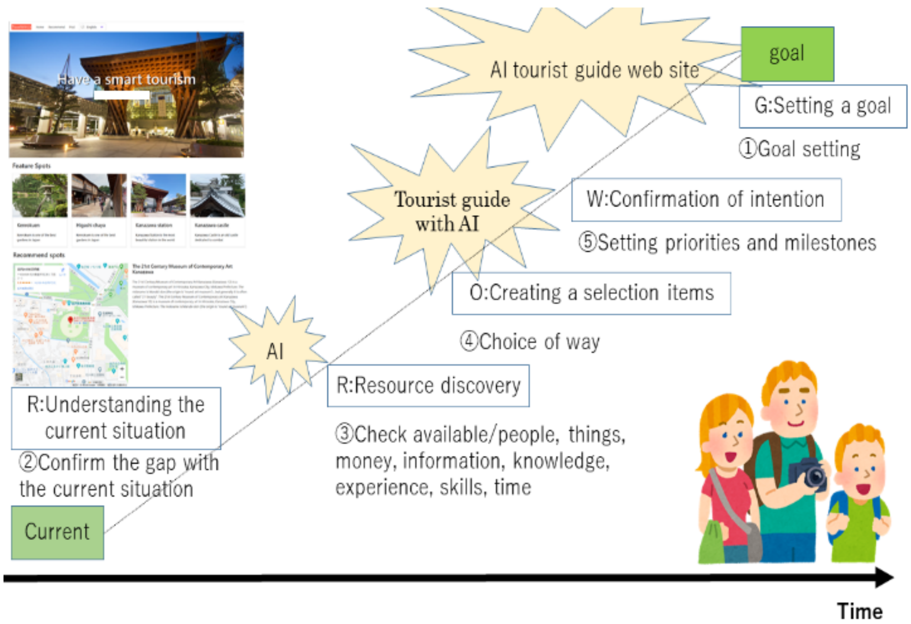

Fig. 2. Determining project activity contents using the GROW model

2 WEB VERSION OF THE BUS LOCATION INFORMATION DISPLAY SYSTEM

2.1 Configuration of the bus location system

Extracurricular classes have been held with the keyword of citizen support, and this activity started in 2015. Approximately 50 students participate every year. These classes are mainly working on information and communication technology at bus stops, and students have developed a system that allows a bus user to check the location of the bus on the WEB. Figure 3 shows the overall configuration of the bus location system developed by students. The bus is equipped with the Global Positioning System, and the location is uploaded to the cloud using Iot Sim or LoRa. The system allows users to check the bus location on their mobile devices, on the Web, or at tablet-terminal-type bus stops. The tablet-terminal-type bus stops are equipped with a tablet, so one can check the bus location and timetable.

As a result of several demo questionnaire surveys, there was a request to continue using the bus location system, so the students started intermittent operation in 2018 and actual operation in 2020. This is the beginning of P: operation education in CDIO education.

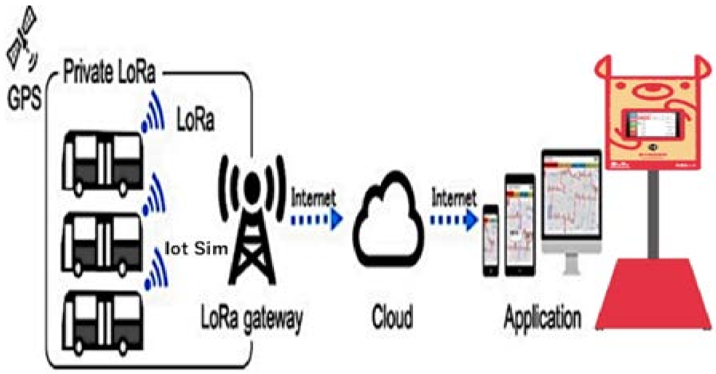

Fig. 3. Bus location system configuration

2.2 Operation education

A questionnaire survey revealed that there were many requests from citizens to continue using the system; thus, students started operation continuously in April 2020. The bus location system that informs the location of the bus was named “Notty bus doko.” There are two main jobs for students in operations:

1. Check whether the bus location system is working without stopping.
2. Update the system according to the revision of the bus time twice a year.

To operate the bus location system, students created a technique to judge whether the system worked properly, and thus avoided constant monitoring. The bus position is updated to the cloud 10 times per second, and if data are not uploaded to the cloud for a few minutes, an email will be sent to all members. As students have to be able to respond even if a breakdown occurs during class, they decided to consider the procedure for identifying the cause in advance and take corrective action. The city official contacted one of the students about the change of bus time one month before; therefore, we decided to consult with the group and create a plan.

Here, we will explain the failure cases in the operation (Figures 4 and 5). The location of the bus is no longer uploaded to the cloud, and the bus driver has informed us that the equipment installed on the bus is not turning on. The student went to the bus operating company, confirmed that the fuse was broken, and collected it. Figure 4 shows the power supply part of the bus location system installed in bus by students, and Figure 5 shows the broken fuse collected by students. The next morning, one of the students received a message from the bus operator that the wiper of the bus did not work. Students had no idea what caused it. The investigation revealed that the power supply position of the fuse collected by the student was also used for the wiper. From these failures, students considered countermeasures. They decided to create a manual and operate it. The following is part of the manual:

1. When installing the device, avoid places that share it with other functions.
2. Be sure to have a replacement fuse and replace it instead of simply collecting the broken fuse.

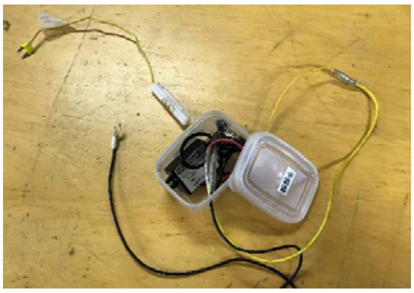

Fig. 4. Power supply installed on the bus

Fig. 5. Broken fuse

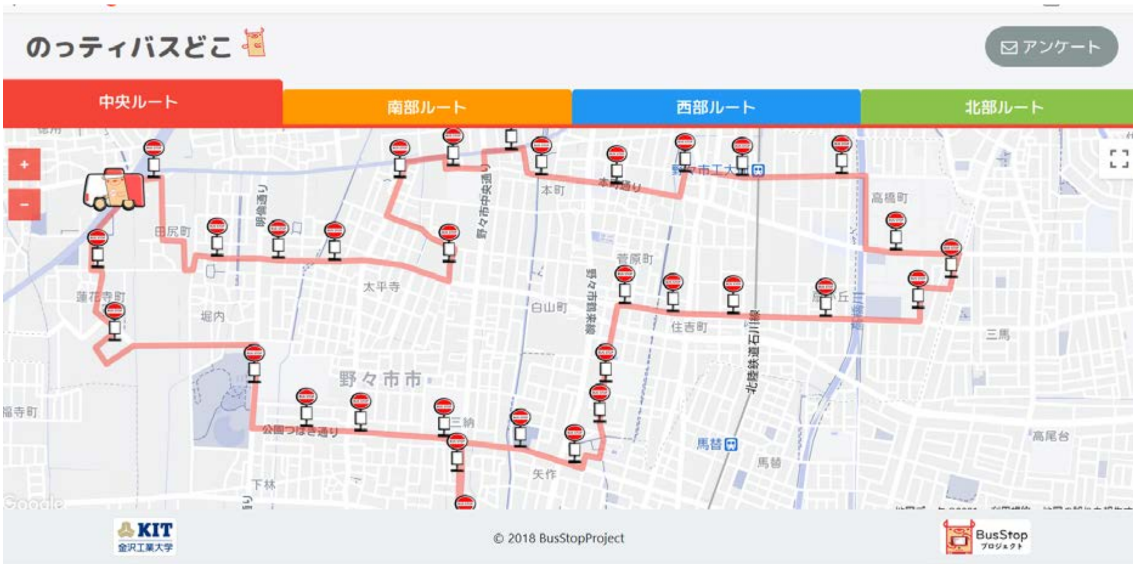

Fig. 6. Web version of bus location information display system

As we continued to use it, we began to want to make the system compatible with routes that the bus location system did not yet support; consequently, we responded to routes extending to other cities and released it. In addition, changes in student consciousness and in the adults began to take a positive direction; for example, a bus driver asked the students to create a bus management system for bus drivers. Since the beginning of 2021, we have been working on the development of a system that supports COVID-19 countermeasures, counts the number of passengers on the bus, and informs the users. Figure 6 shows the Web version of the bus location information display system.

3 EVALUATION RESULTS BY CDIO EDUCATIONAL EVALUATION CRITERIA

In KIT and ICT, Parts 1 and 2 of the CDIO syllabus (see Table 1) are taught as regular classes, and Parts 3 and 4 are taught as extracurricular activities. In extracurricular activities, the project system is adopted, the project is managed by the students, the teachers only give guidance by the coaching method, and the students decide the management method and manage it. Students can learn Parts 3 and 4 of the CDIO syllabus through project activity in regional collaboration.

Table 1. CDIO Syllabus V2.0 [1]

1	Disciplinary 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, social, and environmental context: The innovation process

We evaluated the operation of the system project of the bus location system according to the CDIO syllabus evaluation criteria. Fine-grain details of the third level of the CDIO syllabus V2.0 are Forming Effective Teams, Team Operation, Team Growth and Evolution, Team Leadership, and Technical and Multidisciplinary Teaming. Our project-based education covers all third-level items. Students are recruiting and educating project participants, as well as developing and operating the system in cooperation with city officials and bus companies. With each passing year, the number of project members has increased; further, as the number of jobs that can be accomplished has increased, the number of functions of the systems we provide has also increased. With the support of the members of the graduated project, the chances of learning have increased to a great extent have increased.

The students were able to design, build, and operate the system that could actually be managed considering the business aspect. Therefore, the students were able to learn all the items of Level 4 of CDIO Syllabus V2.0. Table 2 shows Part 4.6 Operation. After experiencing mistakes several times, students could successfully complete all aspects of Part 4.6 except for 4.6.5 (Disposal and Life-End Issues).

Table 2. Part 4.6 of CDIO Syllabus V2.0 [1, 7]

4.6.1	Designing and Optimizing Sustainable and Safe Operation
4.6.2	Training and Operations
4.6.3	Supporting the System Life Cycle
4.6.4	System Improvement and Evolution
4.6.5	Disposal and Life-End Issues
4.6.6	Operations Management

We evaluated students' activity using the evaluation criteria for CDIO syllabus Part 4. Table 3 shows the evaluation criteria for CDIO syllabus Part 4. This activity is not a regular class but an extracurricular activity, and the students who participated did so on their own initiative. In addition, the students was able to take charge of the job decided within the team and accomplish it. In addition, the results were regularly explained to the person in charge of the city, and future plans were also discussed. Furthermore, some of the results were published as one treatise [8, 9]. Through the activities, he learned software and hardware technology and succeeded in operating a system that informs the location of buses that make the lives of citizens convenient. It can be said that the evaluation items of Part 4 were fully satisfied.

Table 3. Evaluation Criteria for CDIO Syllabus Part 4 [1, 7]

1	To have been exposed to
2	To be able to participate and contribute
3	To be able to understand and explain
4	To be skilled in the practice or implementation
5	To be able to lead or innovate

4 SUMMARY AND ACKNOWLEDGMENTS

In CDIO education, operation is defined as life cycle support and evolution. In this paper, we focused on the operation education method and explained CDIO Operation education through regional collaboration by using the bus location system through a WEB application. We explained the results and the educational significance of operation education. This was achieved through extracurricular activities. We chose extracurricular activities considering available time and evaluation.

Operation is the phase of managing the system so that it can be operated without trouble, finding and improving system problems, and considering the next expansion. Students learned how to operate the system steadily by responding to accidents such as bus breakdowns and replacement by new bus purchases.

Operation education faces the difficulty of deciding how to deal with sudden problems. It is not suitable for a curricular course because it is impossible to predict, and it is not possible to create a plan. However, there is also an opportunity to teach the important parts of the system. It can be said that this is the most important part of education that enables students to create a system to earn money. The activities introduced this time follow the CDIO educational philosophy of learning from practice. Students solved the problem by using Information and Communication Technology. The system is still in function. We believe the students were able to learn the operation of the CDIO syllabus.

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GROUP ACTIVITIES WITH AI TEACHER SUPPORT IN PBL EDUCATION

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ABSTRACT

We have built a system that supports PBL education called "AI teacher", and are currently verifying the effects in actual classes. In this paper, we will introduce the mechanism and effect of group activities supported by "AI teacher" which is a part of the system in PBL education.

From 2020, because of COVID-19, we had to do online PBL education with the online communication tools like Zoom. The problem at this time was that when the students were divided into multiple groups and did group work in breakout rooms of Zoom, the teacher could not grasp the situation of the students. Teachers can check by entering the breakout room of each group in turn, but they cannot see the whole students at once. This was a big difference from face-to-face education. Therefore, we introduced the system which possible to check the student's remarks by utilizing the system that automatically records the conversation in the breakout rooms. This allowed teachers to see the progress of each group. Teachers took the initiative and could advice students who did not participate in the activity well.

In this paper, we will explain the system configuration that automatically documents the conversation, and explain effect of utilization of the system and problems. In addition, we will explain the overall configuration and mechanism of the "AI teacher". "AI teacher" use Slack to manage the progress of group activities and provide advice. "AI teacher" is the system that records the conversation as a document, automatically

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participates in group conversations and gives advice. Also, students can check that they wondered with the AI chatbot.

1 PBL EDUCATION IN EXTRACURRICULAR CLASSES

Industry requests the higher education for the engineer development education which is acquire skills, attitudes, patience, spontaneity, creativity, craftsmanship, leadership, motivation, and teamwork. CDIO is a concept devised by the Massachusetts Institute of Technology (MIT) in the United States and three universities in Sweden to respond to this reform of engineering education. CDIO is an abbreviation for Conceive, Design, Implement, and Operate, and is called the "CDIO Initiative," which consists of the "CDIO syllabus" and the "CDIO standard". It aims for high quality education through the framework using real-world systems and products[1].

Our schools have been conducting the CDIO education since 2010. At first, it was introduced in Project Design cource (PD), which is regular class [2, 3]. Figure 1 shows the PD educational class at Kanazawa Institute of Technology(KIT). Our school defines five stages as engineering design processes. PD1 is a class for learning problem discovery, problem clarification, and idea creation, and PD2 is a class for learning idea creation, idea evaluation and careful selection, and concrete implementation of ideas. Evaluating PD education at our school from a CDIO perspective, it corresponds to C: conceive and D: design. At our schools, we teach C: conceive and D: design in regular classes, and we teach I: Implement and O: Operate in extracurricular classes [4, 5].

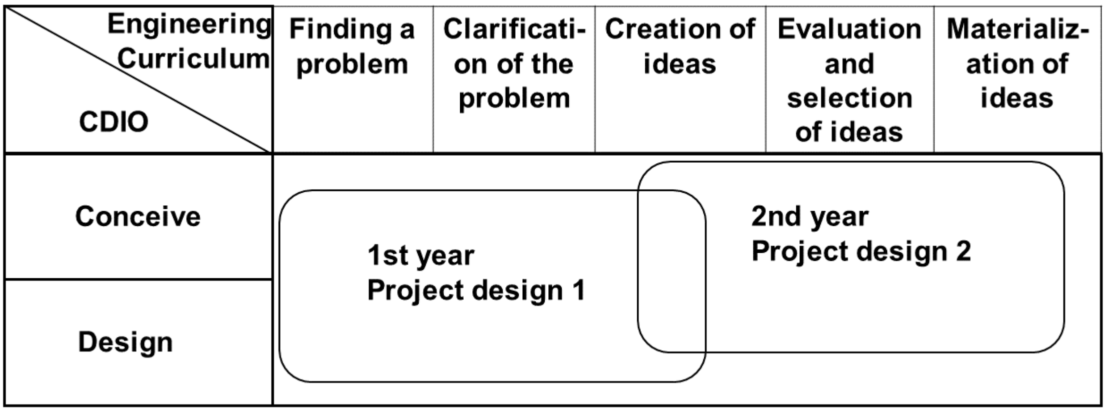

Fig. 1. Engineering classes of KIT

1.1 The e-Syllabus to support student learning

Since KIT launched the e-Syllabus in 2016, the teachers have been utilizing the e-Syllabus as one of communication tools with students. The e-syllabus shows the lesson content for each week and tells students what to prepare and what to review. Also, e-Syllabus provides teaching materials and collecting reports. Some of teachers have been using the e-Syllabus when carrying out flipped learning and active learning [6]. Figure 2 is an example of the e-Syllabus of PD2. The e-Syllabus is displayed, if a student logs in to his page from the portal site, opens his list of courses and click the course. The e-Syllabus displays the contents of learning of weekly classes with the guide of learning targets, scholastic evaluation method, and preferred achievement, etc. Students can check the content of each week's study, prepare for the class, and attend the class. Also, if the class is conducted online, it will be listed here, such as the Zoom (videotelephony software program) participation URL.

The e-Syllabus is a powerful tool when carrying out flipped learning and active learning. It was used as the main platform of the on-line education under the state of emergency of COVID-19. Important information such as "Will classes be held or will they be canceled?", "Will it a face-to-face class or Will classes be held online?", was sent from the e-Syllabus.

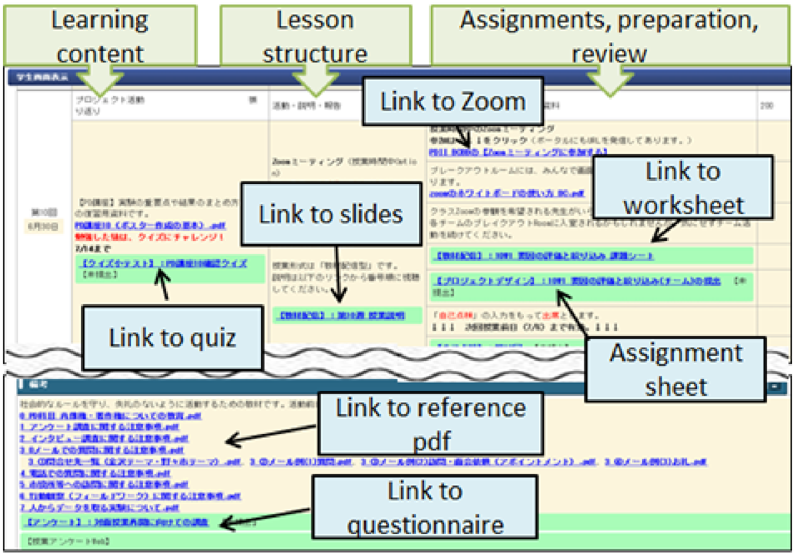

Fig. 2. The example of e-Syllabus

The flow of one class in the PD is explained. In the PD class, the faculty members will first give a lecture on today's activities, how to proceed with discussions, and tools that can be used. After the lecture, students are divided in groups and do group work in Zoom Breakout Rooms. Students report the results of group work and the class ends. In face-to-face classes, teachers visually check the situation of each group, call out to groups whose group activities are stagnant, and give guidance. It was difficult to give this instruction in online classes.

After the class, the teacher confirms learning results of the week from the reports. In online classes, we cannot see what the students are discussing in group activities, so we can only see the situation from the post-class report. As a result, it took a long time to recover of the progress, and some groups did not work well.

2 "AI TEACHER" SYSTEM CONFIGURATION AND USAGE

2.1 "AI teacher" system configuration

We have used the GROW model[7] and CLEAR model[8,9] to develop the learning power of students. Figure 3 shows the CLEAR model process. The primary focus of the CLEAR model is to create students that are committed to team plans and are happy to contribute to shared goals, rather than simply complying to managerial demands. It consists of five phases. The contracting stage focusses on establishing desired outcomes – both individual and group – and revealing how the process can be tailored to be most valuable to the individual's needs. The key aspects of listening stage are 'active listening' that aim to allow the coach and individual to truly understand the situation. Awareness is given on the Exploring stage. The Action stage encourages action. During the Review stage, students will see whether they are on track to reach their goals, asking them to see what's going on and how to improve. By using the coaching method, the student's current position and the words of the question at that position are determined, so it is a method that is easy to automate.

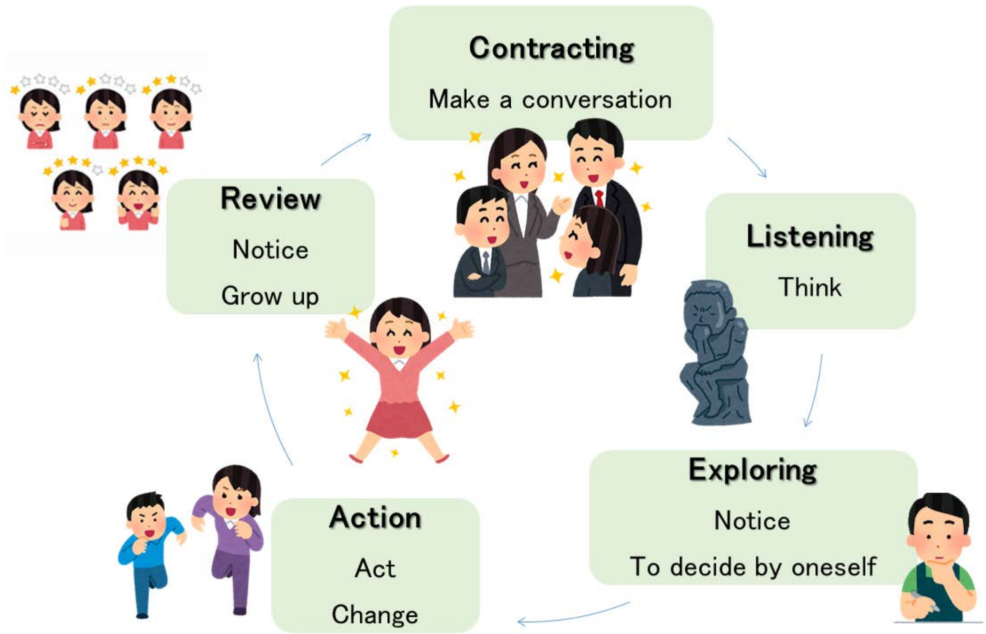

Fig. 3. CLEAR model process

We are developing an "AI teacher" that provides PBL (project/problem based learning) education using coaching techniques. Figure 4 shows the overall configuration diagram. Students access to the digital platform and work on the project team database. The AI engine acts as the facilitator on each project using the course materials and know-how database. Text mining and chatbots serve as main components of AI engine.

We decided to use the chat system Slack (communication platform software program) [10] as a interface of “AI teacher”. Slack is excellent in a user interface, and integration with other services is easy. It can be easily accessed from the e-Syllabus. Use of Slack has spread not only among companies but among students because of its ease of use and basically free of charge. A “Channel” can be set up for each project and project members communicate and work in the channel. All of the conversation and produced data are recorded as a searchable team data.

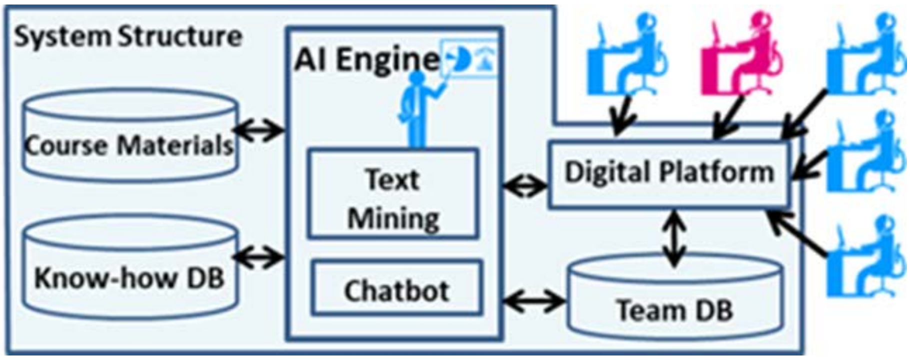

Fig. 4. “AI teacher“ configuration

In the proposed system, more than 6,500 reports are stored in the web server as the students output of the four PD courses from 2012 to 2018, that is, about 1,500 PD Introduction experiment reports, 1,700 PD1 design reports, 2,000 PD2 implementation documents and 1,400 PDIO project reports. “AI teacher” use the DB of the web server. The themes of projects are various from an airplane or a car even to sightseeing and food. Keywords are extracted from each report by text mining, and they are given to the answer report as index. There is also the database which teachers prepared the principles and laws of physics and chemistry. Teachers’ instruction materials including PowerPoint class slides are also on the e-Syllabus and the web server. These data can be saved as course materials and used as the know-how database.

The AI engine facilitates project activities instead of teachers. In addtion, the AI engine help teachers work. It analyses course materials and know-how data using text mining. It also analyses the ongoing project data in the team database. Matching data from the analyses results, the AI engine recommends the course materials and references to the project. Chatbots are used to answer questions from the students, monitor their activities on the project and give them feedbacks. Chatbots behave like teachers who take charge of the projects.

2.2 "AI teacher" system usage

Chatbots can be used as the virtual facilitators. It will extract keywords in the questions and find related materials which best match the keywords from the database. One example question is, "How can we make a poster of our project?". The chatbot answers "You can find a template and a sample poster in this link …" or "You can find some posters relevant to your project here …" . Such a system will reduce teachers' work and students can learn with the chatbot.

The "AI teacher" provides a minutes function to solve the following problems that became problems in online classes. We are currently using AmiVoice® (voice recognition AI engine) [11] for this feature.

1. Students need to turn off the microphone when the teacher is speaking because the voices overlap and it is difficult to hear. This made it difficult for teachers to grasp what the students were doing. In addition, it became difficult to visually check the students. For this reason, it became difficult to grasp the degree of understanding of students.

2. When students do group work, each group moves to a breakout room in Zoom for discussion. Teachers cannot join multiple groups at the same time and can only see the status of one team. In the face-to-face class, I was able to visually grasp the situation of each group, but the class by Zoom made it impossible.

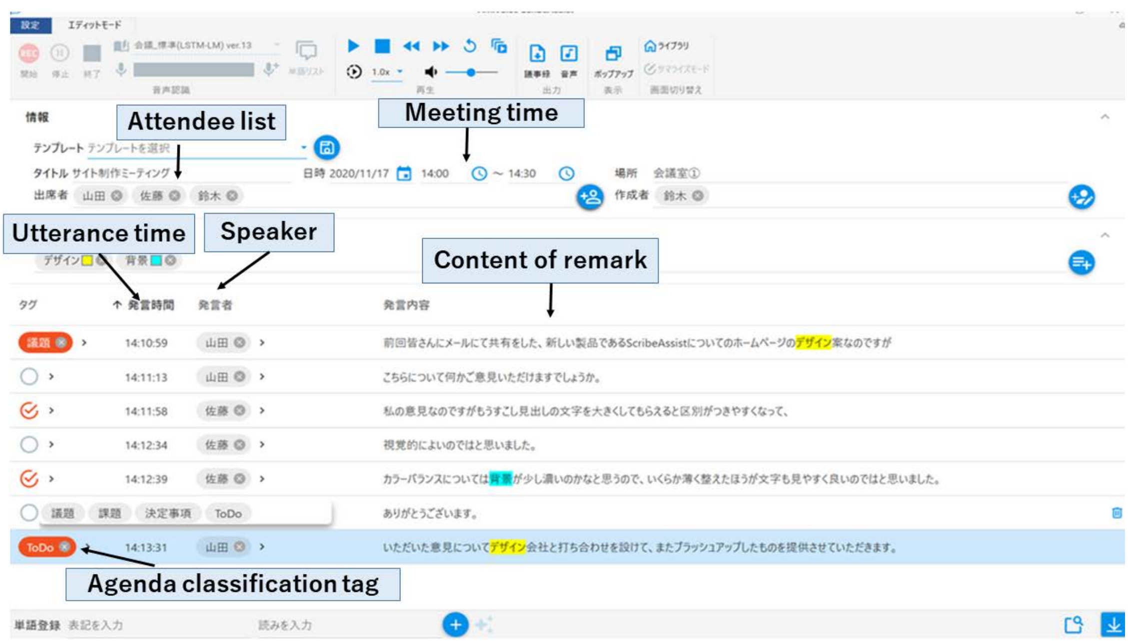

Fig. 5. Automatic minutes creation tool

In order to solve these problems, it was decided to introduce a Speech-to-text reporter . Figure 5 shows how the minutes creation tool creates minutes. In real time, the speaker is identified and the spoken content is displayed as a document. The minutes function records all the content discussed in the group. It also records who spoke.

Therefore, you can check the content of the discussion in real time. You can also check who has not participated in the discussion.

3 EVALUATION RESULTS

The minutes function of the “AI teacher” has shed light on the situation where online classes are required due to the influence of COVID-19. It is not possible to automatically record all the contents accurately, but it is possible to make the document at a level where the contents of the proceedings can be confirmed with a little modification by the initial person in charge while discussing. If you manually create the minutes, you will summarize and record the contents of the discussion, but it is effective that you can record all the contents by using this. As you continue to use it, your recognition level will improve and you will have fewer places to work on.

One teacher said it was useful in finding students who couldn't attend the class. In addition, other teachers said that they are suitable for confirming the depth of the discussion because they can know the content of the discussion including the content that was didn't go well.

4 CONCLUSION

We have built a system that supports PBL education called “AI teacher”, and are currently verifying the effects in actual classes.

From 2020, because of COVID-19, we had to do online PBL education with the online communication tools like Zoom. The problem at this time was that when the students were divided into multiple groups and did group work in breakout rooms, the teacher could not grasp the situation of the students. Teachers can check by entering the breakout room of each group in turn, but they cannot see the whole at once. This was a big difference from face-to-face education.

Therefore, we used automatical recorder of “AI teacher” that record all conversation in the breakout rooms. This allowed teachers to see the progress of each group, who took the initiative and who did not participate in the activity well. The faculty members who used it said that it is effective because we can confirm who is not participating in the discussion. Other faculty members also said that it was effective to understand the content of the discussion in detail. We have confirmed the effectiveness of this system.

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DESIGNING OPEN INNOVATION PROBLEM-BASED PROJECTS: SOCIAL RELEVANCE, STUDENT EXPECTATIONS AND PRELIMINARY OBSERVATIONS

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Keywords: *Open innovation; Problem based learning; Interdisciplinary; Sustainable development goals; Student motivation*

ABSTRACT

In this concept paper, we present insights from an ongoing online interdisciplinary project with a “Technology and Migration” theme. The project is initiated by course coordinators from Medialogy and Techno-Anthropology at Aalborg University, is supported by the United Nations Refugee Agency (UNHCR) and is carried out by Bachelor and Master students from the two programs. We present the design of an open innovation problem-based educational activity, where different stakeholders

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facilitate student engagement in real-world issues regarding technology and migration. We present observations and results from a student survey, reporting on their motivations, expectations, and reactions to the format. We conclude with the expected outcomes and some preliminary results of the initiative.

1 INTRODUCTION

1.1 Vision of Engineering Education

The modern engineer is capable of complex real-world problem solving, is entrepreneurial, is socially aware, and can flexibly work within and outside their discipline [1, 2]. Engineering educational programs at Higher Education Institutions (HEIs) must thus equip engineers for the contemporary landscape. One approach is to simulate real-world engineering work via problem-based student projects that incorporate interdisciplinarity (e.g. where students engage with the content or members of different disciplines) [3] and/or open innovation (e.g. where students engage with stakeholders external to HEIs) [4].

Examples of such cross-boundary student projects are the Innovation Course hosted by the European Organization for Nuclear Research (CERN) [5, 6], the Learning in Interdisciplinary Focused Environment (LIFE) projects at Tallinn University [7], Ocean i3 at the University of Bordeaux [8], and the Open Innovation Laboratory at Tecnológico de Monterrey [4, 9]. In these programs, multidisciplinary groups of students (e.g. from engineering, science, humanities and design) create projects in response to a challenge or problem, and are encouraged to involve external stakeholders (e.g. end-users and industry experts). The United Nations Sustainable Development Goals (SDGs) are often used to thematically unify the multidisciplinary members. In general, students develop their own projects, while guided by a mentor and a process framework (e.g. design thinking or similar).

While cross-boundary projects have produced positive results in developing key competencies in engineering [4, 5, 7] there are various key pedagogical considerations (e.g. high level of involvement of the facilitator(s), reflexive Computer-Supported Collaborative Learning implementation (CSCL), scaffolding interdisciplinarity) [2, 6]. To this end, pedagogical strategies need to be further explored. This paper shares one ongoing initiative by Aalborg University's Medialogy and Techno-Anthropology programs[2], supported by the United Nations Refugee

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[2] *In the Medialogy program, students learn how to develop the technology behind advanced digital media products, such as advanced computer graphics, games, electronic music, animations, interactive art and entertainment. These media technologies are also seen from the user perspective, and therefore human-computer interaction, interaction design, psychology and related fields are also important* [13]*. The Techno-Anthropology program combines disciplinary elements from engineering and the humanities, as students explore the interaction between humans and technologies. It is a two way relationship in the sense that technologies hold intentionality and influence humans accordingly, while humans are not defenceless because technologies are designed, shaped, abused and domesticated by designers and users* [14].

Agency (UNHCR), to implement problem-based student projects that incorporate SDGs, interdisciplinarity and open innovation. We conduct a preliminary assessment of the format using observations and results from a student survey reporting on their motivations, expectations and reactions. We conclude with the expected outcomes and some preliminary results of the initiative.

1.2 The Technology and Migration Initiative

Problem-Based and Project-Based Learning (PBL) are the core of Aalborg University's pedagogy [10]. Every semester, groups of students independently work on problem-based projects, with guidance from academic supervisors and while attending three 5 ECTS courses that support their project work. These semester projects are obligatory modules for all students in all semesters, and they amount to 15 ECTS. Inspired by the SDGs, the "Technology and Migration" initiative (ongoing from February to June 2021) was co-developed by Medialogy and Techno-Anthropology course coordinators, to offer students an enriched project experience by adding further elements of social relevance, interdisciplinarity and open innovation.

Open innovation is understood as opening the innovation process to anyone, especially non-experts with a diverse background, and sharing the output of this process. Open innovation contributes to the circulation of knowledge and embodies science in tangible artifacts. The goal with the "Technology and Migration" initiative was to bring together academic staff and students from different disciplines and engage them in the transformation of knowledge to innovative solutions, prototypes, or artifacts as a response to the social challenges of migration. This initiative invited students and academics from Medialogy and Techno-Anthropology to get together, co-reflect, co-develop, and apply their knowledge to address a problem related to technology and migration and drawn from observation or from previous knowledge.

Bachelor's and master's students across the two programs were invited to create projects under the said overarching theme. Each group would then tackle the theme within the scopes of each group's focused interests and program's curriculum; this brings the opportunity for interdisciplinary collaboration and peer-learning, as student groups may offer peer-support as they progress with their projects. Open innovation is further incorporated by involving the UNHCR as an external expert. As facilitators, the course coordinators' key role is to support the collaborations between the students and with the UNHCR. Eighteen students are currently participating from four groups: one group from Medialogy (Bachelors; six students), two from Techno-Anthropology (Bachelors; four students respectively), and one from Techno-Anthropology (Masters, four students).

The PBL semester projects are part of the curriculum, they start in the beginning of each semester and span four months. The three supporting courses are given in the first part of the semester in order to allow students to apply the knowledge obtained during these courses to their semester projects. Every group is assigned a supervisor for the semester, who is responsible for guiding the students and facilitating the process of working in the project. According to the PBL principles, the supervisor should not instruct students or take the decisions for them. For the "Technology and Migration" initiative, each group was assigned a supervisor from their own program but they had also access to mentors organizing this initiative. The student groups were meeting the mentors and the other groups working under the same theme once per week. An introduction seminar was organized in the beginning of the semester in order to introduce the students to the theme and the process. In the end of the semester, a final seminar was organized, where student groups presented their projects and got feedback from the mentors and the external stakeholder (UNHCR). Due to COVID-19 pandemic restrictions, all these activities and the collaboration among students of the same group were conducted online.

2 VECTORS OF COLLABORATION

2.1 Development and Planning

In September 2020, course coordinators from Medialogy initiated the idea for a cross-boundary semester project and developed a theme that was relevant to the curricula of programs that were invited to participate. Thus, the Technology and Migration theme and ideas for external stakeholders were included in the initial proposal sent to other university programs. With the participation of Techno-Anthropology, both programs identified several focus areas that were relevant to their students (Table 1). These focus areas were communicated in pitch emails to potential external stakeholders i.e., refugee agencies based in Denmark.

In February 2021, a meeting was held between course coordinators and the UNHCR to discuss collaboration possibilities. It was planned that the UNHCR would provide guidance on project topic development, participate in focused discussions with students, and provide project feedback. The meeting also provided invaluable feedback to the focus areas, each presented by the topic's direct representatives from the UNHCR branch in Denmark. Several officers from the World Bank were also present in the meeting; their facilitation was key for articulating different topics that might involve more than one leader within the agency. The three contemporary issues identified in the meeting and defined as the key challenges for the Technology and Migration initiative were: refugee data collection during COVID-19, digital inclusion, and e-learning and digital education (Table 1).

Starting a few weeks before the semester, information on the initiative was disseminated to students. The project was also presented during semester introduction lectures and explorative supervision sessions with bachelor's and master's students from both programs.

Table 1. Project themes development. First, course coordinators identified focus areas within "Technology and Migration" that were relevant to the Medialogy and Techno-Anthropology curricula. The UNHCR contributed key challenges related to these focus areas. Students then developed their project topics using both elements.

Focus areas identified by university course coordinators	Key challenges related to focus areas, identified by UNHCR	Project topics developed by students
1. How can technology be used to measure and gather crucial information on the lives of displaced communities, and the types of challenges they face? 2. How can technology help displaced populations and communities be part of a connected society? 3. How can technology support education for refugees? 4. How can technology be used to support long-term change?	1. Refugee data collection in the context of the COVID-19 pandemic 2. Digital inclusion of refugees 3. E-learning and digital education for refugees	1. App-based secondary education tool with gamification elements 2. Technology assessment of e-learning systems used in refugee camps 3. Privacy issues with collecting refugee data 4. Migrant center in Copenhagen - ways of digital responsible data collection for funding applications.

2.2 Implementation

While the students worked on their projects, the role of the facilitators was to support the students' collaborative activities. Initially, this included creating an online discussion and knowledge-sharing space for students via Microsoft Teams, and hosting weekly support meetings for students. Facilitators also assisted students with contacting the UNHCR – to do so, one representative from Aalborg University and another from the UNHCR were responsible for collecting student questions, determining requirements, arranging future interactions, and arranging feedback sessions. These activities were not compulsory, and their sustainability was driven by the students themselves. Students were also free to initiate other forms of collaborative activities as inspired by their project work, such as interest group meetings.

In addition to knowledge-sharing, other types of support were also developed as the initiative progressed. For example, students required further guidance and support for field data collection. Additional contact with specific personnel (technical staff, teachers, and refugee students) in the refugee camps in Kenya, Jordan and

Denmark was necessitated by some groups. Thus, through an exploration into the authors' contacts network, it was possible to reach Norwegian Refugee Council (NRC) representatives from the Education program in the biggest refugee camp in Jordan and technical staff in one refugee camp from Kenya. Subsequently, we gained access to staff from a refugee camp in Northern Uganda. These contacts would enable field empirical data collection remotely.

3 CURRENT OBSERVATIONS

3.1 Student Motivations for Participation

An online student survey distributed at the start of the initiative provides insight to the students' motivations for participation. The open survey was sent to the students working under the "Technology and Migration" theme and was focused on the motivation for participating in this initiative, their preferences on collaboration, and their expectations. The results from 18 responses are summarised here.

The biggest motivator was interest in the Technology and Migration theme itself. Seven students described the theme as an opportunity to produce a meaningful project with real-world impact. As one student writes, "*Migration issues are of the most vital and while there are also other problems that ought to be dealt with, I find the labour conditions for migrants and, generally the living conditions of people who try to make a new start, very important and fundamental in society*".

Four students also described the educational potential of the theme, that it "*fits well with my studies*" and allows them to gain "*general knowledge about… immigration and refugees*", "*tools and knowledge to engage in a very pertinent and important problem in the world*", and "*improving and applying the skills that I have in Techno-anthropology*". Other main motivations included interest in interdisciplinary collaborations ("*The collaboration between Techno-Anthropology and Medialogy, and as a software developer myself that intrigues me*"), guidance from mentors and experts, and being able to include the experience in their resumés.

In terms of collaborative activities, all students expressed interest in receiving feedback from external experts, 78.9% were interested in weekly support meetings, 78.9% were interested in presenting their final projects external experts, 74.7% were interested in discussions with students from other programs, 68.4% were interested in using a Microsoft Team for sharing resources, and 42.1% were interested in virtual social activities.

While such activities motivated these students to participate in the Technology and Migration initiative, we also experienced some difficulty in attracting involvement in the first place. For example, it was difficult to attract Medialogy students to participate (only one group joined), and within a month of the initiative's commencement, two students from Techno-Anthropology (Bachelors) left the initiative and their group to pursue a different theme. The lack of interest was largely due to the impression that the initiative would require additional responsibilities to complete their semester projects, since it would involve collaborating with stakeholders beyond their individual student group (students are more accustomed to working only within their group). These additional activities and the personal initiative they demanded, though opportunities for developing key competencies, were unattractive to students who could not commit to them. As is the case for the two students who left after a period, students may also prefer a more straightforward project where the tasks were, to a higher extent, predefined by a supervisor. These doubts were likely compounded by the general uncertainty brought on by the abrupt transition to online learning and the pandemic context [11]. A lesson learned is that it is difficult to do interdisciplinary work that is not framed by the curriculum.

3.2 Considerations for Collaborating with External Stakeholders

Students were inspired by the input from the course coordinators and the UNHCR but formulated their own specific project topics (Table 1). Hence, they did not copy the ideas presented to them. This level of student engagement is aligned with Aalborg University's pedagogical model and its strategic aim of producing knowledge for real-world applications. It also fits well with study programs involved in this project, as they are all concerned with the societal effects of technologies. However, this approach by the students presented challenges to the UNHCR, who were not expecting this level of student engagement. On one occasion, the agency asked students to not pursue the project they had initially formulated, as they were already conducting a similar project. An important lesson is concerned with the need for a stronger pedagogical framework that specifically aligns external stakeholder and student expectations for collaboration. For example, facilitators should help UNHCR prepare specific challenges, rather than general themes, for student projects. Students generally delegate background data collection to the external stakeholder and do not exhaust other search possibilities. If the external stakeholder suggests challenges for student projects, they could be accompanied by background material.

3.3 Considerations for Active Online Learning

Considering the COVID-19 pandemic and its related restrictions, it was critical to foster a culture of open communication that can modulate, with relative ease, between professional and more casual tones. As previously mentioned, the authors had set up online information sessions as well as weekly support meetings via Microsoft Teams, and have used both to systematically engage all participants.

One result of these efforts has been an interdisciplinary collaboration initiated between one Medialogy (Bachelors) group and one Techno-Anthropology (Bachelors) group, as their projects were similar thematically and could potentially support one another ("App-based secondary education tool with gamification elements" and "Technology assessment of e-learning systems used in refugee camps"). The students created their own interest group channel in Microsoft Teams, crafted a code of conduct to harmonize working styles between the different groups, and are actively sharing insights and challenges at the weekly support meetings.

These actions are in line with the proposed culture of oscillation between professional and casual activities and are an example of open collaboration between students from different disciplines, who are engaged to follow a shared academic interest in an interdisciplinary fashion. We propose that this approach to an open and online education is in line with the ongoing educational innovation and active distant learning, accelerated by reactions to the COVID-19 pandemic [12].

The relatively small number of participants has been helpful for facilitators to create an active online learning environment. With 18 students, the four facilitators could easily leverage a sense of community between the two disciplines, as well as facilitate interdisciplinary collaboration between smaller groups. Supported by the weekly support meetings and a somewhat shared academic vocabulary between Medialogy and Techno-Anthropology, students were able to form interdisciplinary groups and engage in interdisciplinary project work.

We learned from the project that the small number of participants and high level of engagement by the stakeholders contributed to a successful outcome. We did not, however, utilize the full potential of active online learning. Partly because we did not develop a tailor-made CSCL method that facilitates student project work and external collaborators priorities.

3.4 Lack of Funding to Support Students' Project Activities

When attempting to connect with experts and stakeholders closely related to refugee camps, we noticed that it might be necessary for the initiative to allocate funding to support activities that this contact and interaction may incur. For instance, funding may be needed to cover transportation to visit refugee camps (internationally, when it is allowed), to hire a local contact to remotely act on the behalf of the students in the refugee camp, to pay an interpreter service when there is a language barrier, and, very importantly, to support refugees and other informants with transportation costs, a per-diem, and access to the internet on their phones to hold interviews.

4 DISCUSSION AND CONCLUSION

The Technology and Migration initiative by Aalborg University was designed as an enhanced educational experience for Medialogy and Techno-Anthropology students, by incorporating SDGs, interdisciplinarity and open innovation into problem-based student projects. While the initiative is still ongoing, observations so far indicate that the initiative has been an educational experience for students. For the first time for many of them, students are exercising key competencies associated with interdisciplinary collaboration and open innovation, such as communication, project management, conflict management, and leadership. As exemplified by their project topics (Table 1) and collaborative activities, students are exploring how their field of education could be used to address a real-world challenge and are learning about a socially relevant topic that does not traditionally arise in their field of education.

There were many pedagogical considerations involved in realising the Technology and Migration initiative. Adding to the highlighted considerations in section 1.1., we observed a stronger need for facilitator-student collaboration and reflection sessions. In general, it was useful for us coordinators to identify activities that students were interested in at the start to ensure continued student engagement. For instance, weekly support meetings were arranged because students expressed a keen interest in them, and indeed these meetings have been well-attended and have played a key role in the initiative's success. As with any real-world cross-boundary project, collaboration challenges have arisen, such as managing the interests of various stakeholders. However, due to their inevitability, the challenges themselves serve as educational experiences for students. Once the initiative is completed, final student projects and a post-activity survey will be analysed for the final learning outcomes, student feedback, the relevance of collaborative work from different semesters and programs, and the complexity of collaboration or facilitation involving big organizational structures. A next step for the current initiative would be to integrate the lessons learned into the existing higher education infrastructure of Aalborg University.

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BRINGING INDUSTRY AUTHENTICITY TO TRADITIONAL TAUGHT PROGRAMME ELEMENTS

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Conference Key Areas: *Methods, formats and essential elements for online/blended learning, Changes beyond Covid-19*
Keywords: *industry, online, engineering science, Covid-19*

ABSTRACT

This paper discusses a project which leverages professional contacts to build industry linked activities into areas of the curriculum which are often seen as focussed more on fundamental theory and less on the wider aspects of practical implementation.

While part of a much wider initiative, to show the process, we will focus in on one exemplar - the development of a learning package in support of pump flow - classic fluid dynamics, taught normally through theory classes supported by laboratory exercises. The new development however involved collaboration with a major supplier of fluid handling equipment with whom we had existing contact via recent alumni. The result was an online self-directed learning package combining a compact masterclass with a senior engineer together with a 'have a go yourself' active and adaptive mixed-media activity with a recent graduate acting as host. The paper reports on this experience, reflections from academic, industrial and student partners and offers a guide to those wishing to try something similar particularly in current Covid restricted times when physical involvement with industry is otherwise difficult.

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1 INTRODUCTION

1.1 Industry involvement in degrees

Involvement of industry in engineering degrees is seen as vital to add currency and authenticity to the learning experience [1]. This involvement may take the form of both direct engagement with the learning experience via student facing activities or indirect engagement such as industrial advisory or steering boards [2] designed to support the teaching team in their development of curriculum.

1.2 Typical touch points and engagement mechanisms

Direct industrial input into the curriculum commonly involves engagement in dissertations, capstone exercise [3], visits [4], guest lectures [5,6], internships [7,8] or design projects [9,10]. These typically are linked to design type modules [11,12] or projects and are often biased toward later years at which point students are perceived to have accrued the skills needed to cope with the challenges posed.

1.3 Engagement in taught aspects of the programme

Less common is the embedding of industrially linked activity in conventional didactic topics such as core underpinning engineering science particularly in early years. Normally taught via lectures, tutorials and laboratory exercises, these core skills modules impart the requisite theoretical technical knowledge but may offer less in building the confidence students need to allow them to use this theory in real world scenarios. A student on a fluid dynamics course may be able to specify an idealised pump for a job based on calculations of pressures and flow capacities but may not join this up with practical considerations such as servicing, cost, spares retention, over or undersizing to deal with uncertainties in the expected demand, performance drop-off over time etc. This potentially creates a confidence and skills gap for graduates transitioning to industry.

1.4 Industry club

To aid in engagement with industry a number of institutions around the world have developed industry clubs [13,14]. For the industrial companies, such a scheme offers a low risk, low cost involvement with the University, access to students to undertake projects and helps raise awareness in the students minds of companies and sectors which may not have the profile of more obvious areas of the graduate jobs market. At Aston University such clubs have been running for three or so years in Mechanical Engineering, Chemical Engineering and Computer Science. Initially these focussed on placing industrially linked projects with final year dissertation students but the scope has gradually increased to look at other opportunities to share activity. This paper looks at how the partnership has been expanded into the taught elements of the programme with a particular consideration of implementation under Covid restrictions which has made company visits, face to face guest talks and similar activities difficult.

1.5 Proposal

To address the lack of industrial content in didactic engineering science modules it was proposed that a number of interactive online case studies be developed to help show how fundamental engineering science can be applied in authentic industrial problems. A small team consisting of an academic, a material developer and a member of the University business link unit was assembled.

2 METHODOLOGY

2.1 Raising awareness

As with many initiatives of this type, raising awareness among industrial and academic partners of the opportunites is a key first step (Fig.1). To achieve this and with Covid restrictions limiting direct interaction, an online event was held to which all academics and industry club members were invited. Here a number of students working on industry club linked projects presented their work. In addition, pilot work on the design of the interactive case studies was presented.

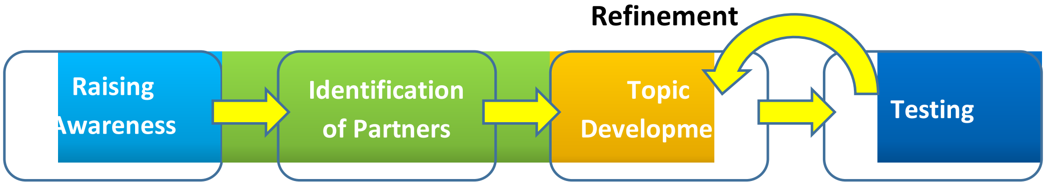

Fig. 1. Educational material development process

2.2 Identification of partners

With awareness raised, a number of academics came forward with areas they felt could benefit from added industrial authenticity. In some cases, they already had industrial partners in mind but were needing support in getting over the inertia to make development of support material viable. In other cases academics would approach the team with a need and the supporting team would then help them map these needs to the strengths of partners within the Industry Club or wider industrial contacts with the required skills who may then be able to work with them.

2.3 Topic development

With partners and academics identified, a meeting was set up to clarify objectives and ensure a consensus between all those involved in terms of commitment and hoped for outcomes.

This was then followed by specific meetings between the developer, academics and industrial representatives before beginning material development.

3 DEVELOPMENT OF MATERIAL IN VIRTUAL LEARNING ENVIRONMENT

3.1 The Context

The work was carried out under fluctuating national lockdown conditions imposed to control Covid-19. This precluded visits by academics or the development team to the industrial partners or vice-versa. While this prevented direct contact between students and the industrial partners it did encourage the development of virtual and online material to support the learning which then has the capacity to be reused for other cohorts without significant extra workload.

3.2 The Virtual Learning Environment

While virtual learning environments (VLE) have been around for a couple of decades the impact of Covid-19 have seen these move to a leading rather than supporting role in the learning process.

To provide a readily accessible development environment for both the development team and the students the standard VLE available at Aston University, “Blackboard”, was utilised. As with most VLEs this offers the opportunity to deposit documents and videos for students to view while also offering interactive features such as quizzes, tests and adaptive release of material based on completion of previous tasks.

3.3 Material Development

While the development team was open to delivering a tailored learning package to suit each case, the example presented here (Fig.2) covers the development of a response to an authentic queary sent to a water services supply company. The queary was made in relation to changes in the existing industrial set up to introduce variation and to establish if such variation was within the performance of the water pump already installed. The educational material developed was to be suitable for use in a second year fluid dynamics module with the module leader a key part of the development team.

The material developed was designed to augment and follow on from the normal delivery of academic theory supported by simple case studies, tutorial problem solving and laboratory exercises. The newly developed material was then to complement these underpinnings with an online package of interactive material to contextualise the theory in an authentic setting.This learning reinforcement comes from the fact that students must first analyse the brief given in the query, make sense of it and define what needs to be calculated themselves with the workflow moving from the brief to the solution

To make the material interactive, significant use was made of relevant VLE tools. Videos were used to introduce the company and the role of the lead engineer, a former graduate. This progressed to a video run through of a typical scenario when the company is asked to devise a pumping solution for a customer. At points through this process, small check quizzes were used to allow students to check their understanding and adaptive release allowed material to only be released to students on completion of previous steps.

The material was based on the successful talks carried out online between the educational developer and the industrial engineer.There were a number of consultations between the developer and the module lead academic to ensure the

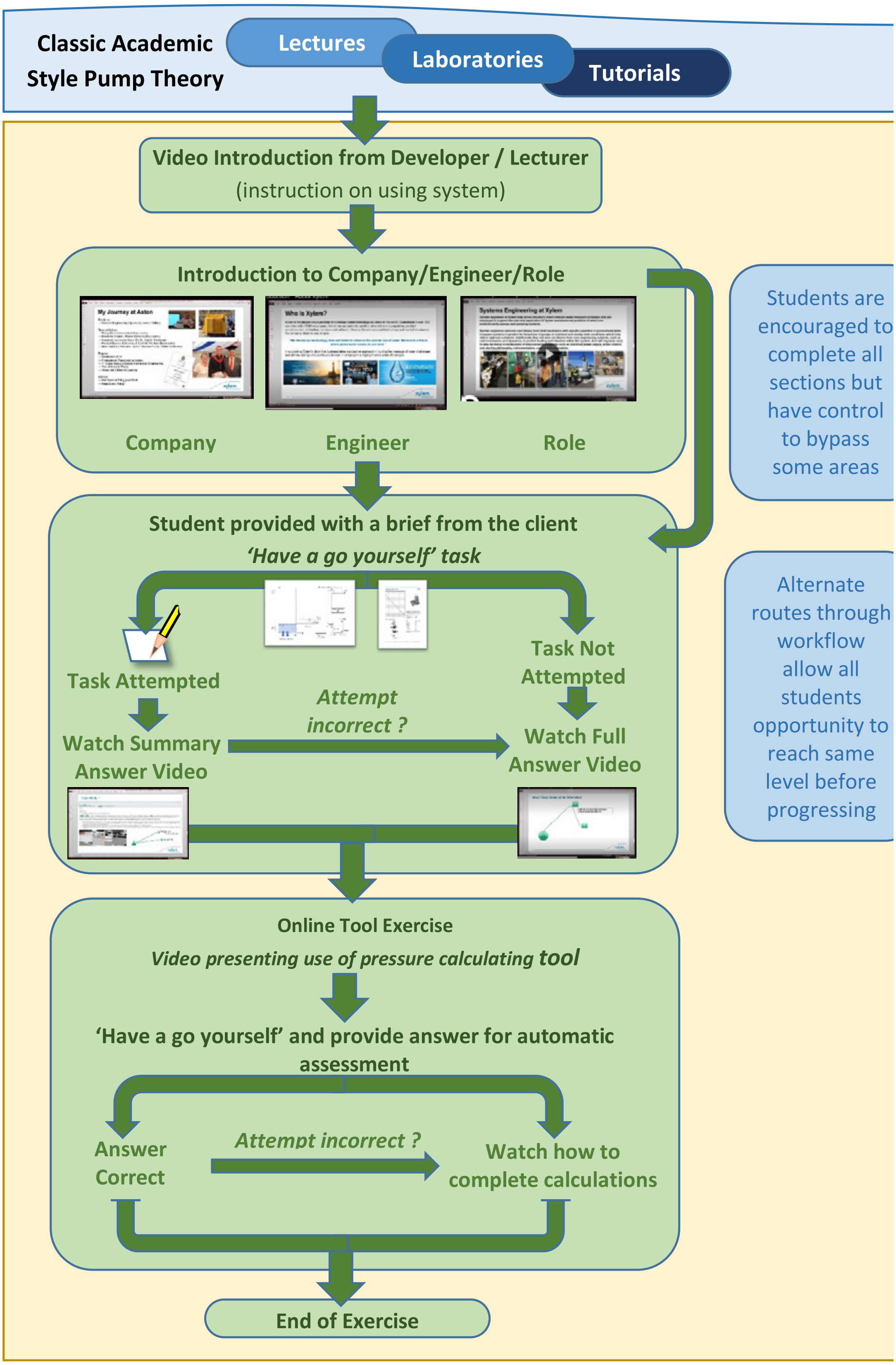

Fig. 2.Structure of Online Industry Linked Learning Material for Pump Problem

level of sophistication and difficulty was set at the right level for the group of students. This verification also allowed for consistency in wording used between the material delivered as a part of the course and the one developed in partnership with the industry. There has been circumstantial evidence from the students that they experience fatigue from excessive use of computer for studies. As a result, the introductory parts were trimmed to represent relevant topics and grouped as 'non-obligatory but beneficial', giving a student a choice to engage with the material if desired to do so.

The tasks themselves were designed to ease the students into the activity beginning by setting out the task, explaining and providing necessary information. The students were then asked a true/false question on the brief to test the ability to turn a real-life scenario into appropriate engineering task themselves – a key skill that had been noted as not fully explored in the current delivery of curriculum. New recording material was then released upon the answer to either view the summary for the students to confirm if their analysis concurs with that of a senior engineer and if not to view the process taken to conduct it.

The framework created was also enhanced by a 'how to video' delivered by the educational material developer showing how to navigate through the module and use various aspects of it.

3.4 Test and Refine

As part of the creation process, the learning material devised was partly co-developed and tested by students prior to full deployment. Key elements to refine at this stage by the team including student input include:

- Technical accuracy
- Industrial authenticity
- Clarity of material
- Validity of any tests
- Usability and robustness of online module

The approach taken by student participants in trials varied between them, however, most typically participants would take breaks at the point when new content was unlocked. Lack of certainty over how much time to commit to the task was a challenging aspect for the students. The input required was individual and varied from participant to participant subject to the level of engagement. It was possible to breeze through the material without much commitment just as it was possible to spend a few hours completing the tasks. Student feedback was collected as an interview following engagement with the material. There was some agreement between the participants in the areas such as

Participants raised the issue of technical difficulty that the task created. Although some of the students taking part in testing were not on the 2nd year Mechanical

Engineering course but on other engineering courses. This posed a challenge to assess if the students will be able to complete the 'brief analysis' independently.

Students were very surprised by the specialist terminology used in the material presented, which showed the importance of introducing the external presenters into the modules to offer exposure to these terms.. The online delivery offered the students an opportunity to pause video to search for unknown words and return to it when completed. The vocabulary was specific to water industry and therefore might have caused uncertainty compared to more general one used in the module delivery.

The material was described as clear and easy to follow, however, some participants raised an issue regarding the quality of the recording. This might have been caused by internet bandwidth issues at the student end but as the material was recorded in two separate sessions some inconsistencies between the video were noted such as change to background noise or the size of the font.

The test was limited to self-reporting by the students as to whether the brief and the problem analysis was completed successfully. Each phase of the activity was followed by guidance on which video to watch next. Participants did not report any issues in relation to completing the test or following the advice.

The content of the material was deemed complicated but not above the knowledge delivered in the part of the course. Accuracy of the material was felt to be very relevant to the work.

Participant were very excited about the gamification aspect of the material developed which incentivise progress. Some suggested further development of the concept to improve the interface of the module and to make it more interactive.

4 REFLECTIONS AND CONCLUSION

4.1 Reflections

By creating online content as a series of bite sized linked activities, natural breaks are created which not only aids the learning by affording break and reflection but also reflects the experience in industry.

Often in commercial work a system engineer handles multiple projects simultaneously and while progressing through the workflow, gathers information from stakeholders and while awaiting their response shifting focus elsewhere. The same is possible in this approach, where a task can be paused to ask for further information from the internal (or external) client with the respnse provided by the lecturer or automatically by the VLE after certain period of time. An increase in sophistication of the delivery of the material would also remove one of the drawbacks reported by the students, that is to make videos shorter and smaller tasks to make them more manageable.

It was important not to overcomplicate the questions set to the students, at times a simple 'yes/no' questions as to whether they are able to complete the task at hand was enough to guide a student to next video for the appropriate level. It was also important to introduce an ability for the students to check their answers and to be able to watch any analysis that they might have got wrong in their own attempt, this serves a purpose of bringing the whole cohort to the same level before a new task is introduced.

4.2 Conclusions

The work presented offers a route to embedding authentic industrial content in some of the more academic areas of the teaching curriculum. The exploitation of VLE tools can enable a blended team of academics, industrialists, students and material developers to develop an online learning experience bridging some of the gaps between traditional underpinning academic theory and industrial practice. While the general approach could also be adapted to face to face activity by having the material as an online activity it helps to ensure a degree of industry contact under Covid restricted times. The development of an online package also allows the ability to access material as and when required in future and makes it easier for students to reflect and repeat until confidence is established.

There are however some issues to be aware of. Development of this material takes effort and engagement by academics, industrialists and students on an ongoing basis during the creation process. The use of a specialist developer to help smooth and act as a catalyst has helped but this may not always be available. In addition, while VLE tools are developing and becoming more sophisitcated, some of the more advanced features which might have been developed to allow for example a branching rather than purely linear structure were not possible at this stage.

Despite these issues, the development has been positive and has shown a way to invigorate many traditional underpinning core engineering topics.

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ANALYSIS OF ANALYTICS 2 – STUDENTS' ONLINE ACTIVITY IN INTRODUCTORY PHYSICS COURSE

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Conference Key Areas: *Physics in engineering, Methods, formats and essential elements for online/blended learning*
Keywords: *Continuous assessment, Student activity, Learning analytics*

ABSTRACT

The global pandemic forced universities globally to rapidly change their way of teaching. All possible learning activities had to convert to online off-campus activities. These activities can be synchronous live events or implemented in a way that students can participate asynchronously, for example with the help of videos. Online courses and blended courses have been running for years, so the situation was not completely new one. But how well do we know what students are really doing during the course? In the paper we present students' studying habits concerning asynchronous introductory physics online course on electricity and magnetism. In the course, assessment is based partially on week exams and partially on final exam at the end. The studying in the course is based mainly on video material delivered in Moodle. The data used in this research is based on the log files on Moodle and the assessment data of the course. Similar research has been implemented in the same University in 2014 in a blended course. The interesting questions rising are:

1. How did the students' activity change during the course overall?
2. How does the video watching activity vary according to the course timeline?
3. How does students' final grade correspond to video watching activity?
4. Has the activity changed compared to previous blended course?

Results show that watching activity is concentrated close to assessed week exams. There is also a strong relation between watching activity and students' final grades.

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1 INTRODUCTION

The global pandemic situation forced the whole higher education to transfer into distance learning during 2020. However, there were a lot of experience for implementing successful online teaching and learning beforehand. Experience from online pioneers were very important when all possible teaching was forced to transfer into online mode. There was no time to prepare a well-manuscripted video arsenal for every course in an emergency situation. A typical solution was, for example, transferring the lectures to a virtual environment as synchronous online teaching. If necessary video material was available or made during the course, asynchronous online learning was also possible.

In Tampere University of Applied Sciences, introductory physics theory courses have been delivered on both, blended and online since 2014. Course outlines and study methods have been presented in SEFI conference in 2014 [1]. Online courses are asynchronous but scheduled in weekly level rhythmed by week-exams and measurement assignments that have 50 % weight in the final assessment. In this kind of asynchronous learning we are not able to observe students' activity directly like in lectures. It can be observed indirectly with using LMS's (Moodle) log data or students' voluntary weekly announcements of their activity. [2]

Compared to traditional f2f courses, online students study isolated from other students, if the pedagogical manuscript doesn't allow them to work in groups. In this way, students may feel disengaged and the dropout rate may rise higher than in traditional courses. Experiences from MOOCs show that the dropout rate in online courses may rise even up to 90 % [3]. On the other hand, a study by Doggett shows that students prefer more individual assignments than group work [4]. However, activating methods and working with peers have a positive impact on students learning.[5]

2 METHODOLOGY

The data used in this article is based on the learning outcomes and student activity data of two similar implementations, (later "A" and "B"), of engineering physics course "Electrostatics and Electric Circuits, Magnetism". Both implementations were fully online and lasted 10 weeks including the re-examinations after the final exams. The total number of students in this study is 90.

The course contents and assignments were delivered in Moodle. Course structure is described in Fig. 1. The study material included 42 short theory video clips and 58 problem solution videos. All assignments were in Moodle and they served as the basis for continuous, weekly assessment of the course. The short weekly exams and measurement assignments had 50 % weight in the final assessment, whereas final exam had the rest 50 %. Because the contents were largely delivered in video format, the average number of video watches per student and its relation to learning outcomes is an interesting aspect of the data.

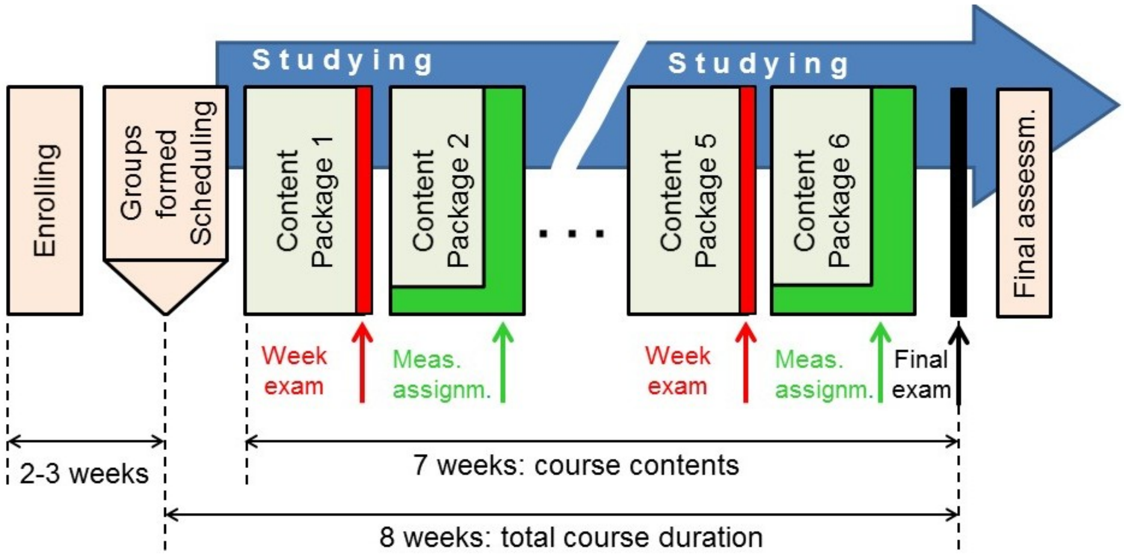

Fig. 1. Online course structure.

Moodle log file stores the learner activity that takes place at the main page level in Moodle. Therefore, the course was constructed in such a way that time-stamp data was stored of all meaningful student actions in Moodle, such as opening a video or reading an assignment. The log file was analysed after the course implementations.

Students' success in the course is described with the final grades after the assessment. The distribution of final grades is shown in Table 1.

Table 1. Students' final grades

	Implementation "A"	Implementation "B"
Dropped out	12	10
Fail	5	6
Pass, grade 1 (lowest)	8	3
Pass, grade 2	10	7
Pass, grade 3	7	6
Pass, grade 4	4	5
Pass, grade 5 (highest)	4	3

3 RESULTS

3.1 Temporal distribution of student activity

The daily distribution of students' activity on both course implementations are presented in figure 2. Both distributions have similar structure: the spikes represent days of some assessed assignment, either a week exam or a measurement assignment. On the "B" implementation the activity is somewhat more spread out in comparison to the implementation "A", which distribution is spikier. However, there are no statistically significant differences in the learning outcomes of the two groups and therefore this difference is not discussed further. The highest peak at the end of the course is the final exam. Seemingly, the assessment has a very strong effect on students' time usage and therefore we recommend a continuous assessment method, which helps the students to distribute their workload more evenly throughout of the course.

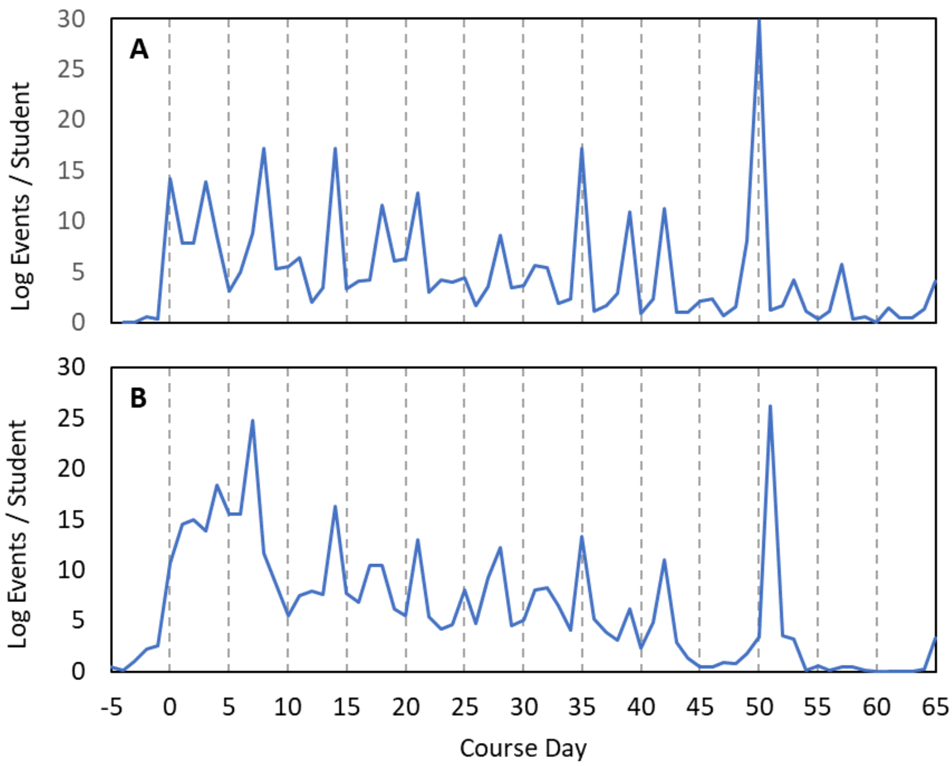

Fig. 2. Daily sum of log events per student for two different course implementations.

3.2 Activity distributions

Student activity and engagement is naturally essential for learning. The distributions of number of log events (A) and number of video watches (B) are presented for each learning outcome category in Figure 3 for all students of both course implementations. Clearly, there is a positive correlation between activity and final grade up to grade 4. The same applies also to number of video watches and final grade. However, it seems that those students who got the highest grade (5) didn't need to be so active or watch as many videos as those who got grade 4. The best students in the group either learn faster, have a better prior knowledge, or have more confidence in themselves. Whichever is the explanation, this finding is in good correlation with our earlier study [2]. Another interesting observation is that those students who dropped out of the course didn't even start to study. Most of them (77%) have zero or almost zero interaction with the material. Thus, dropping out seems to be caused rather by some other life conditions, not due to too difficult course contents or course arrangements.

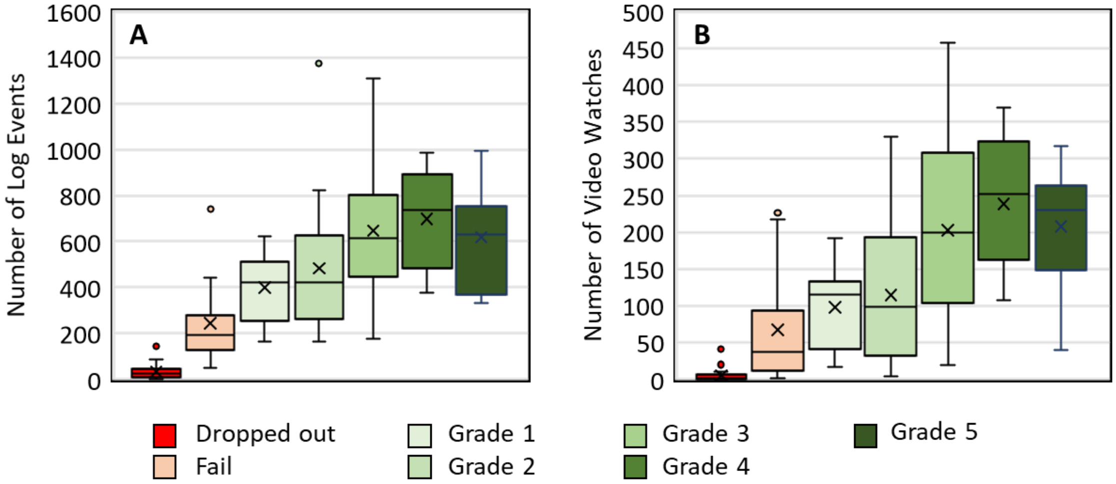

Fig. 3. Distribution of number of log events (A) and number of video watches (B) per student in different final grade categories.

To investigate the students studying behaviour further, weekly cumulative sum of log events in different final grade categories was calculated. This is presented in Figure 4. Clearly, those who dropped out, stopped studying after the first or second week. And as mentioned earlier, most of them didn't even start to study. The activity graph shows that studying pays off: the higher the activity the better the final grade. This applies to grades from fail to 2. The higher grades (3-5) all have rather similar activity which is higher than that of those of lower grades. Again, the data shows that the best students succeeded with somewhat lower activity than those who got 3 or 4. This may be a result from students' earlier studies in physics, because the course contents was introductory electricity and magnetism.

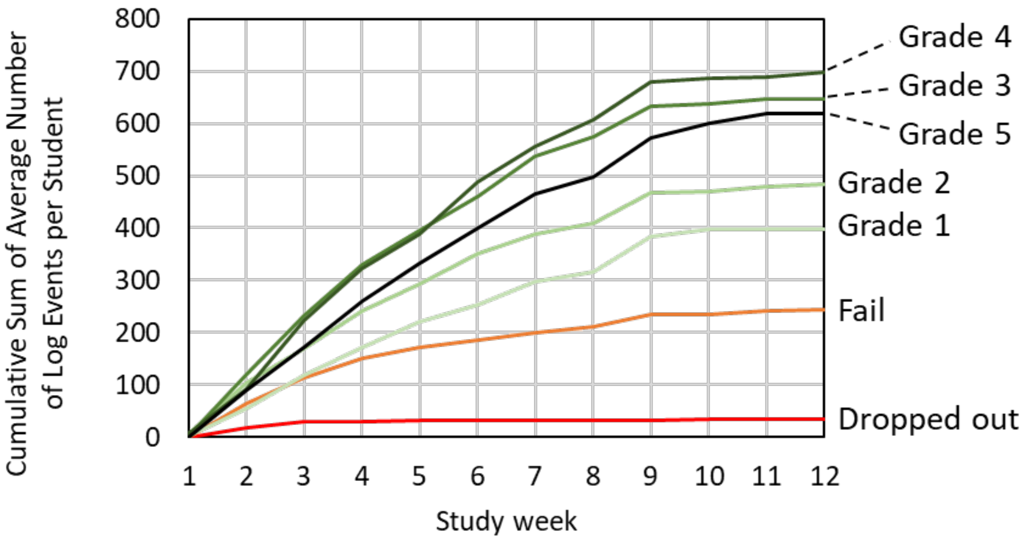

Fig. 4. Weekly cumulative sum of log events in different final grade categories.

A similar analysis was made in a blended introductory physics course in the same university of applied sciences in 2014. The results presented are well in line with previous results from blended course [2]. The figure of the video watching activity (largest part of the log events) with different final grades in the earlier blended course (2014) is presented in Fig. 5.

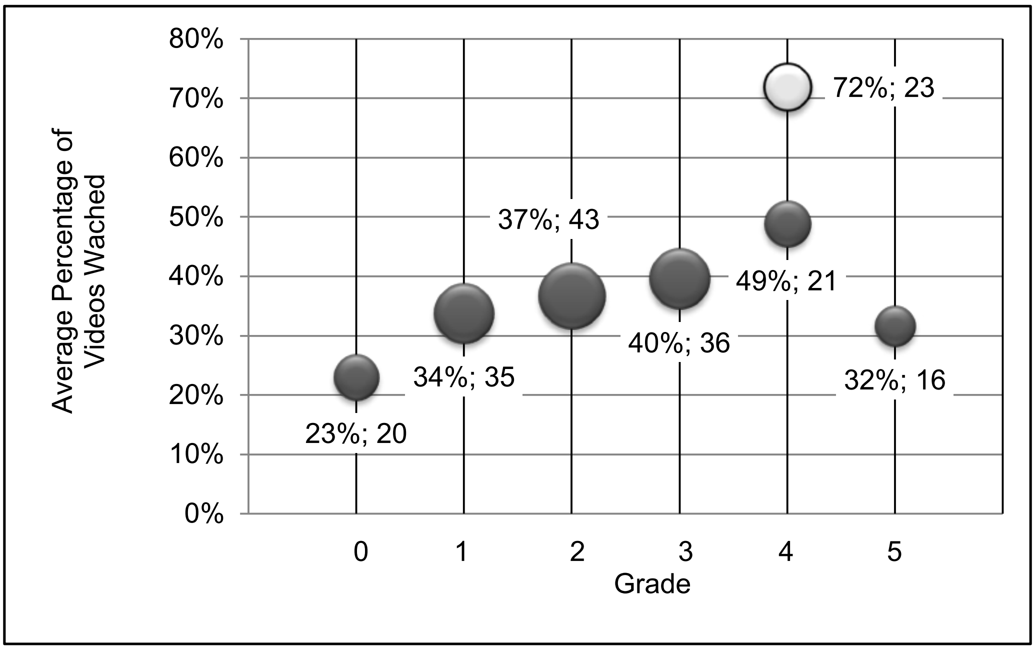

Fig. 5. Average percentage of videos watched in different final exam grade categories. The bubble size presents number of students at that category. Data labels contain the viewing percentage and number of students [2]

4 SUMMARY

According to study, it can be said that students' activity is a good predictor for success, which is obvious. Even though at higher grades, activity is not the only predictor. One solution to increase students' activity is to use continuous assessment throughout the course, because the assessment strongly directs students' behaviour. Question that remains is how we as teachers manage to attract and activate those students, who drop out the course in the early stage, to start and maintain their interest in active studying.

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STUDIFICATION – PROCEDURES TO FORMALIZE OUTSIDE CAMPUS INFORMAL LEARNING

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ABSTRACT

Today, students enter universities with more varied backgrounds than before. During their studies, they may work actively and take part in different societal activities. These activities can develop competencies that are already included in their academic curriculum. Studifying work or societal activity means recognizing and utilizing this competence development as a part of learning. In this way, several advantages are found. For example, study times are shortened, learning environments are widened and self-regulation skills are developed while students will be more and more owners of their learning processes. Studification is the next step after recognizing prior learning. It can have a significant role in the current pandemic and future post-pandemic situation, where we need to find alternative ways to study.

Studification of work or similar activity is not easy. It requires well-defined processes and procedures. Curriculums must be competence-based so that the learning outcomes from work fit with competence-based assessment criteria. It also requires a change in the learning atmosphere among the teachers, organizational leaders, and students. Leadership must support the new ways to study, and finally, students must be ready for active learning ownership.

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1 INTRODUCTION

The current COVID-19 pandemic forces us to look for new ways of teaching and learning in HE from a resilient perspective. Resilience can be understood as an ability or competence to overcome a change caused by a disturbance, shock or stress [1]. Covid-19 forced educational institutions to re-check their bases for learning possibilities. The situation forced us to see the curricula via new eyes. Restrictions and regulations limit the number of people gathering in lectures or labs. Traditional theoretical lectures are transferable into an online format to Zoom or Teams, but there are other ways to help our students learn and assess it. One possibility to help students proceed with their studies is to find out the possibilities of learning outside the classrooms: working or taking part in other societal activities. There is a possibility for learning by doing, and new ways to be a teacher. This means that teachers reduce their teaching time and become more like counselors. There is a need for theorizing the outside world learning experiences. That is what we call studification. One crucial point is that studification is not an automatic trick to turn off-campus working hours into ECTS credits. Expected learning outcomes must be at the correct EQF-level and in line with the learning outcomes of the degree students are aiming at. If studification is taught on a broader perspective, it also gives possibilities to include some learning contents that generally are not included in a student's degree. For example, suppose a student is working with robotics, and the contents of robotics are not included in the student's regular curriculum. In that case, studification gives a possibility to tailor the degree contents according to student's competencies and preferences. In this paper, we concentrate on possibilities of studification in EE during the Covid-19 era. We have analyzed reports on studification in the Finnish HE context and empirical data collected from EE at TAMK. In the end, we will show some pros and cons for studification.

2 STUDIFICATION IN GENERAL

Studification is a method (or process) to formalize informal learning that students learn in their outside-campus activities, work, or societal activities. It is always goal-oriented. The goals, the learning outcomes must be in line with the student's curriculum or degree that he/she is aiming at.

Why studification? Globally, there is a need to rethink the ways to promote employment. There is a need for a solid commitment to education and skills. Work and its demands are changing rapidly and bring along a need for upskilling and continuous learning for people who already are in working life. The traditional classroom and time-based learning need to be refreshed towards more resilient learning models to serve this requirement.

For students, studification offers a possibility to shorten the study times and use their work and hobbies as a part of their studies. Students also want to study for life, not for a degree, and that should also be in the interest of universities of applied sciences [2]. Combining work and studies helps students commit to their studies, future profession, and society [3]. As a part of competence-based education, studification offers a possibility to concentrate on studying new things, not on those already mastered.

In the Finnish context, there is a trend that students are working more and more besides their studies: 50-60 % of HE students work at the same time they study, and the average working hours are 15-24 hours per week [4]. Vanhanen-Nuutinen et al. found it as a double-edged sword: if working is too demanding, it takes energy and time from studies, but if the demands fit well with the content of the studies, working is found as a source for study motivation and learning, and this point of view should be utilized more while organizing studies.

3 PREREQUISITES FOR SUCCESSFUL STUDIFICATION

There are three prerequisites needed to make studification possible: supportive and guiding teacher, self-regulated student, and well-defined organizational processes.

The teacher needs to know the curriculum and assessment criteria profoundly; he/she needs to know the working-life and how to combine it with studies or study modules. The main task for a teacher in the studification process could be that he/she will offer the possibility for students to study outside the campus and classrooms. This means that teacher is able to see the possibilities to learn in working-life and in societal activities. There is also a need to guide students in their studies, offer and show them possibilities. "The guiding/counseling teachership" could be the synonym for a modern way to be a teacher. Teachers' work in current vocational and higher education is very fragmented: in studying recent reports or researchers among vocational teachers, 53 separate skills were identified. Anyway, they could be summarized in three main categories: scholarship in teaching and learning, scholarship in authentic learning and development, and scholarship in evaluation and monitoring [5]. In studification, teachers need all these: understanding the possibilities of authentic learning and evaluating it plays a central role in successful studification.

The second essential part is the student and his/her willingness to study alternatively. This willingness has to do with both self-regulation and self-efficacy. Students are maybe not born self-regulated but can be taught to be: [6] have noticed in their study in the Finnish teaching context that students can learn to be self-regulated if they have the possibility for that. There is still a trend among students that they also want to learn traditionally: they want to be taught. This students' trend means that the competence of teachers is needed to make the learning shift happen [7]. In the review of 108 self-regulated learning articles, self-regulated learning (SRL) concerns students that actively take command of their learning. Researchers in this review share the opinion that SRL is linked to academic success. SRL has become much more critical for students to complete their education: students need to see learning goals and their benefits. The core of the SRL can be found to achieve learning goals [8] and its ability to help survive, for example, in the information jungle.

This all is embedded in the educational context. The procedures, well-defined or not, play a remarkable role in the successful studification. Prerequisites for the education organization are willingness for studification, competence-based curriculum, competence-based assessment criteria (competence-based thinking overall), and the processes and procedures to implement studification.

The willingness means that the educational organization recognizes that working-life is a learning environment that can produce university-level learning outcomes if the process is appropriate. University staff must also be committed to the idea and the process. University's curricula and assessment criteria must be competence-based. The targeted competencies are easy to transfer and modify into working-life context and recognizable by a student who wants to start the process. The process itself needs well-defined procedures to succeed. Procedures help to maintain the quality that is required in HE.

4 BASIC MODEL FOR STUDIFICATION AND EXAMPLES

4.1 The basic model of studification

The basic model for studification is presented in fig. 1. It was presented in Verkkovirta-project [9] in 2017.

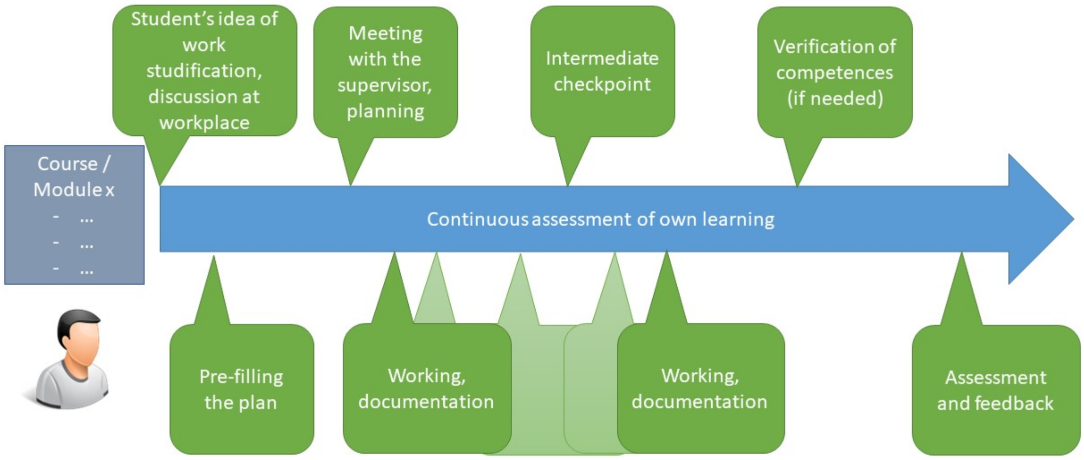

Fig. 1. Basic model for studification [9] modified

The initiative for studification always comes from a student. This student works or has such a societal activity that develops competencies that are included in his/her curriculum. He/she must know the curriculum and the activity so well that competencies are identifiable on both. Of course, the curriculum must be competence-based. After the initiative student makes a plan for studification, which a supervisor from the university approves. In approval of the plan, goals and the methods to verify that the goals are reached are agreed upon. During the work or activity, the student carefully documents the development. After the work or activity period, there is a possibility to verify the learning if needed. At the end, there is a time for assessment and feedback.

It is essential to admit that some parts of an engineering degree are easier to studify than others. If the engineering curriculum is very content-oriented or if the skills targeted are very theoretical, it may be difficult for a student to find content for studification. If there are some meta-skills or common skills written in the curriculum, they are more accessible to studify. For example, the theoretical basis of engineering degree, mathematics, and physics are challenging to studify in working life. Still, study modules that include more practical things like engineering design, planning, and customer relations, are more accessible.

Studification is also an essential tool for continuing education. Suppose curricula are written in competence-based, and they are read and interpreted resiliently. In that case, some more significant parts of curricula can be replaced by a various, but equal level professional or academic competence that student has gathered in his/her earlier working life.

4.2 Some examples of studification in engineering

One concrete example of studification is described in mechanical engineering [10]. A student can carry out extra practical training (30 credits) in addition to the standard 30 credits training. A student may utilize the competencies gathered in his/her workplace and add this content to his/her degree. Studification at Tampere university of applied sciences offers students a way to personalize their study plans. A student may present a study module that he/she would like to study via studification: the student's self-regulation is needed because it is his/her task to suggest how to study the module. The study module can be something else that is taught at the university, but the student can study it while working.

For example, the Tampere University of Applied science contacted a student who has not been active with his studies for a year. The student had completed his thesis. He still has 30 credit points left to complete his studies. The discussion with the student revealed that the company was planning to implement a new PHP framework for their programmers. Tampere University of Applied science proposed using the studification option for this implementation work. It was proposed that the student write a learning diary to deepen his expertise of the system and its programming tools while working on a programming project. It was also proposed to this student that he could increase his understanding of cash flow management and liquidity. His programming work embraces these topics strongly. This approach could improve this student's programming work with these topics' specifications. Learning diary should include reflection on articles and blogs. We believe that this student could his expertise and learn to improve new meta-skills, e.g., learning to learn.

All work can be helpful in learning skills needed in life and in society. In every work, there is a possibility to learn at work so-called meta-skills that are useful in all branches. Some students argue that it is also helpful to work in other areas that the study field [4]. In Eurostudent study, it was recognized that the best hits for working and studying were in social & health care and tourism fields. In technical branches, the students worked less than in other fields, but they worked more hours than others. Student experience also says that

By combining work to studies, they could identify some phenomena that were not considered in the studies [4].

But of course, all jobs are not helpful for all studies. Sometimes work is just for work, something to add to cv. Maybe an engineering student in a supermarket as a salesperson is not learning for studies but life.

5 CONCLUSIONS

Studification can be seen as a new, different method for students to study and learn. At the Tampere University of Applied Science, the teachers feel that studification in a single course for a single student is laborious. Therefore, the teachers promote the idea to accept a large set of studies as a result of the studification process. It also offers teachers ways to see their work and update it. It has several pros and cons depending on the point of view. They are presented in Table 1.

Table 1. Pros and cons detected

	Pros	Cons
University	• Shortened study times • Increased student orientedness • Closer relations to working life for teachers • Possibility for variations in degree contents – working life-oriented curriculums	• Ineffective compared to traditional lecturing • Requires deeper understanding of working life • Needs time and especially interest to personalize student's paths
Student	• Shortened study times • Richness in study methods • Combining studying and working • Stronger relation between theory and practice • Possibility for variations in degree contents	• May need more time compared to traditional methods • Not possible for every content • Needs self-regulation skills

The essential advantage of studification concerns the possibility to re-educate academic people who have already been working for years. A rapid change in working life and technology leads to massive needs for continuous education, leading to university degrees or perhaps some smaller but well-defined and recognized academic certificates. One of the teachers emphasizes as follows: "Working life can enable the emergence of skills that are not included in the curriculum, but which are nevertheless key skills in the field."

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ENVIRONMENTAL ENGINEERING UNDERGRADUATE DISSERTATION WORK DURING THE COVID-19 PANDEMIC

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Conference Key Areas: *Methods, formats and essential elements for online/blended learning, Changes beyond Covid-19*
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ABSTRACT

The dissertation has been widely recognised as an important component of the engineering bachelor's degrees. However, undergraduates' lack of prior research exposure and acquisition of the necessary research skills can be exacerbated by the COVID-19 pandemic. This research analysed the influence of COVID-19 on the undergraduate dissertation of an Environmental Engineering programme at one university in the UK. A mixed-methods approach, a combination of quantitative and qualitative methods, was applied to understand the process of engineering students' dissertation work and their mental health during the pandemic. The results show that approximately 28.13% of the students thought the pandemic largely or very largely impacted their dissertations. In addition, 29.69% of the students thought COVID-19 had largely or very largely impacted their mental health. Notably, more female students (34.88%) considered that the pandemic had largely or very largely impacted their mental health. Around 24.14% - 37.50% of students with first or second grades thought COVID-19 had large or very large impacts on their dissertations. Nearly 50% of students with first grades and 37.5% of students with lower second grades considered the pandemic had largely or very largely impacted their mental health. The interviews indicated that the pandemic caused more anxiety, sleep disorders, and other mental health issues among students. This research sheds light on the challenges faced by Environmental Engineering undergraduates during the pandemic. In addition to academic support for engineering students, mental health is indispensable for them, particularly for girls and students with special educational needs, during the pandemic.

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1 INTRODUCTION

The dissertation or research project is an important component of the pedagogy for engineering undergraduate students [1]. Working for nearly one year, students are equipped with various skills, including collecting samples, analysing data, and writing reports. For some Engineering programmes, such as Environmental Engineering, most students are often involved with field sampling and laboratory work. Different from postgraduates, undergraduate students often have limited research experience before their dissertations. One of the critical changes of engineering students that are quickly required is to transfer from directed study in large classrooms to independent research under the advice of a supervisor. Most engineering undergraduates encounter enormous difficulties throughout changes from coursework learning to independent research. The inadequacy of research training and acquisition of required skills can be exacerbated by education disruption, such as the COVID-19 pandemic.

Studies on undergraduate dissertations indicate that students valued supervisors' support and the increased autonomy, but they also struggled with data collection and time management during the whole dissertation period [2]. Many students would like more supervision, and a survey suggested that around one-third of students are not satisfied with the supervision they obtain [3]. Although there are many studies on postgraduate dissertations, the lessons learned from these studies cannot directly transfer to undergraduate dissertations due to no or very limited research experience, lower research interest, and a shorter timeframe to complete the dissertation [4].

The COVID-19 pandemic has produced an unprecedented disruption of global education. It is estimated that around 1.6 billion learners have been affected globally [5]. Over 94% of the world's students have been impacted by the closures of universities and other learning spaces. Restrictive movement and social distancing policies have brought massive disturbances to the traditional educational system. Clearly, new educational and assessment strategies are required during the pandemic, even after.

Remote and online learning, or hybrid education in certain periods or some areas have become a remedy for this unprecedented COVID-19 pandemic. However, the rapid change from traditional face-to-face education to online education is huge challenge for both teachers and students, called "Crisis distance education" [6]. Universities and teachers have taken "Education in Emergency" strategies through numerous online platforms, for example, Blackboard, Microsoft Teams, Google Classroom, and others. Teachers and students have to adapt to the new technology and changes quickly, while their adaptation needs to be supported and gauged carefully. Researchers have highlighted the large challenges for the education sector during the pandemic, for example, the poor online education infrastructure, teachers' inadequate exposure to online instruction, and non-conducive home environment for learning [5].

Notably, university students' mental health has received increasing attention. In this research, I adopted the World Health Organization definition "*Mental health is a state* *of well-being in which an individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and is able to make a contribution to his or her community*" [7]. Having good mental health means that students are able to think, feel, and act the way that the students want and need to live their lives; students with poor mental health might find it difficult, or even impossible, to cope with the way they regularly think, feel and act. Mental illness can largely influence students' motivation, concentration, and social communication, which are all important factors for students' success. Worse, the COVID-19 pandemic can exacerbate the mental health damage to this vulnerable group. A recent review reported the mental health damages by the pandemic, for example, the anxiety of virus infection, frustration during quarantine and lockdown period, depression, sleep disorder, stigma, and others [8].

However, the impact of the COVID-19 on Engineering students' dissertation has not yet been explored. Based on the "Crisis distance education" theory [6], this study used a mixed-methods approach (questionnaire and interview) to analyse Environmental Engineering students' dissertations during the pandemic. The overall research question is "How did the COVID-19 impact environmental engineering students' dissertation work and mental health". The main aims of the research are to 1) evaluate the impact of COVID-19 on students' dissertation; and 2) estimate the influence of COVID-19 on students' mental health. The findings will be useful for universities and instructors to understand students' challenges during conducting dissertation in the COVID-19 pandemic. The findings will have immediate implications for developing new measures to support students during conducting dissertations in the ongoing pandemic and future crisis periods in Europe and other regions.

2 METHODOLOGY

This research applied a mixed-methods approach, a combination of quantitative and qualitative methods [9]. An online questionnaire survey was carried out to understand engineering students' experiences of conducting dissertations. The questionnaire is composed of 10 questions, including students' opinions of the impact of COVID-19 on their dissertation and mental health. Students' backgrounds, including gender and academic grades (First, Upper Second, Lower Second, Third, and Fail), were also surveyed.

The semi-standardized interviews were performed to produce a micro-level view of students' experience of conducting dissertations. In total, 12 students were recruited via purposeful and voluntary sampling. Interviews were recorded and transcribed for thematic analysis [9].

This research is subject to ethical review in conformity with the standards established by the Research Ethics Committee, University of Reading, and has been allowed to proceed.

3 RESULTS

3.1 Questionnaire results

In total, 64 Environmental Engineering students participated in the survey, including 21 male and 43 female students. In terms of their opinions of the impact of COVID-19 on dissertations, less than half of students (43.75%) thought there was a small impact of COVID-19 on their dissertations, but 28.13% of students thought there were large or very large impacts on their dissertations (*Figure 1*). In general, male and female students shared similar opinions of the impact of COVID-19 on their dissertation projects. Notably, more female students (13.95%) than male students (9.52%) considered the pandemic had very largely impacted their dissertations.

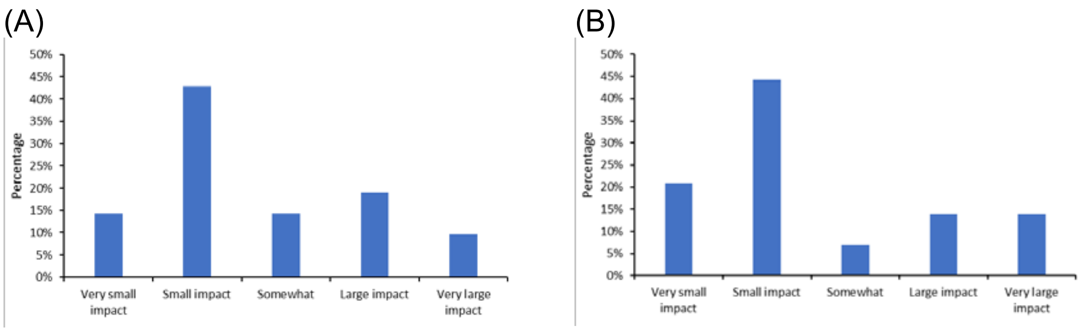

Figure 1. How has the COVID-19 pandemic affected your dissertation project? (A) is male and (B) is female students.

Regarding students' options of the impact of COVID-19 on their mental health, 53.13% of the participants thought the COVID-19 had small or very small impacts on their mental health, while 29.69% of the students thought their mental health had been largely or very largely impacted by COVID-19. It is worth mentioning that more female students (34.88%) than male students (19.04%) considered that their mental health had been largely or very largely impacted by the pandemic (*Figure 2*).

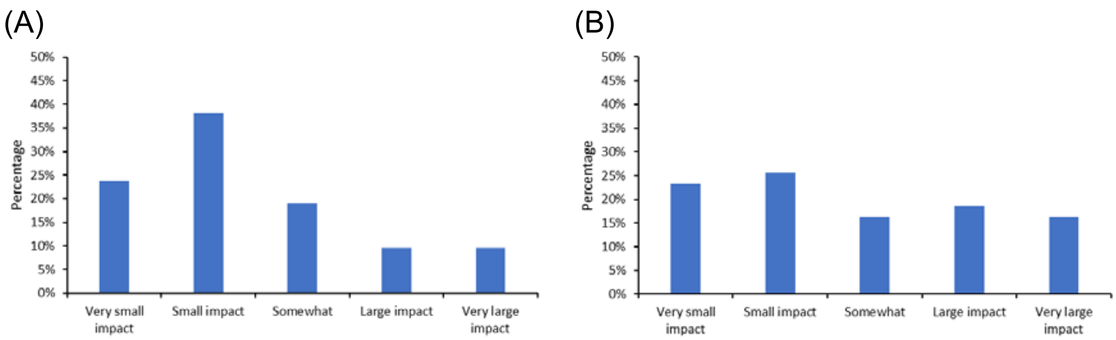

Figure 2. How has the COVID-19 pandemic affected your mental health? (A) is male and (B) is female students.

Students with different grades had various opinions of the impact of COVID-19 on their dissertations. Obviously, 24.14% - 37.50% of students with the first or second grades thought COVID-19 had large or very large impacts on their dissertations (*Figure 3*). However, students with the third or fail grades only thought small or very small impacts of COVID-19 on their dissertations.

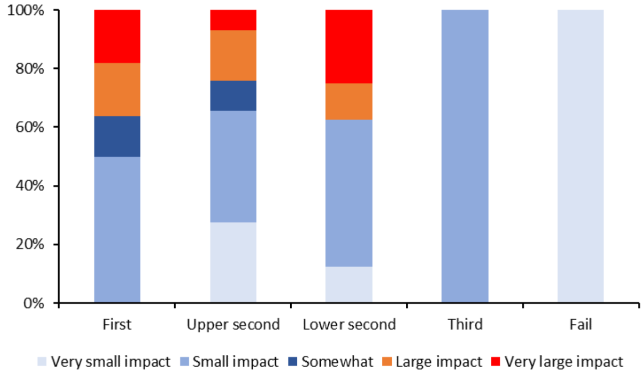

Figure 3. Students' opinions of the impact of the COVID-19 pandemic on their dissertation versus students' grades.

There are also differences in students' opinion of the impact of COVID-19 on their mental health between students with various grades (*Figure 4*). Nearly 50% of students with the first grades and 37.5% of students with lower second grades considered the pandemic had very largely or largely impacted their mental health. All students with the third grade thought COVID-19 had a large impact on their mental health, but the student with fail considered only small or very small impact of the pandemic on their mental health.

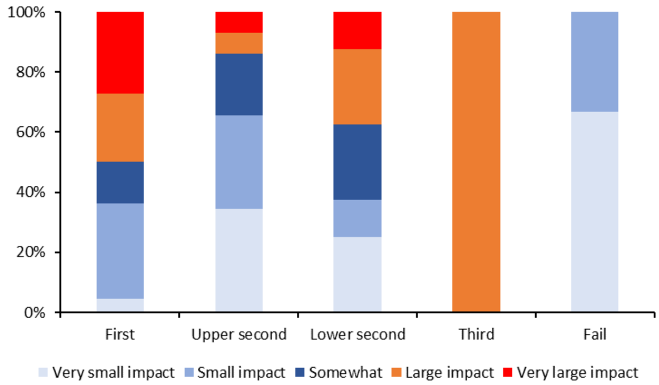

Figure 4. Students' opinions of the impact of the COVID-19 pandemic on their mental health versus students' grades.

3.2 Interview results

We have interviewed 12 students about their study and research experience when doing the dissertation projects. Obviously, students emphasized the large impact of COVID-19 on their dissertations. Several students elaborated on their mental health issues, although sometimes they have not yet realized them.

1) A difficult journey during the pandemic

Most students felt it very difficult to do the dissertation due to various restrictions by pandemic, and the most obvious one is the challenges to do field sampling.

However, many Environmental Engineering students would like to do fieldwork. One student clearly commented:

I prefer to go sampling in the field.

Without sufficient research training, many students felt dissertation is difficult. One student exemplified this by the struggling of data analysis:

I think it is quite difficult. I do not really know how to analyse the data.

One student described a desperate situation as follows:

I feel it was extremely hard to do a dissertation. I felt like I was going to burn out.

2) Large mental health damage to some students

In the interviews, some students addressed apparent mental health issues, such as anxiety commented by one student as follows:

During the year, I am often very anxious and stressed because there's still so much knowledge I don't know, so much analysis I have not done, and I get very worried about the results.

Sleep disorder was also mentioned by some students. They found it very difficult to fall asleep and wake up much earlier than they normally do, called insomnia. For example, one student commented:

I sleep less than other people. I sleep six or five hours a day, maybe even less. I just cannot sleep.

4 DISCUSSION

4.1 More academic support for engineering students' dissertations during the pandemic

"Crisis distance education" theory [6] emphasized the suddenness, imposition, and medical emergencies for the education sector during the pandemic. The current survey and interview results are in good agreement with the theory. During the pandemic, students generally felt more difficult to complete the dissertations, for example, restriction to field for collecting first-hand data and struggles with data analysis which were emphasized by several interviewees. Previous studies have confirmed the importance of supervisors' support and students' autonomy in such a difficult time [10]. To help students conduct dissertation research, students in this researched University have been provided with more secondary data analysis training, such as collecting and analysing data from Environmental Agency. Instead of field and laboratory work, some students adopted online questionnaires and interview projects, and more training on data collection and analysis of surveys and interviews was also provided. The University also introduced the Circumstances Impact Process (CIP) to minimise any anxiety and academic disadvantage caused by the COVID-19 pandemic, as part of a series of measures to support students in the COVID-19 pandemic. Despite such support, some students still experience challenges when conducting dissertation projects in this pandemic, as shown in Figures 1-4.

In particular, supervisors need to offer clear and directed advice, inspire and support students' confidence, and foster student independence and development. To obtain secondary data for conducting dissertations, supervisors need to help students explore more secondary data sources. Some analyses of secondary data, for example, statistical analysis and modelling, are usually not taught before, and thus more supports are also needed from supervisors.

According to the survey results (Figure 2), more girls (34.88%) than boys (19.04%) thought the pandemic had largely or very largely affected their mental health. Because 67.19% of respondents are girls, the resurvey results may be biased. However, it at least indicates that more support is needed for female students to prevent and alleviate their mental health issues during the pandemic. In addition, students with special educational needs suffered more challenges in the pandemic. Therefore, there is a requirement for providing more time and resources to explore the best alternatives for the special educational needs of these students.

4.2 Support engineering students' mental health during the pandemic

It is important to check the well-being of students during the pandemic and effective measures are taken to minimise the damage of pandemic on students' study and their health, including mental health. This survey showed that 29.69% of the students thought COVID-19 had largely or very largely impacted their mental health and the proportion is even higher for girls (34.88%) (Figure 2). Most students mentioned that they have tried to deal with anxiety, sleep disorder, and other mental health issues, mainly by distracting themselves by entertaining, such as watching videos or doing other tasks. The university provides the tele-counselling, but the students with mental health issues had rarely or never used the counselling services in the VOVID-19 pandemic. Some researchers have ascribed it to not being perceived as severe enough to seek professional counselling, not comfortable engaging with unfamiliar people, and little trust in the counselling services [11].

Clearly, more vigilance and support are needed to help these students, especially those are suffering some mental health damages while they may have not yet realized the impacts and consequences. Our interviews suggest that students preferred self-management. This should be encouraged, but it is clearly insufficient. With the development of telehealth applications and digital technologies, it is promising to enable more self-management of mental health problems. More importantly, students should take adaptive coping, for example, acceptance and proactive behaviours. It is also important to identify students' coping behaviour for informing the support systems. For instance, the participatory models of intervention development can be applied. By engaging with the target individuals, psychologists can adapt interventional programs to students' specific contexts.

4.3 Limitation and future research

Similar to most studies, the results of the current research should be applied in light of the study limitations. This study can be bias by the research sample sizes and the imbalanced gender ratio of the survey participants. However, it is convinced that students' difficulties and mental health issues during the pandemic illustrated in the current study have broader relevance throughout engineering education. Future work should expand the sample size and recruit more engineering students to the study. Further exploration of students' difficulties in each stage of conducting dissertations (selecting research topics, designing research methods, collecting and analysing data, and writing) is also warranted.

5 CONCLUSIONS

The unprecedented COVID-19 pandemic has brought massive negative impacts on higher education. The questionnaire results indicated approximately 28.13% of the students thought the pandemic had largely or very largely impacted their dissertations and 29.69% of the students thought COVID-19 has largely or very largely impacted their mental health. The interviews also suggested the large mental health damages, for example, anxiety and sleep disorder, during the pandemic. The findings of this study highlight the importance of developing interventions and preventive strategies to address the difficulties and mental health of engineering students.

ACKNOWLEDGEMENTS

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Short Papers

ordered alphabetically
by first author

DAYBYDAY: A CONTINUOUS ENGAGEMENT FOR BETTER LEARNING IN A FIRST-YEAR MATHEMATICAL COURSE

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Conference Key Areas: *Mathematics in engineering, Methods, formats and essential elements for online/blended learning*
Keywords: *first-year mathematical course; transversal skill; peer-to-peer learning; educational experience*

ABSTRACT

This study describes the DayByDay project that aims to support the students' understanding of a first-year mathematical course through a continuous engagement in large classes (250 students). Students are weekly suggested to do various activities throughout the semester, either alone or in a group.

Thanks to the DayByDay project, they receive support to structure their study to understand the lessons' content and self-evaluate their knowledge. The main activities proposed are individual multiple-choice tests and exercises to be solved and cross corrected in groups. Peer-to-peer support becomes even more critical in the pandemic condition in which distance learning changed traditional face-to-face interactions.

The experimentation has been randomly applied to 7 of the 20 parallel mathematical courses at Politecnico di Torino, Italy. Thanks to the randomized control group design, the project impact has been analyzed in terms of self-awareness of the student's preparation and the final grade.

The educational experience proposed to students improved technical competence and overall professional competence in problem-solving, collaborative work, time management and organization, creativity and critical thinking.

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1 INTRODUCTION

Arriving at the university, students perceive a big jump in the content and methodological approach compared to the high-school context [1]. This shift translates into a non-homogeneous class with some students who have difficulties remaining on track and decide not to face the exam right at the end of the course [2]. What can be done to support their technical competence and transversal skills with a reasonable effort for the lecturers?

2 CONTEXT

Politecnico di Torino (PoliTo) is an Italian technical university with Engineering and Architectural courses. Considering the engineering bachelor's degrees, the university enrols around 5000 students every year. During the first year, they are divided into 20 parallel classes of about 250 each. The subjects are not related to the degree chosen and cover all the basics science courses (Chemistry, Computer Science, Mathematical Analysis I, Linear Algebra and Geometry, Physics I and an elective one). The academic year (a.y.) is divided into two semesters of 14 weeks characterized, in the first year, by three subjects each. Although different lecturers teach them, all the parallel courses have a standard syllabus and the same assessment. Typically, the evaluation consists of an exam at the end of the course covering the entire program. Students can choose when to do the exam between four calls: two calls right after the classes end (called "first session"), one at the end of the other semester, and one in September. Students pass the exam if the score is higher than 18/30 and the maximum obtainable score is 30/30.

The role of the introductory science courses is not limited to a pure knowledge transfer but represent a preliminary approach to science. As a secondary goal, they have a reinforcement of many soft skills required by engineering studies. In particular, the Mathematical Analysis' course consists of 60 hours of lectures and 40 hours of exercise classes. Theoretical lessons are devoted to presenting the topics, with definitions, theorems, examples, properties and proofs, which are believed to facilitate the learning process and the students' metacognition. Every theoretical aspect is associated with introductory examples. The exercise hours aim to gain an adequate ability in computation.

Consistent with the literature, the shift between the high school teaching style and the university represents a first challenge for the students. Some of them find it hard to organize their time properly and to remain on track. The COVID-19 pandemic condition has even stressed these difficulties.

For all these reasons, the Mathematical Analysis' lecturers decided to apply a course revision through an ADDIE cycle [3]. The new strategy requires a revised assessment structure. Until a.y. 2019/20 consisted of a multiple-choice test with 20 questions followed by a written exam with two structured problems and a not mandatory oral exam. The test lasts one hour and takes place in a computer lab. Each correct answer is worth one point, and the wrong answers do not give any penalty. If the score is less than 12, then the exam is failed; otherwise, the student proceeds with the written exam.

The written part lasts 75 minutes, and the maximum achievable score is 13. If the score is less than 5, then the exam is failed; otherwise, the final score of the exam is obtained as the sum of the scores of the test and the written part, unless the teacher (or the student, provided that the final score is at least 18) requires an oral examination. The significant change in a.y. 2020/21 is the introduction of "ongoing activities". These require the active participation of the student during the semester. Each lecturer details the ongoing activities; they include, for example, answering self-assessment tests and solving exercises to be delivered according to methods and deadlines announced at the beginning of the course. The maximum score is 3. The test has been curtailed, and it consists of 15 multiple-choice quizzes in 45 minutes with a proctoring system (Respondus). Each question is worth one point, so that the maximum achievable score is 15. If the score is less than 8, the exam is failed; otherwise, the student proceeds with the written exam. The written exam still consists of 2 structured exercises, but the maximum achievable score is 15. If the score is less than 8, the exam is failed; otherwise, the final score of the exam is obtained as the sum of the scores of the ongoing activities, the test and the written part, unless an oral examination is required.

This study describes the ongoing activities methodology, called the "DayByDay project", adopted by a cluster of 7 of the 20 parallel mathematical courses. It aims to support the students' understanding of a first-year mathematical course through a continuous engagement in large classes (250 students).

3 METHODOLOGICAL APPROACH

Under the post-positivism quarry, this research evaluates the DayByDay project's methodology using a randomized control trial (RCT) design. The RCT suits this purpose perfectly as it allows us to study the impact of the intervention that is the newly adopted methodology on ongoing activities.

In a.y. 2019/20, a pilot qualitative study was run to support the development of the project. This study involved only one of the twenty parallel courses with about 60 over 250 students. Participation was voluntary, and students did not receive any additional points for the final exam. Those who joined received a detailed study program and the opportunity to take an online quiz weekly. If the quiz was not completed within a week, the student received an email reminder. At the end of the semester, we analyzed the data relating to the weekly quizzes and the exam outcome. We observed how the majority of the voluntary students got hooked by passing the exam in the winter session with this pilot.

Thanks to this experience, the structured DayByDay project has been designed as a possible way to include the "ongoing activities" inside the newly revised course in a.y. 2020/21. Seven out of twenty courses decided to adopt it. The other courses, chosen as a control group for this study, adopted more straightforward actions either alone or in smaller clusters. For example, some lecturers decided to have a couple of oral discussions with each student; others organized a monthly quiz while other lecturers had two sets of exercises to solve individually. The most remarkable difference between the experimental and the control group is that, in the first one, the weekly activities required an ongoing study. On the contrary, in the second one, they were typically individual and monthly; therefore, the students' effort was more discontinuous.

Three tutors were available to support the extra load related to the ongoing activities organization and implementation. One of them was dedicated to the experimental group, the others to the control group.

The main activities proposed by the DayByDay project are:

1. individual activities: multiple-choice tests (T)
2. group activities: a set of exercises to be solved (E) and peer corrected (EC).

An activity is proposed weekly, repeating the pattern T, E, EC. Students can choose when to fulfil it inside the week starting from the fourth week. All the activities replicate the exam environment: the tests use the same structure and platform, while the exercises are structured like the written part.

The individual activities consist of carrying out four sets of 15 multiple-choice tests to be performed via the Moodle platform. Each test has only one attempt and lasts one hour. At the same time, groups activities consist of carrying out, in collaboration with teammates, three sets of 12 structured exercises and uploading the solution in Moodle. The following week, each team receives another group's solution on the platform and is asked to evaluate it, correct the mistakes, and upload the revised document on Moodle. Students receive a structured layout in which they need to fill the list of people that took part in E and EC and a grid for the exercises' solution. This latter one includes a space for the solution, the peer-to-peer score (zero, one or two points), a space for the peer-to-peer corrections, and the lecturer's grades. The lecturer can confirm or modify the peer-to-peer score associated with the exercise solution and gives one point to the correction if it was acceptable or zero if something was missing or incorrect. Therefore, each group activity receives a score up to 36 (24 for the solution and 12 for the correction).

At the beginning of the course, the teacher organized homogeneous groups of about ten people based on the admission test. That is, we tried to maintain the same average of the entrance test between groups with similar score variance within each group. Each team autonomously choose a spokesman that is responsible for the files upload. In addition, s/he must communicate to the lecturer when they plan to meet for the E and EC activities. Students could decide where to meet, but all meetings were held online due to the pandemic condition. The lecturer could join these meetings to check who participated in these activities and how the load is distributed inside the team. The lecturer played an auditor role and did not intervene in any way in the discussion.

Considering that the total weight of the ongoing activities is a maximum of 3 points of the final exam, the individual activity will count one point. The group activities will count two points as follows.

Individual activities:

- 1 point = four tests performed with score >= 8/15, of which at least two tests with score >= 12/15
- 0.5 points = at least three tests performed with score >= 8/15

Group activities:

- 2 points = three sets of exercises delivered with score > = 20/24, at least two with an overall score, following the correction phase, > = 32/36
- 1.5 points = three sets of exercises delivered with score > = 20/24, at least one with an overall score, following the correction phase,> = 32/36
- 1 point = at least two sets of exercises delivered with score > = 20/24
- 0.5 points = at least one set of exercises delivered with score> = 20/24

To evaluate this DaybyDay project, this study considers two directions: (i) horizontally, comparing the students' results of the intervention group against the control group in a.y. 2020/21; (ii) vertically, comparing the results of both groups between a.y. 2019/20 and 2020/21. The sample includes only students enrolled for the first time.

The study considers the number of students taking the exam during the first session and the score obtained at the test part. The ongoing activities and written part's results have a subjective bias due to the lecturer's correction style. For this reason, they are not used.

4 RESULTS AND DISCUSSION

The first element to consider evaluating the impact of the DaybyDay project is the number of students that decide to take the exam in January. Applying to the first call available at the end of the course implies that one could follow the course and remain on track with the study. There was no difference between the course taught by the lecturer of the experimental and the control group in the past. In a.y. 2020/21, the experimental group has a +2,34% of students who sit at the test compared to the control group (Table 1). However, for both groups, the overall number of examinees is decreased. This change can be linked to the pandemic condition and the related shift to online courses. Looking at the number of students that pass the test part, in a.y. 2019/20, the two groups are comparable. While in a.y. 2020/21, the experimental group has a +5,74% of passed students compared to the control group. Considering the score distribution (Figure 1(b)), the experimental group has a higher average (9,51/15 points vs 9,05/15 points) with a lower standard deviation (3,37 vs 3,53). Also in this case, as shown in Figure 1(a), in a.y. 2019/20, there was no significant difference between the scoring average (12,12/20 vs 12,22/20) and standard deviation (4,02 vs 4,03).

Table 1 Test results related to January call

	January call 2020		January call 2021	
	Experimental group	Control group	Experimental group	Control group
Test passed	730 (47,04%)	1560 (48,84%)	839 (56,38%)	1587 (50,64%)
Test not passed	548 (35,31%)	1121 (35,10%)	313 (21,04%)	766 (24,44%)
No showed up	274 (17,65%)	513 (16,06%)	336 (22,58%)	781 (24,92%)
Total	1552	3194	1488	3134

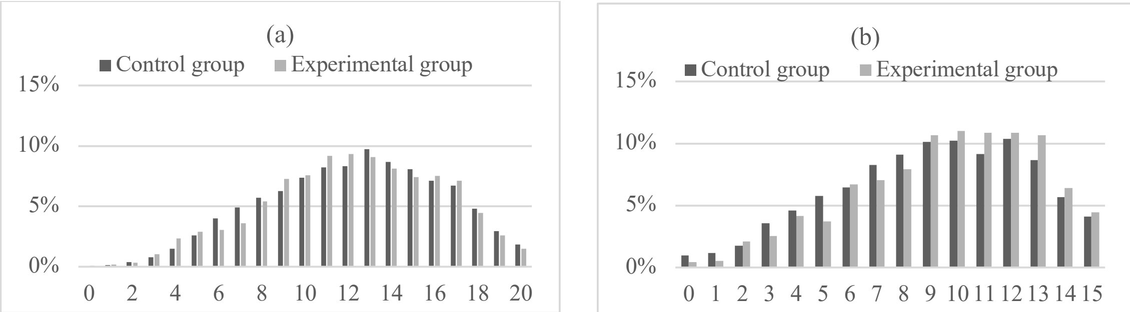

Figure 1 Test score distribution in (a) January call 2020 and (b) January call 2021

Considering the entire first session (Table 2), the number of students that did not show up is comparable between the groups. Moreover, the experimental group has a better rate of success in the overall exam.

Table 2 Exam results related to the first session

	First session 2020		First session 2021	
	Experimental group	Control group	Experimental group	Control group
Exam passed	851 (54,84%)	1662 (52,03%)	823 (55,31%)	1441 (45,98%)
Exam not passed	486 (31,31%)	1135 (35,54%)	431 (28,96%)	1168 (37,27%)
No showed up	215 (13,85%)	397 (12,43%)	234 (15,73%)	525 (16,75%)
Total	1552	3194	1488	3134

This analysis highlights that the DayByDay project satisfies its initial objective of supporting the daily student's organization to improve mathematical analysis. Students who took part in the project were prepared immediately at the end of the course with a better understanding of the subject. Despite the pandemic condition, the experimental group maintain a success rate in line with the previous year, while the control group significantly worsen.

5 CONCLUSION

Thanks to the DayByDay project, students receive support to structure their study to understand the lessons' content and self-evaluate their knowledge.

It is essential to underline that some limitations may have undermined some partial results analyzed in this paper. Firstly, the COVID impact; not only on teaching and learning but also on the students' daily life. Our habits changed a lot due to the pandemic situation, which also impacted the learning performance. Another aspect is the difference in the structure of the assessment between the two academic years under study. All the significant findings come from comparing the control and experimental group in the a.y. 2020/2021 to reduce this bias. Moreover, only objective evaluations such as test results have been considered to avoid the possible bias introduced by the writing exam assessed by different professors.

The individual activities help to keep the preparation in line with the lesson contents. Whilst, the group activities become crucial for peer-to-peer support, a critical element in the pandemic condition in which distance learning changed traditional face-to-face interactions. The educational experience proposed enhances students' learning to acquire technical competence and various team-based skills such as communication skills, presentation, time management, and problem-solving [4,5,6]. This secondary learning knowledge and skills gained by the regular ongoing process and team activities will be further analyzed in the next academic year.

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PARTICIPANTS' PERCEPTION OF A FLEXIBLE PEDAGOGICAL QUALIFICATION PROGAM AT A GERMAN UNIVERSITY OF TECHNOLOGY IN THE COVID-19-YEAR 2020

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Conference Key Areas: *Academic teachers needs and support for online teaching*

Keywords: *Pedagogical qualification program, evaluation, digital teaching support, Covid-19*

The covid-19-pandemic affected pedagogical qualification of academics. It required a sudden digital transformation and reaction on needs for qualification in digital teaching and learning. This study spotlights participants' perceptions on a flexible, needs oriented, hands-on pedagogical qualification program at a German University of Technology in the Covid-19-year 2020. It is questioned how participants evaluated the program. Based on a mixed-method approach, data was gathered using an online survey (8 responses) and semi-structured interviews (4 interviewees). First, the results show that overall the program has been appraised positively and individually diverse regarding program reaction and learning as well as future teaching behavior. Second, participants highlighted most but not all program elements as being beneficial and appropriately transferred into a digital format. Third, participants appraise most program characteristics as appropriately implemented, especially the flexibility. Most participants find an individual compilation of their program more important than running through it in cohort while appreciating, but missing networking opportunities in the digital program version. Forth, participants needed to develop applicable digital teaching competencies in tools, course design and tackling challenges while these desires have been covered only partly by the program. Finally, participants requested to improve the programs' digital communication and collaboration platform, to strengthen digital teaching and learning in the program and to offer voluntary, foremost informal networking options. Finally, it is argued that a future pedagogical program has to increase digital competence development and requires to be open, agile and multidimensionally supported in order to react to abrupt need changes.

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1 INTRODUCTION

The Covid-19-pandemic disrupted teaching and learning in higher education, and in turn pedagogical qualification of academics around the world (see [1]). It forced a sudden shift towards comprehensive digital pedagogical trainings (see [2]) and an unprecedented reaction on needs for digital teaching and learning qualification (see e.g. [3]). Complex cohort-like as well as individual pedagogical programs have been evaluated positively prior to the Covid-19 pandemic (see e.g. [4], [5]). Now, this small study spotlights participants' perceptions on a flexible, needs oriented, hands-on pedagogical qualification program at a German University of Technology in the Covid-19-year 2020. It is questioned how participants appraised the program after finalization by the end of 2020. Therefore, this short paper emphasizes participants' reaction, learning and behavior, their view on an individual program compilation, their perception of how their needs in digital teaching and learning were adressed as well as their recommendations for the program development. It concludes on how to handle such a pedagogical qualification program in striving for high quality in ongoing, compelled digital teaching.

2 METHODOLOGY

2.1 Running a pedagogical program

To ensure high quality education, the Executive Committee of a German University of Technology initiated an obligatory pedagogical qualification program, called I³ProTeachING, (see [6]) for research assistants and commissioned its center for teaching and learning (CLL) in cooperation with the graduate academy to implement it. An internationally wide-used framework for researcher development as well as a modified framework for the German context with their teaching lenses/ clusters are used as underlying anchor points (see [7], [8]). This program aims to increase pedagogical competencies in 60 hours within max. two years. It comprises two competence lines, i.e. "Higher Education & Engineering Pedagogy" (HE/EP) (see [9]) and "Research-Based Learning" (RBL) (see [10]) while integrating digital teaching and learning as a cross-cutting topic. It consists of an initial conversation between experts from the CLL and the individual participants, workshops, a personal reflection on teaching, peer visits in courses, projects on teaching innovations, classroom action research or sharing about teaching, a final event with a product presentation and makes use of an e-portfolio. Participants compile their program according their interests and needs in terms of time and content in all program elements within the general program structure. Flexibility, individual pathways and teaching practice are key aspects in the program design and are well located in the manifold teaching activities (see [11]). The program realization started in presence by the end of 2019 and was transformed to digital formats by April 2020 (see [5]).

2.2 Evaluating the pedagogical program

To evaluate the program, we focussed on participants' perception after finalizing their qualification by the end of the year 2020. It was questioned how participants react to the program, appraise their learning and assess their future teaching intentions. Furthermore, it was of interest how they view the individual program compilation and how their needs in digital teaching and learning qualifications were addressed. Finally, it was asked for recommendations for the program development. The evaluation was designed according to the first three levels of evaluating training programs by Kirckpatrick and Kirckpatrick (2015) ([12]): Reaction (R), learning (L) and behaviour (B). After finalizing the program, a self-designed online survey (n=8 respondents of 13 program graduates, November 2020) and four semi-structured interviews, with interviewees representing various aspects, were conducted (with 2 HE/EP and 2 RBL participants). Descriptive statistical analyses were conducted with the survey data. The interview transcripts were coded using the categories "reaction", "learning", "behavior", "individual & cohort compilation", "digital teaching competencies needed & addressed", "digital program realization", "recommendations". Based in the codes, we analyzed the interviews using qualitative content analysis.

3 RESULTS

3.1 Participants' overall reaction, learning and behavior regarding the program

The results of the survey and of the interviews show that overall the program has been appraised positively. First, selected survey results indicate very positive participants' reaction, learning and behavior (see table 1).

Table 1: Selected results of the program evaluation

Level	#	Item	Ø	n
Reaction	1	I find a structured pedagogical qualification as a research assistant important.	1,0	8
	2	I find it personally valuable that I have participated in the program.	1,5	8
Learning	3	I can develop initial approaches for an aligned course.	1,1	8
	4	I can develop initial approaches for a research-based learning course.	1,3	6
	5	I can develop initial approaches for a digital course.	1,4	8
Behavior	6	I am motivated to develop my own teaching continuously.	1,0	8
	7	I am interested in qualification in higher education pedagogy in the future.	1,3	8
With 3 levels (Reaction, Learning, Behaviour), answers possible on a 4-point scale with 1…totally agree and 4…totally disagree (so lower values show higher agreement), Ø: arithmetic mean; n: number of responses with 2 respondents of the competence line "Higher Education & Engineering Pedagogy" and 6 respondents of the competence line "Research-Based Learning"				

Second, the interviews shed light on some dominant positive anticipations, e.g. networking to peers, workshop topics and identification with the competence lines. Furthermore, the interviewees explained to have gained competencies e.g. in terms of designing courses using digital tools and concepts, applying communication methods and developing a self-reflected teaching and research personality. Finally, it is interesting, that they reported on a broad range of teaching intentions like using material on course planning, developing digital courses, engaging in teaching publications and teaching promotion.

3.2 Participants' assessment of the digital program realization

Survey respondents perceived the digital program realization in Covid-19-times as appropriate. They highlighted most program elements as being beneficial (from more to less beneficial: competence line, supervision, workshops, teaching project, peer visit, reflection) besides Mahara (used as e-portfolio, communication and cooperation platform), which was evaluated as not helpful. Furthermore, they valued the realization of the key program characteristics of individual compilation, time and content flexibility as positive. However, needs-orientation and focus on teaching practice was evaluated as moderate only. Interviewees highlighted: The transition from presence to digital workshops was associated with a lack of informal exchange, networking and room to build up a positive group identity.

3.3 Participants' perception on individuality and cohort aspects within the program

Most, but not all survey respondents perceived the individual compilation of the program as more important than running through it as a cohort. In the survey, individual compilation turned out to be an enabling factor for balancing research and teaching duties with fixed or intense timetables and for following individual needs and interests. Three interviewees mentioned less time pressure, the opportunity to look beyond the horizon or into advanced topics as positive when compiling the program individually. Those three assessed more networking as nice to have, but either need to be supported by supervisors or arranged in additional voluntary formats or focussed on in innovating teaching practice. Additionally, the third interviewee strongly argued on (potentially) negative group identity dynamics in case that participants reject an obligatory qualification. On the contrary, the fourth interviewee stressed on questioning the individual need coverage: This interviewee valued cohort-like, stable, powerful networking on personal issues and teaching much more important than individual flexibility. This was pointed out to be effective, but making lonely and going beyond an open university-wide discourse and tackling challenges collectively.

3.4 Meeting participants' needs in digital teaching and learning

Survey respondents found it important to achieve applicable digital teaching competencies in tools, course design and tackling challenges in teaching practice. They highlighted that these needs have been covered only partly by the program: Basic digital teaching has been addressed as a topic (e.g. good teaching principles in Zoom, applying flipped classroom concepts), but advanced topics and an overall digital approach did not become obvious in the program. The interviewees illustrated this program shortage regarding quick need-orientation for teaching practice: Interviewees struggled with the cumbersome dialog in front of the black wall in Zoom, they just started with the learning management platform ILIAS, they needed to practice teaching with Zoom, they lacked alternative digital course design and they desired to announce multiple communication channels. One interviewee clarified that each institute explored manifold digital tools in the beginning before the university made decisions for the main licenced tools to be used.

3.5 Participants' recommendations for program development

To improve the program, participants strongly requested to revise using Mahara. They recommended to strengthen digital teaching and learning in the program regarding advanced topics such as tool variation, exchanging tackling digital teaching challenges, analyzing good practices of digital courses, discussing actual digital implementations concretely and evaluating digital courses. Finally, they proposed to offer various informal networking options, partly attached to a workshop, in order to jointly work on designing digital courses, discussing how to solve hurdles in digital teaching and joyable team building.

4 CONCLUSION AND OUTLOOK

This study highlights the case of a pedagogical qualification program which was conducted in abrupt digital transformation times due to the Covid-19 pandemic. For evaluating the program, two data sets have been used in a common procedure. It should be strongly highlighted that the meaning of the results presented here needs cautious interpretation and is not conclusive due to relative low response numbers in questionnaires and low number of interviews in the shade of the recent global challenge. Based on the results presented here, we conclude that the program was mostly positively evaluated by the participants who responded. It was uncovered that these participants appraised manifold pedagogical learning which however have not been appraised as sufficient when facing the hasty change to digital teaching and learning connected with partly resisting and overwhelming challenges. These participants proposed revisions, which have already been implemented (e.g. focus on digital teaching in the workshop catalog, various formal & informal networking formats) or are under construction (e.g. replacing Mahara by ILIAS). However, it should be strongly argued that, a qualification program is limited (see [13]) and only one opportunity among others to overcome diverse barriers in current digital teaching. In striving for high quality in recently compelled digital teaching, it is synthesized: This pedagogical program needs individual pathways with combined networking options and practice-oriented, comprehensive digital competence development. Further data as well as discussions are desired to revise this program for its recent digital implementation and beyond in the future.

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CHANGING BELIEFS ABOUT INTELLIGENCE BY CHANGING THE WAY MATHEMATICS QUESTIONS ARE POSED

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ABSTRACT

The social psychology theory of growth mindsets – the belief that academic ability is not fixed at birth but can be developed – explains why students may fail to do what they know they should to succeed academically. Lasting behaviour change requires a change in the beliefs that underpin the behaviour.

Recent evidence suggests that developing growth mindsets in engineering students may be more successful if interventions focus on changing learning environments and not just changing students. Following this direction, the aim of this work-in-progress paper is to describe a design-based research framework to design and evaluate modifications to tasks and communication in engineering mathematics courses to support the development of growth mindsets over multiple semesters.

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1 INTRODUCTION

Student dropout from engineering studies continues to be an issue of global concern, motivating much engineering education research. In countries where entry to engineering programmes is highly competitive, it is puzzling that many engineering students who were high academic achievers in school fail at university. Amongst other things, academic success requires appropriate academic behaviour, such as reviewing errors made in tests and not giving up easily when work is challenging. Failing an assessment is an indication that a change in behaviour is necessary. However, realising that one's behaviour should change is often not enough to cause a lasting change in behaviour. Social psychology theories propose that behaviour change requires a change in the beliefs that underpin the behaviour. Specifically, the theory of 'growth mindsets' [1] – the belief that your academic ability is not inherent but can always be further developed – explains why students may know what behaviour they should change (for example asking questions when stuck) but still not make the behaviour change and be at greater risk of dropout.

2 LITERATURE REVIEW

2.1 Mindset and academic success

Holding a growth mindset means believing that your academic ability is not a biological trait beyond your control but can be increased through appropriate effort [1]. Compared to students who hold fixed mindsets, students with growth mindsets are more likely to be intrinsically motivated to learn and they are more likely to use effective study practices. Students with fixed mindsets are more likely to resist study behaviour that would mark them as a 'hard worker' and to set unobtainable, perfectionist goals which can lead to anxiety and depression [2].

Mindset theory [1] has been shown to impact students' behaviour and academic success [3]. Two meta-analyses of the effect of growth mindset interventions on academic achievement [4] showed that there is in general a small positive effect on achievement for students with a growth mindset. Importantly for institutions that value supporting diverse student populations, achievement gains were greatest for students from low-socio-economic backgrounds. However, a systematic literature review on developing growth mindsets in engineering students [5] showed that it is not yet clear how to develop growth mindsets. It would seem that growth mindsets are more likely to be developed in an environment that reinforces growth mindset messages.

2.2 Implications of mindset theory for educators

Growth mindsets and fixed mindsets can be promoted through teaching practices based on different learning theories [6]. Misinterpretation of mindset theory can lead to blaming students for not holding the right kind of mindset rather than recognising the systemic ways that a fixed mindset may be reinforced. Recent evidence suggests that growth mindsets may be developed through course structures such as using active learning, re-taking assessments, and showing students why the selected topics are relevant to them [7]. Furthermore, posing mathematics questions based on growth-mindset-promoting principles [8] instead of in a traditional way were found to increase students' motivation to work on problems [7].

Boaler's [8] growth mindset principles for course design address the increasing diversity in high school backgrounds of engineering students. The principles include:

- Using 'low floor, high ceiling" activities to keep all students engaged.
- Using multiple methods, pathways, and representations.
- Asking the problem before teaching the method to solve it.
- Asking students to explain mathematics using a visual representation.
- Giving students opportunities to conduct their own inquiries.
- Asking students to reason out and convince someone of their findings.

3 RATIONALE AND RESEARCH QUESTION

This research will contribute to research on developing growth mindsets in engineering students in the context of engineering mathematics courses in South African universities. The aim of this work-in-progress paper is to describe a design-based research framework to identify, evaluate and design modifications to tasks and communication in engineering mathematics courses that support the development of growth mindsets in students and staff over multiple semesters.

4 METHODOLOGY

4.1 Design-based research

The five features of design-based research outlined in [9] matched the goals of this research project. First, the central goal of engineering mathematics courses is to equip students with confidence, knowledge and skills that they can use beyond their mathematics courses. The theory of growth mindsets is intertwined with this central goal as fixed mindsets work against the perseverance, self-reflection and collaboration needed in and beyond mathematics courses.

Second, developments and research on how tasks and communication in mathematics courses may reinforce fixed or growth mindsets are planned to take place through cycles of preparation (or more broadly 'design'[9]), action, analysis, and redesign over multiple semesters.

Third, the findings from this research will lead towards sharable theories on the choice of tasks and communication in engineering mathematics courses with implications for designers and educators.

Fourth, by researching current engineering mathematics courses in a variety of authentic settings (small and large classes, first- and second-year courses, different institutions), results will document successes and failures that lead to improvements, or that suggest revision of the theory. Results will refine understanding of mindset theory applied to engineering mathematics.

Fifth, text analysis methods based on mindset theories [7, 8], together with reflective collaboration between researchers and sharing findings in presentations and publications will result in outcomes of interest to the engineering education community.

4.2 Phases

The research will use a design-based research framework with cycles of preparation/design, action and reflection. The research will follow the design-based research phases described in [10]:

PHASE 1: Analysis of practical problems by researchers and practitioners in collaboration

This phase marks the start of the first design-based research cycle focussing on preparation and design. The aim is to establish a community of collaborators (engineering mathematics lecturers) and collaboratively analyse existing course features to determine the extent to which growth mindsets are or are not being supported in tasks and communication, according to [8] and [1].

Surveys and interviews will be used to assess mindsets of students and staff in each of at least three semesters before and after changes are implemented, although challenges with assessing mindsets [5] are noted.

PHASE 2: Development of solutions informed by existing design principles

Using the growth mindsets principles [8], revisions to existing tasks and communication will be collaboratively developed by the researchers, for example, allowing students to choose to work on basic or more advanced questions and using peer-review to showcase alternative methods.

PHASE 3: Iterative cycles of testing and refinement of solutions in practice

Revised tasks and communication will be implemented in at least three semesters. Reflections informed by mindset assessment through surveys and interviews will contribute to the development of principles for enhancing the implementation of changes to tasks and assessments so that they encourage growth mindsets and discourage fixed mindsets.

5 CONCLUSIONS

The scope of the proposed research is the development of growth mindsets but the ultimate goal is improved student success. Other evaluative research may be needed to assess this research, for example the impact of participation in this project on broader issues, such as student wellbeing or the changes in the teaching practice of collaborators.

6 ACKNOWLEDGMENTS

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OPEN BOOK VECTOR CALCULUS ASSESSMENT: SUGGESTED DESIGN PRINCIPLES

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ABSTRACT

Traditionally mathematics tests are done with paper and pencil, no calculator and are written in a secure venue. In March 2020, with three weeks' notice, we had to change our plans to administer a traditional vector calculus test and instead run assessment that was open book and written remotely, with access to electronic tools. The biggest surprise was how easy this was to do. Much of multivariable calculus and vector calculus is dependent on understanding what the question is asking, visualising curves and surfaces and how they interact with one another, and setting up sometimes quite complicated integrals. The final few steps of actually computing the integral are the least important part of any problem. In this short paper I shall set out and motivate design principles for setting such an test, based on our experience in March 2020 and more recently refined in March 2021.

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1 INTRODUCTION

Calculus courses at university are traditionally assessed with closed book tests. Courses adopting a continuous assessment model might include homework assignments, projects, quizzes and so forth but a final summative closed book test remains a mainstay of calculus assessment. In March 2020 at our institution, as at so many others, we were forced by circumstances to shift to online testing. With very little time to prepare the simplest model was non-proctored open book tests which necessarily meant open internet tests. The students would have access to their notes, their textbook, computer graphing packages and online calculators. Hereafter in this article “open book” will refer to “open book and open internet”.

Somewhat hastily we developed principles to guide the setting of the test. In 2021 with more time to prepare and the opportunity to reflect on the 2020 experience these principles were made more explicit and are discussed in this article. As observed by Kahn [1] entry level calculus courses are arguably a poor fit for open book testing, but higher level courses in which we assess for “higher level understanding, such as the ability to reason, conceptualize and solve problems, and not simply memory and knowledge” (p. 1070) are a far better fit. Trenholm [2] observes that in a survey of fully asynchronous online mathematics courses developmental mathematics courses tended significantly more towards proctored assessment than calculus courses preferring closed book tests. While in this article the term open book is being explicitly used to mean access to all notes as well as online resources, the term open book is used variably. Raen [3] uses “open book” to mean access to a self-created formula sheet while Edwards and Loch [4] differentiate between closed book, access to formula sheet, and fully open book.

2 METHODOLOGY

The first step in the design of this test was to go through the syllabus and a selection of previous test papers and make a list of all the types of questions that were typical to ask. Secondly, obvious poor candidates for open book testing were identified. Third, certain types of questions were tested against popular online calculators.

A set of design principles was derived, mostly implicitly at the time given the urgency, but made more explicit in post hoc reflection. The test and the resit (a second chance at the test) were set according to these design principles. In 2021 we were able to refine and be explicit about our design principles.

3 RESULTS

3.1 Observations leading to design principles

Steps one and two of the process involved detailed listing of all types of test questions we could ask and to identify obvious poor candidates for an open book test. These included solving integrals already provided in symbolic form, and calculating div and curl of vector fields. The third step of the process was to test how well popular online calculators could be used . It was determined that typical “change the order of integration” questions were easily solved by online calculators if the integral was provided in the non-solvable order. The first four of the five design principles listed below were used to draw up the test and resit in 2020.

In 2021 the four design principles were formulated more explicitly after their hurried framing in 2020 and were used to design the first test. Reflection on that test and looking back at the 2020 experience suggested the addition of the fifth design principle below. In short the design principles are (1) Provide diagrams, (2) Encourage decision making, (3) Create opportunities for noticing options, (4) Low emphasis on solving integrals, and (5) Avoid formats that have characteristic forms.

3.2 Design principles

Provide diagrams – Two reasons support inclusion of diagrams, those are equity and information interpretation. In a closed book test it can be reasonable to require students to draw a diagram as part of their solution. This requirement is no longer reasonable when the student has access to computer graphing packages and could be regarded as inequitable if some students were more practised at using such packages. Furthermore, providing information through diagrams rather than text requires translating the information into a form useful for the problem's requirements.

Encourage decision making – Provide information-rich problems requiring decisions over what exactly is required; information is given in one form and needs to be changed into another form. Students have to decide what is important and why.

Create opportunities for noticing options – The nature of the vector calculus context is that often there are multiple ways of solving problems. Examples include solving line integrals of conservative vector fields, and replacing a surface in a Stokes' Theorem problem.

Low emphasis on solving integrals – Since online calculators can solve most integrals once limits of integration have been determined there is little point in assessing this skill in an open book context. Put emphasis on the set up of integrals and low emphasis on solving or omit solving altogether.

Avoid formats that have characteristic forms – Avoid situations where a familiar form, for example the line integral of a Green's Theorem problem, triggers the means to solve the problem rather than any decision making on the students' part.

3.3 Example 1 – line integral of (conservative) vector field

The question below is underpinned by design principles 2 and 3, that of encouraging decision making and providing options. Answering part (a) could be done by finding a potential function or by calculating curl. Answering (b) can be done using a line integral for the entirety of **G** or by employing a potential function for the **F** part of **G** and the line integral only for the second part of **G**.

Let $\mathbf{F}(x,y,z) = \langle yz + ze^{xz},\ xz + z\cos yz\ ,\ A\rangle$ and let $\mathbf{G}(x,y,z) = \mathbf{F}(x,y,z) + \langle y, -x, 0\rangle$.

a) What must *A* be equal to in order for **F** to be a conservative vector field? Choose the simplest option.
b) Let *A* be whatever you determined in (a). Determine the work done by **G** to move a particle along the line segment from $(1,2,0)$ to $(0,3,1)$.

3.4 Example 2 – describing a region

The equation of the circle is not given, the student needs to combine the information given in text and in the diagram. This question illustrates design principle 1.

The region in the diagram is bounded by a circle of radius 1. Describe that region in (a) Polar coordinates and (b) Rectangular coordinates.

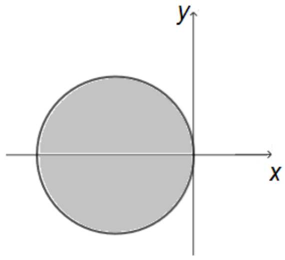

Fig. 1 diagram for Example 2

3.5 Example 3 – Green's Theorem for area

This question is underpinned by design principles 2 and 4, that of decision making and low emphasis on solving of integrals. Once the integral is correctly set up it proves to be easy to solve.

A particle moves along the curve $\mathbf{r}(t) = \langle t^2 - 2t, t^3 - 4t \rangle, t \in \mathbb{R}$ which bounds the shaded region shown in the diagram. Evaluate the area of that bounded region.

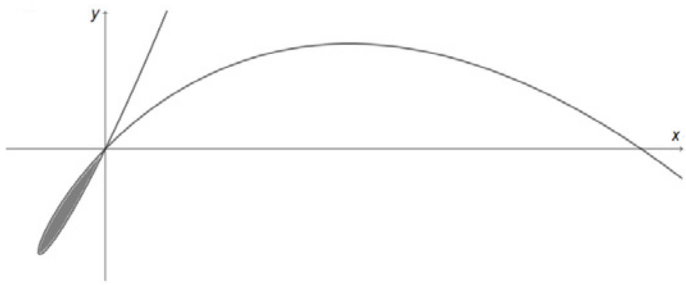

Figure 2. Diagram for Example 3

4 SUMMARY

The sudden requirement to set open book tests in April 2020 required hasty development of design principles which were later refined in 2021. In this paper we have used "open book" to refer to "open book and internet" and hence access to online calculators. A complication in 2020 and 2021 which we hope will have been resolved by 2022 is that the remote, non-proctored nature of the tests could still lead to cheating such as communication with others, both in person and online.

In 2022 we hope to allow students to bring in notes and to have access to certain online resources, such as computer graphing packages and online calculators, while constraining the environment to avoid the potential for cheating unavoidable in 2020 and 2021. We look forward to this new mode of vector calculus testing, thrust upon us initially unwillingly, but upon reflection improving our assessment.

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VIRTUAL WHITEBOARDS & DIGITAL POST-ITS – INCORPORATING INTERNET-BASED TOOLS FOR IDEATION INTO ENGINEERING COURSES

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Keywords: *Creativity, Creative Problem Solving, Digital Whiteboards*

ABSTRACT

Creativity plays an important role in the problem-solving process of engineering. Many engineering tasks can be understood as special cases of creative problem solving. Creative problem solving in companies often includes creative sessions in teams and the use of creativity techniques for groups such as brainstorming or morphological box, where ideas are recorded on a whiteboard with various visualization aids such as sticky notes. Due to the COVID-19 pandemic, courses in creativity and innovation management in engineering curricula face the challenge of teaching creative problem solving, while the lecturer and the students work from home using cooperation platforms such as MS Teams or Zoom to interact. The functionality of these platforms with regard to ideation are limited so that internet-based tools for ideation can offer a sensible complement through e.g. virtual whiteboards enabling e-brainstorming sessions with spatially distributed participants. The paper gives an overview over internet-based tools for ideation (i.e. idea creation and idea evaluation) highlighting their functionality, templates and possible areas of use in engineering education with regard to creative problem solving. Furthermore, the paper discusses first experiences of teaching creative problem solving in a virtual environment including a feedback of students from a master course in industrial engineering.

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1 INTRODUCTION

The problem-solving process of engineering largely depends on the engineer's creativity. Several studies show that maintaining the performance of collaborative work such as creative problem solving in teams while working remotely is one of the biggest challenges during the COVID-19 pandemic [1, 2, 3]. First studies from industry [3] as well as research [4] indicate that workplace tools have a significant impact on productivity and creativity during remote work. According to Malhotra and Majchrzak [5] successful virtual workspaces need to supply two key features: "multichannel synchronous communication" and "support for maintaining a persistent record of knowledge over time". In the first category, the ideation process usually requires visualization tools such as whiteboards, presentation boards or flip charts where people can share their ideas using markers, cards and digital post-its. In a virtual workspace with remote members this has to be substituted with internet-based tools for ideation in the form of digital or virtual whiteboards and post-its. Lecturers of creativity and innovation management face similar challenges, as they instruct students in the tasks and techniques of creative problem solving, while both lecturer and students work from home using collaborative plattforms such as MS Teams and Zoom. The functionality of these platforms with regard to ideation are limited so that digital whiteboards can offer a sensible complement. In this paper, the following chapter provides an overview of existing internet-based tools for ideation. Then, initial experiences in teaching creative problem solving with some of these tools are described. The last section concludes with a summary of the results and an outlook on future work.

2 INTERNET-BASED TOOLS FOR IDEATION

The creative process can be roughly divided into the phases of problem definition, ideation and solution implementation [6]. In the ideation part of the creative process there is typically an interplay of divergent and convergent tasks to generate and evaluate ideas. From these models we derived the following tasks which have to be supported by internet-based tools for ideation:

- Capturing ideas: Using templates and functions of creativity techniques
- Sorting ideas: Re-arranging ideas into relations, categories and hierarchies
- Developing ideas: Fleshing out existing ideas and specifying details
- Evaluating ideas: Assessing ideas to find the most promising one(s)

Additonally the tools need to enable the following two tasks to link the virtual to the real world:

- Documenting results: Generating a file for permanent storage
- Communicating: Using a direct audio/video communication channel for group interaction during ideation sessions

We chose ten common internet-based tools and assessed them based on the functions necessary to support these task (see table 1).

Table 1. Digital Whiteboards (Status: May 2021)

Process	Functions/Templates	Digital Whiteboards									
		Collarboard	Conceptboard	Ideaboardz	Limnu	Lucidspark	Mindmeister	Miro	Mural	Padlet	Stormboard
Capturing ideas	Brainstorming	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Brainwriting	✗	✓	✗	✗	✓	✗	✓	✓	✗	✗
	Mindmap	✓	✓	✗	✗	✓	✓	✓	✓	✗	✓
	Six Thinking Hats	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓
	Synectics	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
	Visual Synectics	✓	✗	✗	✗	✗	✗	✓	✓	✓	✗
	Morphological Box/Matrix	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
	TIPS (Contradiction Matrix)	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
	Business Model Canvas	✓	✓	✗	✗	✓	✗	✓	✓	✗	✓
Sorting ideas	Relocate/Shift Notes	✓	✓	✗	✓	✓	✗	✓	✓	✓	✓
	Arrows/Connecting Lines	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓
	Clustering/Grouping	✓	✓	✗	✓	✓	✗	✓	✓	✓	✓
Developing ideas	Sketches	✓	✓	✗	✓	✓	✗	✓	✓	✗	✓
	Pictures/Fotos	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓
	Additional Files/Media	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓
Evaluating ideas	Points/Emojies/Thumbs up/Like	✓	✗	✓	✗	✓	✓	✓	✓	✓	✓
Documenting results	File Types	PNG	PNG, PDF	PDF,CSV	PNG	PDF, PNG, jpeg, SVG, CSV	Text	PDF, JPG, CSV	PDF, PNG, ZIP-file	PDF, PNG, CSV	DOCX, PPTX, PNG, PDF, CSV
Communicating	Chat	✗	✓	✗	✓	✓	✗	✓	✓	✓	✓
	Audio	✗	✓	✗	✓	✗	✗	✓	✗	✗	✗
	Videoconference	✗	✗	✗	✓	✗	✗	✓	✗	✗	✗

✓ *available* ✗ *not available*

The results in table 1 show that on the one hand there are very simple tools such as Ideaboardz or Mindmeister with few functions, which can serve as an introduction into the field, and on the other hand there are comprehensive tools such as Miro, Conceptboard or Mural with lots of functionality, which can serve advanced needs but need more skills to master. However, it should be noted that table 1 is a snapshot in time. Tools can and do expand their range over time to include additional features. The data collection period for table 1 was from February to May 2021.

3 FIRST EXPERIENCES WITH DIGITAL WHITEBOARDS

First experiences with teaching creative problem solving in a virtual environment have been made in the context of a master course in industrial engineering at the University of Applied Sciences in Düsseldorf. The course called Innovation and Technology Management took place in the summer semester of 2020 (SS2020). During the course, the prospective engineers worked the entire semester of 14 sessions in groups of five on a self-chosen problem to redesign an everyday object ending with the students presenting their solutions. In total, there were 25 students divided into five groups. Students were trained in the basics of creative problem solving and creativity techniques in two lectures with exercises. In this context, it was asked which techniques the students were already familiar with. The assessment of the degree of familiarity shows a similar picture to that from the previous semester [7]. Students show a high familiarity with intuitive creativity techniques and three quarters of them have already participated in a brainstorming session. This is also reflected in the evaluation of various self-assessments from past semesters of the same course. Students prefer intuitive techniques such as brainstorming over others and would be most likely to use them to generate ideas [7,8].

Students from the SS2020 had to use e-brainstorming to generate ideas. The students used two tools selected by the lecturer, a simple tool (Ideaboardz) to capture ideas and a more complex tool (Miro) to facilitate further processes such as sorting and evaluating. After the ideation sessions, a survey was conducted to determine which form of brainstorming (traditional or online) is preferred by the students. Of the 25 students who participated in the course 19 evaluable questionnaires were submitted. The result of the assessment in fig. 1 shows that the majority of the students (63%) prefer traditional brainstorming to e-brainstorming (37%). However, in a more detailed evaluation, e-brainstorming gets higher ratings from students on most criteria. Most students think they were more creative personally (48%) and as a group (54%) when they used e-brainstorming (in comparison to 32% and 12% respectively). They also think an e-brainstorming session is more fun (55%), is easier to do (66%) and promotes a better understanding of creativity (40%) than traditional brainstorming (32%, 20% and 32% respectively). Only when asked which method students would prefer in the future traditional brainstorming (47%) receives a higher approval than e-brainstorming (39%). Students still seem to be unsure of internet-based tools for ideation: In general they still prefer the traditional way of doing brainstorming, but they also perceive the advantages of the online tools. It could be that, in general, the students still assess brainstorming based on habit and need to gain more experience with the new tools for a meaningful assessment.

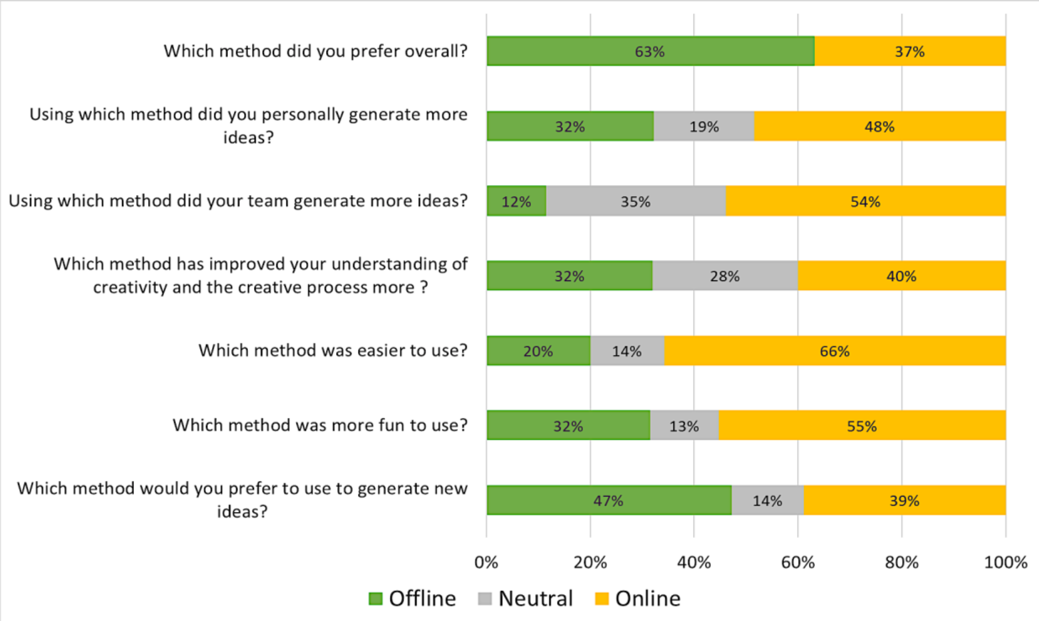

Fig. 1. Comparison between online and offline brainstorming (n = 19)

4 CONCLUSION

This paper gives an overview of ten common internet-based virtual whiteboards, which are meant to be used for for idea generation, and gives an insight on first experiences in teaching creative problem solving with two of these tools. The overview has shown that there are tools that are very simple and have few functions and other tools that have advanced functions. However, it should be noted that the data was collected in the period from February to May 2021 and, thus, represents a snapshot in time. Tools can and do expand the functions offered over time. Initial experience in working with two of these tools (Ideaboardz and Miro) has shown that students in general prefer creative problem solving in the form of traditional branstorming over online brainstorming via digital whiteboards. However, they also perceive the benefits of online tools, as in a more detailed evaluation, e-brainstorming receives higher ratings in comparison to traditional brainstorming. It should be considered that the evaluation is from a small sample size. A total of 25 students participated in the course, of which 19 submitted an evaluation. Future plans for the course include testing other digital whiteboards and repeating the survey with other students so that over time a larger sample size can be created and the results can be compared. As part of the review of the tools, in addition to the expansion of the table with additional tools, the continuous updating of the newly added features is also planned. Furthermore, an investigation can be carried out to determine in how far the individual tools are data protection compliant.

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LESSONS LEARNED? ONLINE-TEACHING DURING THE COVID 19 - PANDEMIC

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Conference Key Areas: *Methods, formats and essential elements for online/blended learning*
Keywords: *online-teaching, interactive quizzes, homework, student feedback*

ABSTRACT

The article presents our experiences switching from face-to-face to online-teaching during the first lockdown of the Covid-19 pandemic and the five essential core elements we used for our online-teaching. These are in detail: 1. Short lecture videos with essential explanations of the technical content, 2. More detailed exercise videos to deepen the technical content by means of various practical examples, 3. Interactive quizzes in the exercise videos to activate learners and to promote their understanding, 4. Weekly homework to encourage students to come to terms with what they have learned, 5. Consultation hours in a synchronous format to support student´s learning process.

The article shows the way we went to create our learning format and the tools we used. Our considerations are supported by exemplary quotes from student feedback, both from the official assessment and from personal emails. Thanks to trustworthy communication with the students, we were always motivated to further develop our online-teaching. Finally, recommendations are given to stay in contact with the students and thus continuously develop the lessons.

1 INTRODUCTION

A good year ago, the corona pandemic paralyzed all university teaching. Within a few weeks, we teachers were forced to switch teaching from face-to-face to online teaching. A situation that had never been seen before and made us fearful that we would have to give up our teaching methods, which had been painstakingly worked

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up didactically over the years, with a focus on application-oriented learning [1] and promoting the understanding with demonstration experiments. Difficult decisions had to be made, which often represented a compromise between desirable and feasible in the short term. We want to present our path through the first two semesters of online teaching and the steps we learned here.

2 DEVELOPING THE ONLINE-TEACHING

2.1 Decisions and first steps

When it comes to online-teaching, you can choose between synchronous and asynchronous teaching formats. Both have advantages and disadvantages, so synchronous formats allow the learners a direct exchange with the lecturer and thus direct queries, on the other hand it is sometimes more difficult for the students, unlike in presence in the lecture hall, to concentrate alone in front of the screen. Not to mention distractions from family members or roommates on both sides of the connection. Furthermore, an unstable internet connection can lead to difficulties for both the teacher and the student. An asynchronous format allows students to learn better at their own pace. The materials provided, such as videos, can be stopped or rewound at any time if something needs to be repeated or if the learner first wants to recapitulate in an individual way what has just been explained, be it through research on the Internet or parallel processing of arithmetic problems. Weighing up these points, we decided on an asynchronous format, which beside allows students to watch the lecture to their preferred learning time. Not least because we feared that the server performance in the home network would not be able to withstand a lecture with around 400 connected students.

Before that, the event consisted of twelve to thirteen 90-minute lectures and six to seven in-depth exercises lasting around 180 minutes, each dealing with two lecture topics. It does not seem sensible or expedient to bring this one-to-one into a video format. While derivations and sketches were carefully built up on the blackboard step by step during the lecture and some practical anecdotes were told in order to keep the students' attention, we now decided to reduce the lecture videos to a maximum of 30 minutes. These should first of all present the essential formulas and explanations of the technical content and thus lay a first basis for the students to deal with the content. For this purpose, the students were provided with the content as well as an overview of questions as PDF files in order to solve them step-by-step with the lecture videos and thus to acquire content self-sufficient [2].

Detailed exercise videos should then deepen the students' understanding of the technical content and stimulate their interest through a variety of practical examples from everyday life and technology. In addition, the application of the formulas should be shown step-by-step through calculation examples.

In order to produce really appealing videos that support the students' learning, we orientated ourselves to the principles for effective educational videos (for example Signaling, Segmenting, Weeding, Matching modality) [2] and the cognitive theory of multimedia learning [3], but of course we could not implement everything perfectly in the first step. First, the existing presentations had to be reprocessed: on the one hand reduced, on the other hand restructured and supplemented with new, easily understandable graphics, images and animations. Internet sources and references for in-depth discussion as well as short sample videos were researched and integrated. A whole team of student assistants was involved in the research and graphic design.

Next, the audio track was added to the finished presentations in PowerPoint [4]. It turned out that the most expensive microphone is not necessarily the best at the same time, you should plan enough time and choose both the room and the time of day well to avoid excessive background noise. The audio-visual presentations were finally converted into a video format. What is described here in a few words took a lot of time and revision loops. In the exercise videos, it was ensured that explanations alternate with practical examples and calculation examples of specific applications in order to get the students' attention in these longer videos (50-75 minutes). For this purpose, it also seems advisable to evoke a change of speaker, so another person spoke the calculation examples. Student assistants were instructed for this. In addition, the students were asked during the video from time to time to stop this in order to first perform the calculation themself or to solve a question on their own.

The videos as lectures and exercises were made available to the students weekly in the online course on the ISIS website (https://isis.tu-berlin.de) of the Technical University of Berlin (Fig. 1.). Furthermore, as already mentioned, there was the content as PDF files and a further presentation with quiz questions on the topics.

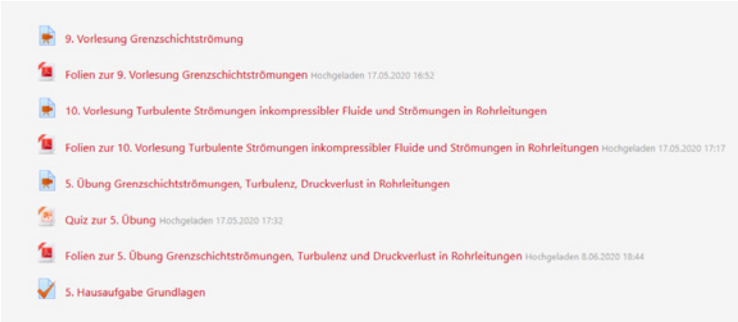
In order to encourage the students to deal with what they have learned, weekly homework had to be done. These were included as tests in the online course. The tasks were available to the students for one week with an unlimited number of attempts. The aim was not to create additional pressure to perform, but actually to create a more in-depth discussion. Therefore, it was always possible to ask questions to one another and to the teachers in the consultation hours and in the exchange forum on the course page. The consultation hours were given in a synchronous format in a virtual meeting room on the course website (meet@ISIS).

2.2 Further developments in the next run

After the first online semester, we wanted to further develop the material for the next round, knowing that the corona pandemic will not allow us to return to regular teaching so soon. The lecture-free time was used to attend an online course "Screencast Masterclass - develop your own videos" [5] and to watch some tutorials [6] on the use of digital instruments, and to become familiar with them.

Now the videos were first revised with Camtasia. The volume was regulated, noises and many "ums" cut out and long pauses in speech shortened. The program also made it easier to integrate and shorten videos for demonstration examples. Furthermore, transitions were used and instructions for students were displayed in the video, such as "Please stop the video now and try to solve the arithmetic problem yourself first! “

In this program, a short personal welcome video was also created with a few tips for the students on how to use the learning videos (Fig.2.). So that the students not only see the lecturer as a picture, but actually personally from the home office, apart from the consultation hours, which were not visited by all students.



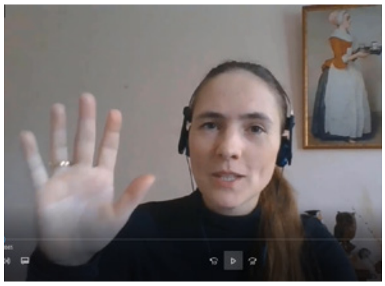


Fig. 1. Learning material provided weekly during the first online semester

Fig.2. Welcome video with five tips for using the learning videos and materials

Another important revision step became possible when H5P [5] content could be integrated into the online course. Now the learning videos could be enriched with different question formats, such as multiple choice (Fig.3.), single choice or fill in the blank questions, and links to further information in H5P in order to actually support active learning [6].

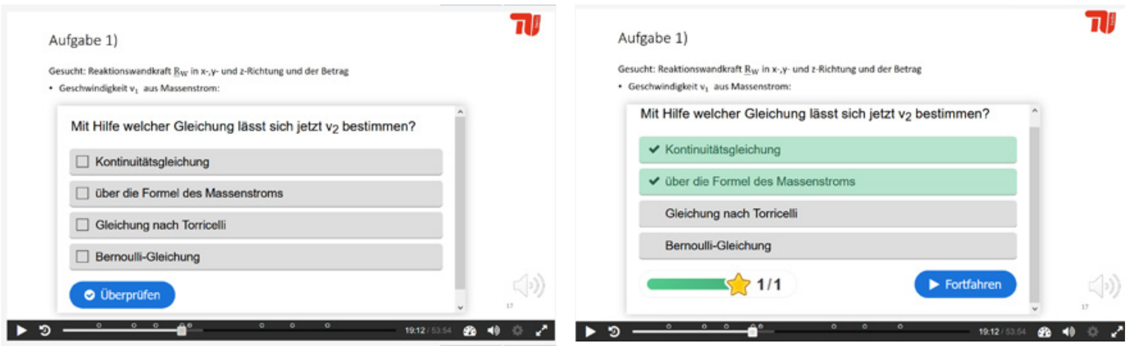


Fig. 3. Multiple choice question in the interactive H5P video

In addition, the consultation hours have been expanded in the second online semester, as well as communication via an exchange forum in the online course in order to stay in contact with the students and to be able to support them in the event of problems.

3 STUDENT FEEDBACK AND ONLINE EXAM

That our efforts bore fruit could not only be read in the official evaluation. We were particularly pleased about the unsolicited feedback from the students, which we received by email, a few examples:

"Good morning, I just wanted to say how well you are doing the exercises. The interest in the topics on your part and the intention to teach us students something can be seen in every single exercise. Thanks." (student email 15.01.2021, 10:52)

"So with this in mind, a silent compliment to your commitment, your preparation and your constant help (and maybe also patience ..) in the forum. Many students will certainly appreciate that too." (from a student email 03.02.2021, 10:24)

"Everything about the topics is very good to understand! The homework serves to practice the topics, the questionnaire helps you to remember the important aspects. Everything great." (from the official evaluation WS2021_032)

Of course there were also some points of criticism, for example it was noted that the arithmetic tasks should be calculated in more detail *("Maybe expand the arithmetic problems better, sometimes found it too fast." (from the official evaluation WS2021_032))*. For this reason, we are currently in the process of completely processing the calculation tasks in the exercise videos as detailed step-by-step instructions.

In addition, we have set up a group division and a group forum in the online course to make it easier for students to find learning groups and exchange ideas. And we're still improving our online exam format [8]. After the first exam, which some students found to be too short in time *("Like many others, I found the exam far too tight and at the end of the day I was unable to enter many of my results." (student comment in the course forum 05.02.2021, 12:37))* and too high in terms of level, we have already implemented some feedback from the students: such as enabling calculation paths to be uploaded directly after the exam, no fixed navigation, restructuring of the exam to make it easier to manage the time and clearer distribution of points for different levels of difficulty. Nevertheless, it remains a great challenge to test competency-oriented via an online format!

4 SUMMARY AND RECOMMENDATION

Any tool is only as good as the hand that guides it. Regardless of whether you opt for synchronous or asynchronous learning formats, each format has advantages as well as disadvantages for learners as for teachers and the decision must be weighed personally. It is then more important to implement the learning format in an activating and supportive manner for the students. We opted for asynchronous online-teaching with the essential elements: short lecture videos as a basis, detailed exercise videos with calculation examples, interactive quiz questions and weekly homework.

If the learning materials are offered asynchronously, opportunities should also be created for students to ask questions and receive feedback on their learning pathways. This is another core element of our online teaching.

On the other hand, close contact with the students enables you to get to know their needs and thus to further develop your online teaching. In addition to synchronous consultation hours, we also recommend active participation in a discussion forum for your course. We also recommend lively exchange among colleagues about online tools in teaching and attending appropriate workshops, as that helped us a lot.

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BUILD IT AND THEY WILL COME: MAINTAINING STUDENTS ACCESS TO FABRICATION AND TESTING DURING A PANDEMIC

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Conference Key Areas: *Lab courses and projects blended and online, Changes beyond Covid-19*
Keywords: *Blended learning; active learning; making; Covid-19*

ABSTRACT

The Civil Engineering curriculum at Sheffield University offers students the opportunity to work in groups to design, build and test models. This fulfils vital learning outcomes including interpreting a project brief, production, design, and teamwork, which are accreditation requirements. The onset of the pandemic restricted the amount of face-to-face teaching. While mature streaming software allows lectures or seminars to take place remotely, delivering design, build and test activities is more problematic. Presented here are methodologies to reconfigure teaching with restricted access to allow learning outcomes to be achieved while keeping students motivated. It focuses on examples within the course where structured teaching tasks are performed by large numbers of students. Traditional hands-on manufacturing and testing were replaced by "service" build and test schemes that hinged around the typical relationship between a designer (students)

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and a contractor. With the use of screens, PPE and careful communication, fabrication activities simulated an “assembly line” relay rather than the traditional “fixed-position assembly” allowing the activity to safely run face-to-face. Students were able to engage individually and in groups on these teaching methods to execute exciting and real projects, in a way that is scalable to large class sizes [1].

The reconfigured teaching is evaluated based on informal student feedback and academics’ self-reflection. We explore the advantages and drawbacks of these approaches and suggest elements to be retained when restrictions are lifted.

1 INTRODUCTION

Projects in industry often require engineers to operate in teams to design, build and test artefacts. It is important for engineering educators to introduce students (or trainee engineers) to these experiences before they start work. The first year Civil and Structural Engineering curriculum at Sheffield University contains a module (CIV1200 Introduction to Civil and Structural Engineering Design), in the Autumn Semester, where students design, build and test wooden small-scale bridges models working in groups of up to twelve. This provides a series of vital Learning Outcomes (Interpret a project brief, produce a design and present the results) which are also required for professional body accreditation [2].

The design stage of this module is supported with lectures, tutorials and lab activities. The making part of this module takes place towards the end of the semester with students having access to two build facilities we refer to as “pop-up project spaces” (PuPS), cabinets on wheels filled with hand tools that students can use with minimal supervision, and the “iForge” Maker Space [3]. Load testing is carried out by one member of the teaching team in front of students.

The pandemic reduced the amount of face-to-face teaching across the University, either through suspension of access during “lockdown” or with reduced occupancy due to “social distancing”. The iForge suspended support to curricular projects and access to the laboratories was severely curtailed. For example, the Structures Laboratory where the bridge building took place had its capacity slashed from 80 students to 20. Additionally, students needed to stay 2 m apart, wear face coverings, and workstations had to be sanitised after each use. While mature streaming software allows lectures or seminars to take place remotely, delivering design, build and test activities is more problematic. An innovative solution was needed to reconfigure the module, while maintaining key learning outcomes and keeping the students motivated and, hopefully, happy.

Possible solutions to this problem might include take home labs [4]. Using this approach would require concessions to mitigate issues of equity and health and safety that would negatively impact on the learning experience. It also precludes group working. Another possibility was getting staff on site to do the work, similar to the approach in industry, such as in case study on pilot plant experiments in [5]. However, this would reduce the team working aspects of the project as only a few members would engage with the fabrication.

Finally, it should be noted that it was not known how many students would be in Sheffield or aboard, and the availability of technology at home. However, Sheffield University ensures students on all courses have access to appropriate technical support as part of their institutional provision.

2 METHODOLOGY

2.1 Fabrication of the components

Prior to covid-19, fabrication of the model's components required advanced manufacturing (i.e., laser cutting) that took place during the Bridge Building sessions. Students would inspect the cut component, assess if it matched what they intended to design and, when necessary, amend their drawing and have parts cut again. While this optimization cycle is well suited to students with limited experience of laser cutting, this fabrication stage does not suitably represent the working dynamics in industry and the usually high costs of rebuilding erroneously designed components.

During teaching under the social restrictions of Covid-19 a new procedure resembling the typical designer/contractor relationship was introduced. Students (the designers) created files for their parts which were digitally submitted ahead of time. Staff (the contractor) reviewed the files, provided feedback when necessary (so the parts could be redesigned before cutting) and manufactured the parts making them available to students on the day of their timetabled Bridge Building lab session.

2.2 Bridge Building

The Bridge Building session ran for approximately 4 hours and all team members (up to 12 students) cooperated to manufacture components and assemble the final bridge. Time constraint was a key aspect for stimulating students to work as a team, splitting tasks and sharing responsibilities.

Due to social distancing and the decreased occupancy, the format required some changes. Recognising the pedagogical importance of teamwork and of the hands-on experience of building engineered components, it was decided to retain this as a face to face activity. They were designed to simulate an assembly line, with one student from each group accessing one PuPS at a time. Each group had a maximum of 12 hours, with bookable slots of 1 hour. A handover between one team member and the next was used to stimulate teamwork and cooperation. Perspex sheets across the middle of the working station allowed the finishing student to communicate effectively with the new starter. The finishing student, after sanitising the working station, tools and bridge, left the space and the next student took over. To further support teamwork, students were encouraged to use digital devices to remotely connect with other group members to discuss arising problems not to feel abandoned.

2.3 Bridge Testing

The wooden bridges were load tested by hanging weights at the mid-span. Since the bridge is tested to failure, the activity cannot be repeated and consequently it could not be offered to all students in the group as only one could be present. To avoid disparities, it was decided that tests would be carried out by members of staff. Because of the high number of bridge models to test, the option of a synchronous live session was discarded. In fact, it would have not been feasible to perform all the tests at a time suitable to all students as they were often in different time zones, with the consequent risk of alienating some students. Thus, tests were recorded, on videos and these were shared with students along with all the relevant experimental results (total weight, peak load, geometrical dimensions).

3 RESULTS

3.1 Fabrication of the components

Simulating the designer/contractor roles as part of the fabrication stage worked very well for the majority of groups. Only in a few instances were problems in the submitted files (e.g., wrong size, unintended cutting lines) discovered once a student turned up to the bridge building session and assessed the components. While generating some delays in the delivery of the amended parts, this also offered the possibility to provide some feedback to the groups and to create a list of "good practice" instructions for submitting the design file (this will be used in future years). In addition, in one of the groups, the student responsible for the drawing parts was working remotely in a different time zone and was not available at the time of the first Bridge Building session to amend the files. This offered the opportunity to discuss task allocation and redundancy.

3.2 Bridge Building

All groups engaged with the activity and completed their bridges ahead of time. Initial informal feedback suggests the activity was well received with three considerations.

1. Some groups used to their advantage the fact that some students were working in different time zone effectively extending the "working hours" of the group.
2. Students appreciated the time allocated to the handover as it represented, due to the pandemic, the first time they worked with another team member in the lab. In addition, a discussion with a student identified a possible strategy to effectively and timely exchange all necessary information; highlighting an early understanding of the importance of teamwork.
3. One group lamented the limited engagement of some group members which resulted in additional workload and pressure. In future, peer-assessment will be introduced in order to attribute the contribution of all team members fairly.

3.3 Bridge Testing

The asynchronous video recordings of the testing were an effective way to reach out to students and to provide dedicated feedback to each group. On the other hand, the authors believe that running this task remotely has lost some of its traditional excitement and engagement.

4 CONCLUSIONS

This module represents an early attempt to use a blended teaching approach to group project work involving the fabrication of an artefact while dealing with the restrictions imposed by the pandemic. Some of the elements herein developed will be retained, in a modified form, for future activities.

1. The assembly line model, optimized to allow two students on each workstation in order to more effectively promote teamwork while social-distancing, has already been rolled out to other modules.
2. The designer/contractor relationship aiming at stimulating the professionalisation of students will be further exploited.

The philosophy underpinning these two points will become integral part of other lab activities after the end of the pandemic when the original room capacity will be restored.

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Tender Teaching in 'Hard' Sciences? – Fostering Gender and Diversity Skills in Engineering Education in Online Teaching and Learning in Pandemic Times

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ABSTRACT

Gender and diversity competencies are now highly valued in engineering. Various studies show that gender and diversity competencies not only help prevent exclusion and discrimination, but furthermore promote successful and sustainable engineering by prohibiting "I-methodology" and masculine professional culture. But when it comes to teaching gender and diversity topics, it becomes apparent that time and space for critical and reflective learning are critical to ensure learning success. While it is already difficult to install critical and reflective learning spaces in face-to-face classes, it becomes even more difficult in online classes. That online teaching should not be seen as a barrier to teaching gender and diversity issues, but can also bring about more accessible and caring teaching practices, is the main argument of my paper. Therefore, I will bring into focus how it is possible to create critical and reflective spaces in online teaching and learning and what teaching methodology promotes understanding of gendered matters and meanings of technology. To support the argument, I will present a range of successful online teaching of gender and diversity competencies in engineering education based on participant observation and evaluation in interdisciplinary learning settings at the Technische Universität Berlin.

INTRODUCTION

1.1 Gender and diversity in engineering education

Gender and diversity competencies are now seen as very valuable in engineering. It is becoming increasingly clear that the technology-driven society needs engineers who are able to understand the social and ethical dimensions of technological problems and critically reflect on their own situatedness. Major international

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organizations such as the American Society for Engineering Education (ASEE) and the European Society for Engineering Education (SEFI) are calling for gender and diversity issues to be reflected in engineering practices and curricula in order to eliminate discrimination and marginalization based on gender and other social inequality structures [1].

Feminist STS has shed light on the fact that if we are serious about the goal of making engineering education sensitive to gender and diversity issues, engineering students need more than a brief dive into inequality and diversity issues to be able to advance technological solutions to highly complex social situations in the future [2]. To this end, engineering education should strive to broaden and deepen students' understanding of social power dynamics by teaching them about the deeply gendered constitution of technology and offering them knowledge about how gender and other power relations become material. Gender and diversity competencies not only help to prevent exclusion and discrimination, but also promote successful and sustainable engineering by prohibiting "I-methodology" and masculine professional culture [3]. It also promotes the acceptance of gender and diversity issues in general and satisfies the desire of students to look beyond their own discipline, as well as providing the opportunity to learn how to reflect on ethical issues in engineering and design processes [4].

1.2 Gender and diversity issues as irritating and uneasy learning material

When it comes to teaching gender and diversity topics, time and space for critical and reflective learning are critical to ensure a successful learning process and to develop research-based gender competencies [5]. While it is already difficult to install critical and reflective learning spaces in face-to-face classes, it becomes even more complicated in online classes, especially during a global pandemic.

Learning about gender and diversity has been described as a difficult learning process that requires students to leave their affective and epistemic comfort zones by being irritated by the change in their perspective and thereby learning to critically reflect on their presupposed beliefs [6]. Therefore, it is critical to design a learning environment that provides a comfortable and safe space. This is especially important in times of pandemic, when teachers and learners face the burden of increased care work and precarity.

2 METHODOLOGY

In the following, I present successful online teaching on gender and diversity in engineering education based on a qualitative research design at the Center for Interdisciplinary Women's and Gender Studies (ZIFG) at the Technische Universität Berlin (TU Berlin).

The observed courses were all conducted online by the author in the winter term 2020/2021 and the summer term 2021 at the ZIFG of the TU Berlin. The participant observations were mainly conducted during the courses. The evaluation took place in the last course of the semester. In four courses students gave oral feedback (in total 31 statements) and in one course students handed in written feedback via online chat. Thereby only 12 out of 20 students gave feedback. The feedback and observations were analyzed using Mayring's content analysis [8].

The general focus of the courses was on developing research-based gender competencies to support students' agency in gender-sensitive and diversity-oriented action. Students also learned to apply empirical methods to research on gender and diversity or to develop understanding of intersectional forms of discrimination and co-constructive processes of gendering artifacts. Courses included topics such as feminist philosophy and critique of science and technology, transdisciplinarity of gender studies of science and technology, gender in higher education, and empirical methods in gender studies. Participants came from various fields of Engineering, Biotechnology, Computation and Design, and Culture and Technology, as well as Gender Studies. The courses were attended by a total of 51 students. For synchronous sessions, the video conferencing tool Zoom, specified by the TU Berlin, was used. The asynchronous sessions were prepared and conducted via an e-learning platform.

3 RESULTS

3.1 Applying a tender teaching methodology to online classroom

In developing an instructional design for teaching online in an interdisciplinary learning environment during a global pandemic, I was guided by feminist scholarship as it seemed to be a rich source of knowledge on how to construct a more equitable and enjoyable, as well as safe, learning environment that would enable students to acquire critical and reflective knowledge about gender and diversity issues.

Bell hooks' concept of engaged pedagogy, in particular, emphasizes the need to activate students and practice "free speech, dissent, and pluralistic opinions" [9]. It also emphasizes the importance of a trusting "interactive relationship between student and teacher" [10] that should enable students to experience learning with joy as an active and pleasurable process. Likewise, Becky Thompson's concept of teaching with tenderness brings in the goal of "keeping more complexity, paradox, and community in mind" [11] by simultaneously emphasizing the embodied dimensions of learning processes. This connection to the more affective and emotional, as well as material, sides of learning is very important as online learning transforms classroom relationships between teachers and learners, and between learners and learners, into more distanced encounters [12].

Therefore, the main focus in the design of the teaching concept was on supporting a trusting learning culture and avoiding feelings of acceleration and exhaustion [13] in online learning. Early on, a culture of kindness and friendliness was implemented by indicating in the syllabus that students were expected to be kind to each other and that failures would be tolerated. Furthermore, students were regularly encouraged to contact me with questions or problems. Introductory rounds were integrated to give time to get to know each other. In addition, the opportunity for students to discuss in small groups was offered on a regular basis. After each group work, students were given time to present their findings in a joint plenary discussion. In order to make the seminars more accessible to working professionals or people with caregiving responsibilities, the seminars were held on a biweekly schedule for synchronous sessions. I also always strove to maintain a teaching attitude that appropriately acknowledged the achievements made in the seminar. A dose of humor additionally contributed to a pleasant course culture when the internet connection broke down, people got lost in online rooms, or children, pets, and parents showed up.

3.2 Tender teaching as a way to further research-based gender competencies

Participant observations clearly showed that applying a tender teaching methodology promotes commitment to online courses. During the term, student's knowledge of gender and diversity developed impressively. Students in all five different courses appeared to be highly motivated, engaged in attentive discussion, and ultimately were able to translate complex topics into their disciplinary knowledge. They behaved very respectfully, avoided interrupting each other, and listened extremely attentively. Some students even felt comfortable enough to share personal stories or talk about their insights and inclinations related to the course content.

Many students also explicitly praised the seminar atmosphere in their feedback, which had supported them well in understanding the topics. One student wrote: "I thought it was good that we had so much time and that you, [author], led the seminar in a very calm, determined and yet time-giving manner. Gender studies is a personally emotional topic for many of those who take part in it, and it requires a lot of sensitivity with all speakers." (Feedback_1). 40 out of 43 students stated in their final feedbacks that they were satisfied with their learning outcomes on the complexity of gender, diversity, technology and empirical methods. Also, biweekly schedule was regarded by 40 out of 43 students as very helpful for cruising the obstacles of studying online while in the midst of a pandemia. Two male students stated that course culture and concept had very much supported them mentally over the winter term.

4. SUMMARY AND ACKNOWLEDGMENTS

The feedback evaluations and participant observations made it clear that students' ability to critically reflect on gender and diversity issues in engineering and technology in online learning thrived through a teaching methodology that focused on engaging pedagogy and the concept of teaching with tenderness. Due to the fact that the pandemic tends to affect the mental health of students, the use of a slower and more tender yet effective teaching methodology could help develop an enjoyable and safe learning environment and in this way support student learning. Online instruction, therefore, should not be seen as a barrier to teaching gender and diversity issues, but rather as a way to promote and implement more accessible and caring teaching methods. The initial results of implementing this teaching method are promising and should be explored further.

I would like to acknowledge the impressive engagement of students in the online seminars despite any obstacles due to Covid-19.

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DARE TO TEACH SUSTAINABILITY

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ABSTRACT

The future role of engineers is facing a shift in focus, from finding technical solutions to sustainable technical solutions. This shift will require engineers to have a different approach to sustainability and technical development. Introducing the Sustainable Development Goals can be considered in conformity with the more traditional methods of engineering where the goals can be seen as a specification where technology can contribute. This change is not only a challenge for the students but also for the teachers. For many teachers, sustainable development was not a part of their education and is not within their area of expertise. Therefore, many teachers feel uncomfortable about teaching sustainable development och struggle with how to incorporate it into their everyday teaching. Other teachers are experts in sustainable development but not in the specific discipline (here electrical engineering or mechatronics). The students need to learn how sustainable development is connected to their specific discipline. A method to introducing the sustainable development goals in discipline focused courses is presented, as inspiration for other teachers. The purpose was to create an assignment that all students found to be interesting and still not require the teacher to become an expert. The assignment was integrated in two discipline focused courses in the first and second cycle. The course evaluations showed that the majority of the students stated that the course had improved their understanding of the Sustainable Development Goals and the

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direct connection to their discipline was appreciated at both levels and made the assignments considered useful.

1 INTRODUCTION

The changes in society are imposing changes in engineering education. Several aspects need to be incorporated in the education in addition to the engineering subjects. Sustainable development is one of the aspects more recently incorporated. Sustainable development is expected to be important for engineers for a long time and needs to be understood in its context [1]. Incorporating professional responsibility for the public good requires a lot, since engineering education until recently was known to even train students to discard these areas [2]. The value alignment of overbelief in technical solutions is another challenge to overcome [3].

To avoid that sustainability will be a subject that the student forget after the course ended, the topic needs to be part of the disciplinary courses [3]. As consequence of that, the situation of the teachers needs to be addressed. In most cases teachers within a discipline have no or very little experience on how to integrate transdisciplinary subjects into disciplinary courses, which in turn could lead to a negative attitude [2].

There are several barriers identified that need to be overcome [4] to make a successful integration of sustainability in a disciplinary course. The organisational barrier is due to the strict division of teachers into groups and/or departments and the feeling of ownership of certain courses. The academic barrier depends on the teachers' interest of developing their own subject while the engineering barrier is based on the unwillingness to add unquantifiable aspects that do not fit methodology. To overcome the barriers several attempts have been made to design courses for teachers. However, these courses only seem to work for the teachers that need them the least [4]. Therefore, a discussion approach based on contribution of the discipline is suggested here and in [3].

In a disciplinary contribution discussion, students can be more involved and be used as drivers in the process [4]. The discussion based bottom-up approach may also limit the risks associated with use of top-down approaches in an academic research culture [4]. There are several pedagogical approaches to address sustainability in engineering education [5], for example the case-study approach. The approach can be implemented by addressing different angles on a particular theme and then bring the different angles together.

A method based on the bottom-up approach, as in [4] and a case study, as in [5] of the Sustainable Development Goals (SDGs) has been developed and tested as teaching activities in two different courses. The teaching activities were developed to ease the introduction of sustainability for both the students and the teachers despite the different goals, to create a win-win situation. The courses were part of one first cycle program (Mechatronics) and one second cycle program (Electric Power Engineering).

The purpose of this paper is to present a method to encourage teachers to dare to start teaching sustainability. The target group is teachers, who will start to integrate sustainability in their disciplinary courses, or pedagogical management who will lead a team of teachers into a more sustainable approach in otherwise technical disciplinary heavy curriculum.

2 TEACHING ACTIVITIES

The teaching activities in both programs were focused on introducing the SDGs. The first activity was an introductory lecture where the teachers introduced the goals and targets as well as gave some examples related to the discipline. The students were then divided into groups and were asked to select a few goals that they would like to discuss. They were later asked to present the goals they had selected. Based on the goals the students made a literature review and reflection in relation to the contribution of their discipline. Their findings were then presented at seminars to the entire student group for feedback, but also inspiration for other, since there are similarities between the contribution of different topics as well as between different goals.

2.1 Mechatronics

The Mechatronics program is a first cycle program and the SDGs were introduced in the first course of the program. The course is an introductory course to mechatronics engineering and the program. Sustainable development and the SDGs were introduced in two workshops. The first workshop started with the introduction lecture and after that the students were asked to study the SDGs briefly and then point out the goals most closely related to mechatronics. The students were divided into groups and each group was given one goal from the list of mechatronics related goals and one goal not on the list. The groups were then given two hours to divide the two goals between them, study them deeper and prepare a short presentation how each goal can be affected by mechatronics.

In the second workshop the question was reversed. The student groups were given mechatronic systems to study and answer how the system would affect the SDGs, positively or negatively. The results were then discussed in class to compare similarities and differences.

2.2 Electric Power Egineering

The introduction of the SDGs was also made in an international master’s program of electrical power engineering with about 50 electric engineering students from all over the world. The subject needed to the re-introduced since the group was very diverse when it comes to sustainability. The activities were a part of a mandatory project course and the topic of the discussion was their specific project assignment, that was different for each group. After the seminar the students were also asked to include their findings in the documentation of their project as a preparation for their master thesis work.

3 STUDENT AND TEACHERS VIEW

3.1 Mechatronics

The workshop concept of introducing sustainability was first used in the Mechatronics program in 2018. That year only one workshop was used. In the course evaluation, several students commented that sustainability was interesting and that they would have wanted to go deeper and discuss more.

In 2019 and 2020 both workshops were used, in 2019 in a classroom and in 2020 in Zoom. Both platforms worked well for the discussions and presentations. All students were engaged in the discussions and showed both interest and insight in the technical solutions and their advantages and disadvantages.

In the second workshop, many of the mechatronic systems were found to raise questions on whatever they would increase unemployment and how the batteries used in the systems were produced. Both questions are later addressed in the program. The ethical question about unemployment is used in an ethical essay and a course about batteries, energy and sustainability is given in the second year of the program.

3.2 Electric Power Engineering

In the Electric Power Engineering program, all students stated that they learned more about the SDGs and mostly they appreciated (> 85 %) the strong connection to their ongoing project. However, it had only a minor impact on their project, probably due to late scheduling of the activity in relation to the start of the actual project. Before the introduction lecture they thought it would be a hard assignment, but they reconsidered later. The students primarily selected the middle goals (4-12) which have more technical focus while the teacher addressed the more general aspects regarding climate and environment (13-16) to challenge the students. It turned out that the students preformed at similar level for both types of the goals.

Apart from the introductory lecture the students were very independent and due to different backgrounds of the students in each group they could handle the assignment almost on their own. Most questions could easily be handled with counter-questions as they were asked to reflect and there were not any really right and wrong answers.

4 REFLECTION

The teaching activities were used in two different courses: one first cycle course and one second cycle course. However, as the students in the second cycle course had studied sustainability (but not the SDGs) in their earlier studies, they were given a longer writing assignment and the first cycle students made shorter oral presentations, as the method allows adaption to the level of the students

The required preparations for the teachers are in form of reading up on sustainability, the SDGs on a basic level and identify some basic and easy identifiable examples of contribution. This can be done with support from a colleague or by literature. The main goal of the activity was to start a discussion and for the students to be aware of the SDGs and how they can be affected by different aspects of the discipline. In those discussions, the teachers' discipline specific knowledge was more important than the expertise in sustainability.

As a result of the discussions and the direct link between sustainability and their discipline, the students became more interested in sustainability and wanted to know more. To fulfill that desire and to help the students gain deeper knowledge it is important to continue teaching sustainability throughout the program. This work can with advantage be done in cooperation with an expert in sustainability. Then the link between sustainability and the discipline will still be visible and the knowledge deeper.

5 RECOMMENDATIONS

The results from these two courses show that the interest in sustainability can increase if the introduction to sustainability and the SDGs are made in a discipline specific course by the main teacher in that course, who does not have to be an expert in sustainability. Therefore, the first recommendation is to dare to teach sustainability, even if you are not an expert.

The students often have personal driving forces that the teacher can benefit from. Therefore, do not be afraid to take support by the students and have the students driving the discussions forward.

The introduction in a discipline specific course is a good start but need to be followed up by more specific courses later in the program, where experts in sustainability can interact more easily with students and discipline teachers as the bridge is already started.

The students come with different backgrounds and different knowledge in sustainability and that is an asset. The deeper knowledge of some students and the diversity in background can be utilised in the discussions to get a broader view in the discussion. Let the students be the experts when the teacher is not.

In many discussions, there will be no right or wrong answer. The discussions in themselves are the goal. Therefore, it is important to let the students work with the SDGs in groups and learn from that, rather than from lectures and the teacher.

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USING FILM IN ENGINEERING ETHICS EDUCATION

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ABSTRACT

In our engineering ethics teaching, we use films to illustrate and exemplify the ethical implications of engineering. While engineering ethics education can sometimes be seen as a chore or a box to be ticked, we argue that the use of film can contribute to a number of learning outcomes in engineering ethics education such as stimulating moral imagination and eliciting a sense of responsibility. In this paper, we argue that film could make the integration of ethics more meaningful to students by revealing and addressing their emotions, and by bringing fun and excitement into the classroom. We discuss different ways in which film could be used, and their benefits and drawbacks. Educators could: 1) micro-insert references to film, and illustrate or have students discuss ethical concepts using episodes from films. 2) encourage students to watch a film (chosen by the student) and have them analyse it from an ethical perspective. 3) collectively watch a film followed by discussion or activity. 4) encourage students to script and produce a narrative, which could be filmed or performed.

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1 INTRODUCTION

In our engineering ethics teaching, we use films like *Black Mirror*, *Star Wars,* and *Gattaca* to illustrate the ethical implications of engineering. While engineering ethics education can sometimes be seen as a chore or a box to be ticked (e.g. [3]), we argue that the use of film can be an interesting and exciting way to contribute to a number of learning outcomes in engineering ethics education such as stimulating moral imagination and eliciting a sense of responsibility. In a foundational paper in engineering ethics education, Harris et al. [4] produce a set of learning outcomes, namely, that it should:

- stimulate the ethical imagination of students,
- help students recognize ethical issues,
- help students analyze key ethical concepts and principles,
- help students deal with ambiguity,
- encourage students to take ethics seriously,
- increase student sensitivity to ethical issues,
- increase student knowledge of relevant standards,
- improve ethical judgment,
- increase ethical will-power.

Because film evokes emotions, imagination, sensibilities, and a connection to the personal, we believe that it can play a crucial role in engineering ethics education, not least because such education will not have an impact if it only becomes an exercise in moral reasoning without any connection to one's self [9, 10].

Given this, we find it remarkable that there is not an ongoing discussion about the use of film within engineering ethics education research. A search using the keywords "engineering ethics" AND "film" on Scopus returned only three papers that were returned, namely Berne [1] about the use of *The Matrix* in engineering ethics teaching, one paper by Riley [12] on a feminist critique of the educational film *Henry's Daughters*, and a short piece about the educational film *Incident at Morales* [13]. While not explicitly linked to engineering, Teays [11] presents an interesting how-to guide which suggests five strategies for using film in ethics classes. The paper includes a significant number of examples and exercises that the ethics instructor can be inspired by. However, it lacks explicit links to engineering education and learning outcomes.

Our paper is therefore aimed at developing this conversation, which can include reasons why film can be used in engineering ethics education, how it can promote different learning outcomes, and the advantages and disadvantages of using film in these contexts. We want to stress that we do not see film as *the* way to teach engineering ethics, but as *one* way: an educational method that can complement other more well-trodden routes, such as discussions about codes of conduct, case studies, and ethical tools [5]. Another clarification is that by describing film, we mainly mean those that are fictional, but could also include documentary films or films that are produced for the specific purpose of engineering ethics education. In this short paper we present four different ways in which film can be used, and illustrate each use with examples from our own teaching practice, which is followed by a concluding discussion.

2 USING FILM

There are several options available for educators wishing to use film in engineering ethics education, to some extent inspired by different ways of using drama in engineering ethics education [2]:

2.1 Micro-insertions: use references to film, and illustrate or have students discuss ethical concepts using episodes from films

Here, film is micro-inserted into an engineering ethics curriculum. For example, the story of the software engineer Morris in the TV series *24* and his ethical conundrum when he is kidnapped on his way to work and forced by terrorists to arm a dirty bomb to be detonated in the middle of a large US city can be a dramatic opening to a textbook [8] or course. Similarly, an instructor could lecture about this little episode in class, perhaps discussing it in terms of the concept of free will and coercion - how much responsibility does Morris really have for the consequences if he is tortured into arming the bomb?

Another somewhat more substantial, but still time-efficient exercise, is to use the case of Galen Erso found in *Rogue One*. After watching a clip of Luke Skywalker blowing up the Death Star in *Star Wars IV: A New Hope*, we turn the perspective over to the chief engineer of the Death Star, namely Galen Erso. He is forced to work for the Empire, so designs the Death Star with a flaw and leaks the drawings to the rebels so they can destroy it. The students can then be asked to analyse Galen Erso's action by using the ten principles in the Swedish honour code for engineers: which principles were followed and which were breached? This is a way to have students familiarize themselves with the honour code in an engaging way.

2.2 Encourage students to watch a film of their choice and have them analyse it from an ethical perspective

In this example, students could choose a film from a list of options, perhaps all centred around one topic. For instance, in the category of Artificial Intelligence (A.I.), films include *Her*, *2001: A Space Odyssey*, *Ex Machina*, and *Chappie*. Students could watch the chosen film as individuals or in groups, and analyse the conflicts and character choices according to ethical theories, principles or motivations. Each student or group could give a presentation to the rest of the class about how they found ethics to underpin the issues raised by the film, or write reflections about their personal reactions to the possibilities and potential perils of A.I. Additionally, technical and historical aspects can be brought into a class discussion: students could analyse the accuracy of the portrayal of A.I. technology and consider the perspectives of filmmakers and the public on their reactions to A.I. at different points in time.

In the course “Nature and Human Values” (NHV) at the Colorado School of Mines, instructors regularly use film to complement teaching about the ethics of different emerging technologies. NHV has had a structure that combines a large lecture with smaller seminar sections, and film has been used in both learning formats. For instance, in the unit about nuclear technology, excerpts of the documentary *The Day After Trinity* were shown to the large lecture section to present the reflections of the Los Alamos nuclear scientists and engineers on their efforts 40 years previously to build the atomic bomb. These film excerpts fed into ethical concepts like dual use and whistleblowing. In smaller seminar groups, students have watched episodes of *Star Trek* or excerpts from *Gattaca* to spur discussion about issues surrounding cognitive robotics, autonomy, and moral agency. These discussions enable students to increase awareness about ethical implications of technologies on people, culture, and policy [7].

2.3 Collectively experience a film followed by discussion or activity

Another possibility is to collectively watch a film and have a discussion about it afterwards. Positive effects include that all students experience the film concurrently, so emotional responses might be enhanced by the reactions of others. It is also a way to have all students watch the same film, rather than different ones, which means that they can all relate to the film and have an informed discussion with potentially diverging interpretations of what they saw.

At Uppsala University, we organized a voluntary meet-up with students in financial mathematics, to discuss the ethics of the finance industry. To do this we screened the film *Margin Call*, with an explicit encouragement that students should discuss the film afterwards, fueled by abundant servings of popcorn and non-alcoholic beverages, which was easily handled as the main teacher of the course had some funding. It was a bit complicated to get the rights from the Swedish distributor to show the film. Once approved, the film screening all took place in the teachers’ room at the Department of Information Technology, a spacious room with sofas, chairs, tables, and ideal for relaxed, creative discussions. After the screening, the student sat down in groups of five, and discussed different questions, for example: What were the ethical dimensions of the film? How does the finance industry work, and what subjectivities does it shape? Two teachers were walking around in the room discussing with the different groups. Groups argued intensely about issues including wage differentials and salary gaps.

2.4 Encourage students to script and produce a narrative, which could be filmed or performed

In this activity, students are charged with writing, directing, and producing a film related to a topic on engineering ethics. The film’s focus could range from professional situations such as those covered by the National Institute for

Engineering Ethics (students could even be asked to update or modernise the existing films) to covering ethical concerns like privacy, diversity, or autonomy, and they could be either documentary or fictional. For instance, in a class about “Water and the West” which addressed issues of sustainability and justice around water consumption in Colorado, some Mines honors students created a film in conjunction with their efforts to conserve water during the annual “World Water Day” initiative. Another option is for students to re-write the endings to existing films in order to demonstrate what would have happened if a character had made a different choice, or to explore a character’s perspective that wasn’t shown in the original. This example may be the most time-consuming and resource-intensive option, but it can also help students to practice relevant skills and meet engineering learning outcomes in other areas, such as teamwork, project management, and communication.

3 CONCLUDING DISCUSSION

As we have seen, using film in engineering ethics education has the potential to bring many benefits to students ranging from meeting learning outcomes to improving attitude toward what can sometimes seem to be dry or uninteresting topics. Film also provides the opportunity for instructors to incorporate other high-impact educational practices such as writing, collaboration, and even research into both technical and ethics courses [6]. However, some challenges and limitations do need to be addressed. Of course, some of these activities can be time-consuming, especially if they involve watching films together or scripting and producing a film or performance. Additionally, films might reinforce or amplify existing stereotypes about engineers, technologies, or cultures in terms of how characters or situations are represented and portrayed. Left un-critiqued, these could actually be detrimental to ethics education. Finally, there is still a perspective that film study is not “serious” or intellectually challenging, perhaps contingent on the hidden curriculum in engineering education [14], and instructors and students alike may be criticized for engaging with it as a method of learning.

To sum up, film can be an impactful addition to a program of engineering ethics learning. It is a way for students to consider the relationship of emotion to morality, to practice their ability to recognize ethical dilemmas, to analyse the perspectives of different stakeholders and consequences of different decisions, and to apply ethical reasoning to various scenarios. In many respects, it is a place to “play,” trialing ethical habits of mind in a safe-to-fail environment. Used in conjunction with other methods of teaching engineering ethics, film has the potential to make the integration of ethics more meaningful to engineering students.

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SUSTAINABLE CHANGES BEYOND COVID-19 FOR A SECOND SEMESTER PHYSICS COURSE FOR ELECTRICAL ENGINEERING STUDENTS

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Conference Key Areas: *Please select two Conference Key Topics*
Keywords: *Please select one to four keywords*

ABSTRACT

The course Physics for Electrical Engineering is part of the curriculum of the bachelor program Electrical Engineering at University of Applied Science Aachen. Before covid-19 the course was conducted in a rather traditional way with all parts (lecture, exercise and lab) face-to-face. This teaching approach changed fundamentally within a week when the covid-19 limitations forced all courses to distance learning. All parts of the course were transformed to pure distance learning including synchronous and asynchronous parts for the lecture, live online-sessions for the exercises and self-paced labs at home. Using these methods, the course was able to impart the required knowledge and competencies. Taking the teacher's observations of the student's learning behaviour and engagement, the formal and informal feedback of the students and the results of the exams into account, the new methods are evaluated with respect to effectiveness, sustainability and suitability for competence transfer. Based on this analysis strong and weak points of the concept and countermeasures to solve the weak points were identified. The analysis further leads to a sustainable teaching approach combining synchronous and asynchronous parts with self-paced learning times that can be used in a very flexible manner for different learning scenarios, pure online, hybrid (mixture of online and presence times) and pure presence teaching.

1 INTRODUCTION

1.1 Physics module before covid-19 crisis

At the faculty of Electrical Engineering and Information Technology physics is a second semester module with 7 ECTS for the electrical engineering students. Main topics of the module are mechanics, thermodynamics, optics, waves and solid state physics. According to the curriculum it consists of 4 lessons lecture, 2 lessons exercise and 1 lesson lab per week and up to 120 students participate each summer term (one lesson corresponds to 45 minutes). In addition to the 7 lessons per week the students should work for another 7 hours at home for learning, preparing,

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exercising and wrap-up. Before the covid-19 crisis the module was conducted in a traditional way. Besides the experimental work also reports are part of the labs. During lectures some activating elements were included like live experiments and demos and online quizzes. ILIAS was used to distribute the learning material [1].

1.2 Ad-hoc change to online teaching

During March 2020 – the beginning of the covid-19 crisis in Germany – the situation for the summer term starting end of March was unclear. No efforts were spent at that time to prepare an online semester – a great misjudgement. One week before the start of the summer term it was decided by politics and university administration to change the semester to pure online mode. Therefor, just one week remand to find a suitable solution and setup to run the module without any face-to-face elements.

2 METHODOLOGY

Based on department internal discussions and strong support by the IT department it was decided for all modules of the department to use Webex Training to replace the face-to-face elements. The concrete setup of how to integrate this video conference tool dedicated for online trainings was up to each module. For the physics module the ad-hoc setup was a mixture of synchronous and asynchronous elements and communication channels to enable an activating learning style using inverted classroom methods with distance learning, similar to Ref. [2], to focus on the discussions about the content during the live online sessions:

- **Lecture:** The lecture changed to distance learning with an inverted classroom approach ([3], [4]), the slides were completed with an audio track to form rather short (up to 30 to 40 minutes) learning units. Videos form the live experiments were included in these units for visualization and basis for explanations. These learning units were uploaded to ILIAS using a date based folder structure for better orientation of the students. During the synchronous live sessions via Webex training the content of the corresponding units were discussed and the integrated quiz supported the students to control their learning success.
- **Exercise:** The exercises were conducted synchronously during online live sessions to enable discussions about the approaches, unclear methods and solutions of the exercises or other questions.
- **Lab:** The lab was purly asynchronous. Therefor, simple using inverted classroom like in [5] was not possible. Also a transfer from experiments to pure written work like in [6] was not suitable for the learning target. Two new experiments were developed – one using a pendulum, one using a rolling element – in such a manner that these experiements can be conducted by the students at home in groups of two using just basic sensors of a smartphone and some basic material. The reports for both experiments were uploaded to ILIAS, corrected and returned to the students until the report was correct.
- **Communication:** As the pure online execution of the module was new to both lecturer and students, several communication channels were set up, for

instance synchronous communication during the live sessions, and asynchronous communication via mail and a Webex Teams group. In addition the students used Whatsapp for their communication.

3 EVALUATION, DISCUSSION AND RESULTS

The evaluation was done in several steps, a self-designed online survey during the semester, the official evaluation and own observations of the lecturer.

3.1 Online survey during the semester

The self-designed online survey took place 6 weeks after the start of the semester. Main purpose of this survey was to check whether the ad-hoc setup of the module works for the students or not. 32 students participated and main results of this survey are listed in Table 1. From suggestions by the students a detailed plan for the lecture as well as an optimized file size for the learning material were taken into account. All communication channels were used. Main drawbacks of the current setup were the missing live sessions at the campus and the distraction of attention at home.

Table 1. Summary of main results of self-designed online survey and the evaluation (1: very good; 5: very bad or 1: much to high; 3: fitting; 5: much to low for workload)

Question	Online survey	Evaluation
How satisfied are you with the module?	1.8	1.5 (1.6)
How is the structure?	---	1.6 (1.5)
How is your learning success?	---	1.8 (2.3)
Does the setup supports self-learning?	---	1.6 (---)
How is responsiveness of lecturer	1.3	1.2 (1.4)
What about the workload?	---	2.5 (---)

3.2 Evaluation at the end of the semester

The formal evaluation took place at the end of the semester with 30 participants. Even though the sample size is again rather low, the results were used for analysis and main results are also listed in Table 1. For comparison the average results of presious years are given in brackets. Compared to the online survey both satisfaction and responsiveness improved at the end of the semester. Compared with previos years there is just a slight difference for structure, satisfaction and responsiveness whereas the learning success improved significantly. Considering that the evaluation survey differs both from the online survey and the survey from previous years, this results shows at least that the online module maintained its results and could improved the learning success – at least for the participants. Main topics of the written feedback were problems with the lab at home including the report and again the missing live session at campus (Fig. 1).

3.3 Lecturer's observations

Both lecturer and students adapted quickly to the new teaching format. After some technical issues and lacking experience in the beginning the setup with synchronous and asynchronous parts worked very well (Fig. 1). During the live sessions fruitful discussions evolved, even to a higher extent compared to live sessions during normal semesters, demonstrating highly motivated participants. On the other hand just about 40 % of students joined the synchronous sessions. Hence a majority failed to attend the live sessions. Unofficial feedback was both missing motivation and self-organization as well as satisfaction with the learning material provided via ILIAS. The lab ran rather well, but the iterations until the final report was higher compared to the previous years. Even though several communication channels were used it was difficult for many students to find and build their own study groups. The average result of the final exam corresponded very well with the results from the previous years (2020: 3.2; 2015-2019: 2.8-3.6).

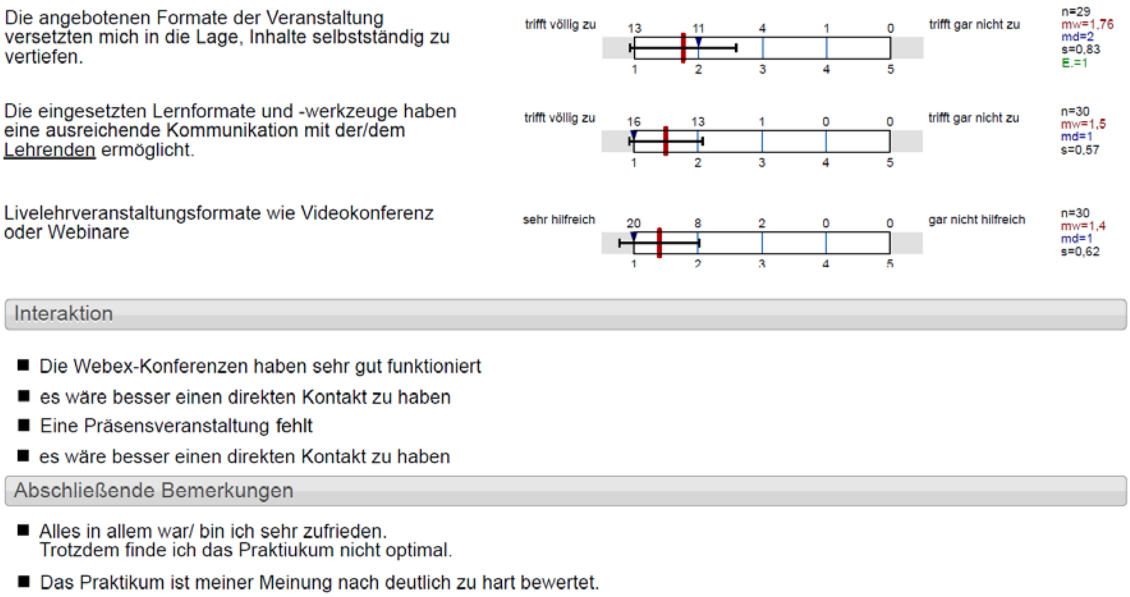

Fig. 1. Extract of some results of the formal evaluation

4 IMPROVEMENTS AND SUSTAINABILITY

Several improvements were taken into account to increase the learning success for the students and to convert the ad-hoc setup into a sustainable format with a high degree of flexibility for on-site and online sessions. The structure for the lecture and the exercise was not changed as this inverted classroom setup with asynchronous and synchronous parts provided a clear structure for the students and imporved the quantity and quality of debates about the contents. This format also allows a high degree of flexibility with regard to online or live sessions at the campus. More sophisticated quizzes and additional videos are introduced to increase activation of the students. Also the lab can be easily switched from online to on-site execution to adopt to the overall situation. Additional training sessions to improve the writing skills for the reports are introduced. For the whole department a dedicated team building forum is implemented in ILIAS.

5 SUMMARY AND ACKNOWLEDGMENTS

Despite the challenges of the ad-hoc change to a pure online semester the implemented setup turned out to be rather successful. In addition, it forced the implementation of new learning methodologies. To transfer this setup into a sustainable and flexible setup the evaluation and feedback from summer term 2020 were taken into account. The new setup, which is used in summer term 2021 with unclear perspective whether on-site sessions will be possible, shows a high degree of flexibility for online and on-site teaching and incorporates elements of the inverted classroom concept wherever suitable. The author thanks the IT department for strong support during the ad-hoc transition to online teaching including excellent tools, suitable IT infrastructure and fast and helpful responses to any inquiry.

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THE IMPACT OF COVID-19 ON HIGHER EDUCATION – ARE BLENDED LEARNING FORMATS THE WAY FORWARD?

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ABSTRACT

Higher education institutes all over the world have rapidly adopted emergency remote teaching in response to the COVID-19 pandemic. This shift has been analysed by numerous publications and from various angles. The state-of-the-art literature spans from descriptive analyses, which provide overviews on which tools or Learning Management Systems (LMS) were most frequently used, to more complex analyses that focus on the perception of technology adoption. The pedagogical field is urgently trying to understand and leverage the advantages and mitigate the drawbacks of e-learning to transition to post-pandemic scenarios. An early consensual lesson learned

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seems to be that presence learning cannot be fully compensated with digital formats, thus hybrid/blended learning formats seem to be the way forward. Yet, comprehensive insights into whether European higher education institutes intend to permanently incorporate the didactic shift to more digital formats post-pandemic are currently missing. Here, we present a review of 42 publications on digital learning during the COVID-19 pandemic and derive hypotheses regarding the future implementation of blended learning formats. This literature review will serve as the methodological foundation for the pedagogical studies planned within the ide3a project (https://ide3a.net). We plan to complement this effort with a Europe-wide survey among higher education institutes to identify best practices in digital synchronous and asynchronous, as well as hybrid/blended learning formats for international and interdisciplinary settings. ide3a will then provide the environment for testing some of these formats, as well as hypotheses related to the identified best practices.

1 INTRODUCTION

The COVID-19 pandemic has forced a rapid global shift to emergency remote teaching from March 2020 onward. At the time of writing, more than one year after the start of the pandemic, education is still largely remote. Various scientific and technical publications have analysed this abrupt shift to remote teaching and delivered first conclusions regarding its success and the overall impact of COVID-19 on higher education. This work presents the findings of a literature review aimed at identifying current trends, open challenges, and priority research questions to be investigated within the ide3a project (https://ide3a.net). As a project funded by the German Academic Exchange Service (DAAD), ide3a aims to test and establish blended learning formats within an international and multidisciplinary consortium of partner universities. The literature review presented here was conducted to formulate lessons learned during the pandemic in terms of pedagogic added value, or hindrances to take into account for future blended learning formats.

2 LITERATURE REVIEW

The literature review described here was conducted using the Technische Universität Berlin's (TUB) library search engine 'Primo' (https://tu-berlin.hosted.exlibrisgroup.com). Primo searches across the TUB's and Berlin University of Arts' collections, covering several hundred million articles and e-books, which are published by Springer, EBSCO, Wiley and ACS, among other academic publishers. The search was carried out in February 2021, which is why this review only includes publications up to mid-February. The search terms used were ("E-learning" OR "Remote learning" OR "Digital education" OR "Digital learning" OR "Online learning" OR "Distance learning") AND ("COVID-19" OR "Corona" OR "Sars-Cov-2" OR "Pandemic" OR "Crisis") AND ("Higher Education" OR "Tertiary education" OR "University OR Universities"). The search initially returned 12,999 results. These were filtered by publication date to fit the COVID-19 pandemic time span (2020-2021), by format (scientific peer-reviewed journals) to exclude newspapers or other non peer-reviewed formats, and key terms (Distance Learning, Education, Education & Educational Research, Learning, Higher Education). After filtering, the search returned 1,315 results. These were then further filtered based on their relevance as indicated by their title. Exclusion critieria were (i) 'Too sectoral (e.g., Dental Education)', (ii) 'Research on COVID-19 itself', (iii) 'Policy or practice suggestions during COVID-19', (iv) 'Mental Health effects of COVID-19 or the pandemic', or (v) 'Explicit focus on the first weeks of emergency remote teaching'. Fifty-one publications remained afterwards for review. During the review of these 51 publications, another 9 had to be excluded upon reading, as they turned out to be opinion, single page conference papers, data articles, or concentrated on secondary education. The final number of articles reviewed was 42 and their metadata are available in an open-access repository [1].

3 RESULTS

3.1 Literature Review Outcome

3.1.1 Descriptive overview of review results

The remaining 42 publications were first categorised chronologically, according to their submission date. As can be observed in Figure 1, the majority of the publications reviewed was submitted before October 2020. It is likely that, at the time of writing, some of the publications submitted during the 'late stage pandemic' were still under review and not yet published. Otherwise, the contributions appear quite balanced, with only the student perspective articles slightly increasing during the 'mid stage'.

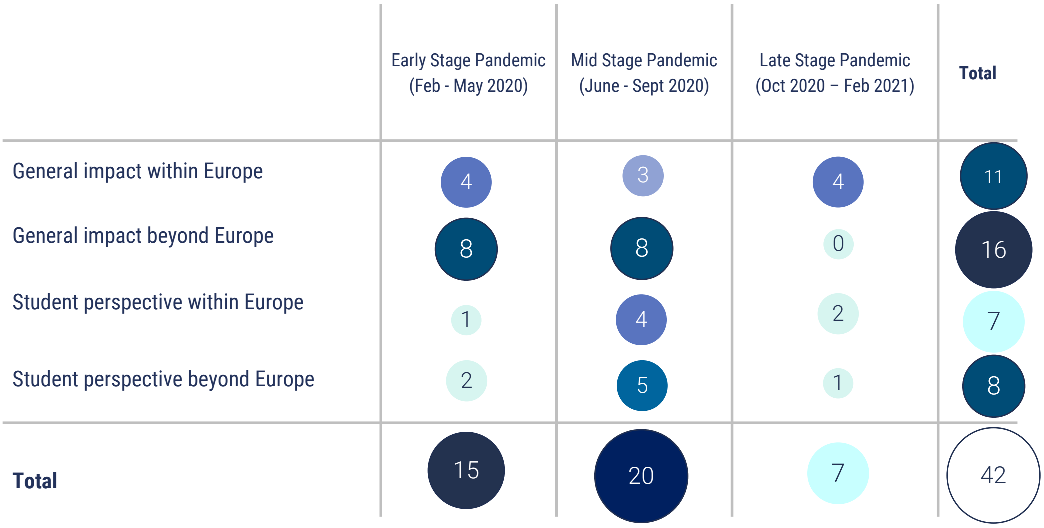

Fig. 1. Overview of literature review outcome. Note: The reviewed publications are categorised according to their submission date. Marker size and color are proportional to the number of papers in each category, indicated also by the label in each circle. Pandemic stages were determined by the global case number trend.

Regarding methodology and format, the majority of articles made use of surveys (50%), followed by experience reports (26%), interviews (9.5%), documentary analysis (9.5%) and literature reviews (5%). Characterised by their methodology, early stage publications concentrated more on qualitative analyses, with 66% of publications relying on experience reports, interviews, and documentary analyses, while this is the case for only 40% in mid and late stage publications. The use of surveys doubled from early stage (30%) to mid (60%) and late (60%) stage publications [1]. Despite filtering for explicit niche focus, it can be said that analyses of COVID-19 impact on higher education were still quite sectoral, with almost 50% of all reviewed articles concentrating on one sector or broader study field; 40% of these sectoral analyses focused on the medical or health services education sector. Additionally, 26% of articles were single-university studies. Although several articles also conducted multi-university surveys, there has only been one global study (n=30,383 participants) to date by Aristovnik et al. [2], concentrating on student perception.

3.1.2 Emerging conclusions

E-learning is not the same as emergency remote teaching, which became clear even in articles where authors used the terms interchangeably. As pointed out by 28%

(n=12 publications), the emergency response did not contain the same level of pedagogical planning and theory that e-learning usually should, and which would be required to ensure similar perceived success of the format compared to face-to-face teaching. Various tools were used to simply 'move' traditional formats online, making synchronous (live) remote lectures the most often used format (59.4%), followed by asynchronous formats (35.9%) such as sending presentations, video recordings, and written chat or forum communication. The remaining 4.7% were audio recordings [2]. The acceptance and intention to use tools such as these and digital pedagogy during the pandemic has been evaluated by several psychometric analyses using the Technology Acceptance Model (TAM), a model used to statistically identify psychological determinants of acceptance of information technology. The main predictor for acceptance and intention to use remote teaching was perceived usefulness, which for students was most strongly moderated by enjoyment [3]. In order for emergency remote teaching to be similarily effective and accepted compared to face-to-face teaching and e-learning, adaptations in the delivery of digital formats are therefore necessary.

The rapidness of the shift exposed large gaps in digital readiness and existing underlying issues, which explain the improvisational nature of the emergency response. 40% (n=17) of the reviewed articles pointed to the fact that instructors were lacking digital competences to execute proper e-learning, and additionally, in most cases received little structural or institutional support in aquiring these skills [1]. Many authors were also stern in pointing to underlying issues with their respective educational systems, which were highlighted by the pandemic. Legislative hinderances surrounding data privacy and e-learning in general are halting the digital transformation underway in Germany and Italy for example, silo-thinking and rigidity in schedules and curricula have created an often stressful experience for students, and access to higher education is still limited by the physical capacity of universities. Higher education institutes in developing countries are faced with the additional challenge of unreliable or expensive access to critical infrastructure, including electricity and cost of data bundles, pointing to missing investments on larger scales. Due to this confrontational experience, 47% (n=20) of reviewed articles saw the current emergency remote response as a chance for pedagogical improvement [1].

Levering the benefits of digital education formats could lead to a didactic paradigm shift after the pandemic. It is evident that the current state of emergency remote teaching is not going to remain the educational model after the pandemic. Yet, several articles indicated that some of the benfits experienced, especially related to the flexibility remote education can bring to the educational sector, should be retained. Some even directly voiced the wish to continue using digital or hybrid formats [4]. Blended learning therefore seems to be the way forward, both for enabling education during the eventual final phases of the pandemic and afterwards. 40% of reviewed articles (n=17) pointed to possible lasting effects or necessary shifts in didactic thinking for post-pandemic scenarios which could constitute a paradigm shift within higher education or a reinvention at least. Taking into consideration the lessons learned and still remaining aware that the true benefit of e-learning within higher education could not have been experienced during the emergency response, could allow for large scale integration of permanent e-learning formats, such as blended learning. Given the proper competences and infrastructure, such a shift could also enable larger access to higher education especially in developing countries, allow for flexibility in students' schedule and with that for other engagements such as care work, family and sources of income.

3.2 Future research priorities within ide3a

Based on the findings of this literature review and calls for research on both best practice formats during emergency remote teaching and the potential of future e-learning use by several articles (n=12), we have formulated the following research priorities to be investigated within the ide3a project. First, the relationship between instructors having received support during the shift to digital formats and their intention to incorporate digital pedagogy in the future should be explored. Second, based on the findings on predicting factors of technology acceptance of some articles, and the additional generational gap between digital natives and their instructors, is there a difference between student and instructors' hopes and intentions for post-pandemic education formats? These research priorities will be examined within the ide3a project using a large scale Europe-wide survey addressed to both students and instructors. Finally, different digital best practice formats (synchronous and asynchronous formats) will be compared to blended formats and evaluated in their instructional effectiveness as well as for benefits in international short-term mobility within the ide3a project.

4 CONCLUSION

In this paper we summarised the outcomes of the literature review we conducted on the impacts of COVID-19 on higher education and the research priorities we derive from them for our ongoing ide3a project. Our literature review findings largely confirm those of Aristovnik et al. [2], dated August 2020. Most data and conclusions regarding the impact of COVID-19 on higher education stems from relatively early stages of the pandemic and are largely sectoral or focus on single universities. Nontheless, it is evident that the current emergency remote teaching formats are to be distinguished from e-learning, which has not been adopted in its full potential. The improvisational nature of the shift to digital teaching is largely due to underlying structural and institutional deficiencies in digital readiness, which have been exposed by the pandemic and present a unique chance for pedagogical reinvention. Whether digital pedagogy will remain within higher education and possibly transform teaching all together remains to be seen. Our findings are also confirmed and complemented by a recent analytical report by the European Comission [5] (published in March 2021), which formulates policy recommendations to address the challenges a continuned adoption of digital education formats will pose. Within the ide3a project, we will contribute to tackle the challenge of understanding and supporting instructors in their adaptation to digital formats and safeguarding the quality of higher education experience for students.

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STUDENT BEHAVIOUR AND LEARNING OUTCOMES IN A FLIPPED CLASSROOM WITH ON-DEMAND LECTURES AND ONLINE PEER TEACHING

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Conference Key Areas: *Methods, formats and essential elements for online/blended learning*
Keywords: *Distance learning, online, flipped classroom, peer teaching*

ABSTRACT

To create opportunities for collaboration among students and to improve learning outcomes during the COVID-19 pandemic, we designed a flipped classroom that combined on-demand lectures and simultaneous interactive online classes with peer teaching. We assessed the relationship between student behaviour and learning outcomes. The results showed that the students who achieved higher grades were more active and autonomous learners than their counterparts with lower grades, in both on-demand lectures and peer teaching.

1 INTRODUCTION

1.1 Flipped Classroom

Flipped classroom is an instructional strategy where students are provided with a set of preparation tasks prior to participating in more socially active and engaging face-to-face lessons [1]. Mason [2] pointed out the effectiveness of the flipped classroom in comparison to the traditional classroom in terms of content coverage, student performance and student observations and perceptions of the flipped classroom format. Overall, the flipped classroom is effective reliant on the level of student engagement with the preparatory activities prior to attending the face-to-face teaching sessions [3].

1.2 Fully Online Flipped Classroom During the COVID-19 Pandemic

If faculty members deliver one-way online lectures to a large class, students may have difficulty staying focused and can become demotivated. Moreover, students who are isolated within the context of the COVID-19 pandemic are deprived of the opportunity to learn from each other. To solve this problem, a fully online flipped class was designed to strengthen students' independent learning and concentration as well as to promote their collaboration and mutual learning. The flipped classroom combined on-demand lectures and simultaneous interactive online classes with peer teaching [4]. It was applied in 'Systems Engineering', a course offered through the College of Systems Engineering and Science. Approximately 600 students from five departments enrolled, and four faculty members taught the classes. The face-to-face lessons were held in four large classrooms for 160 students each.

1.3 Aim of the Study

This study investigates the relationship between students' behaviour related to preparing for class and their learning outcomes in the flipped classroom with on-demand lectures and online peer teaching.

2 METHODOLOGY

2.1 Procedure

We designed a combination of on-demand and simultaneous bi-directional classes, as shown in Figure 1, and followed the procedure shown in Figure 2. In the fully online flipped classroom, students acquired knowledge through on-demand lectures and studied the subject matter before attending a simultaneous interactive online class. During the class, they were divided into small groups for peer teaching. This allowed them to learn independently and actively and to freely communicate with each other.

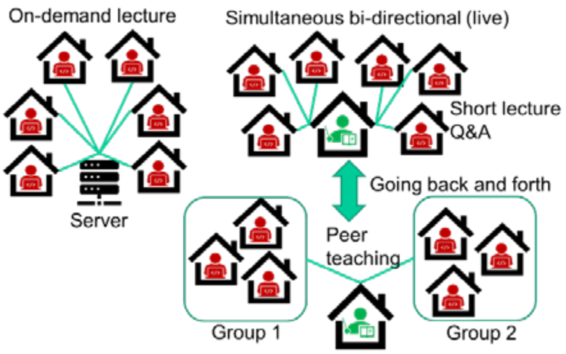

Fig. 1. Configuration of the fully online flipped class with peer teaching.

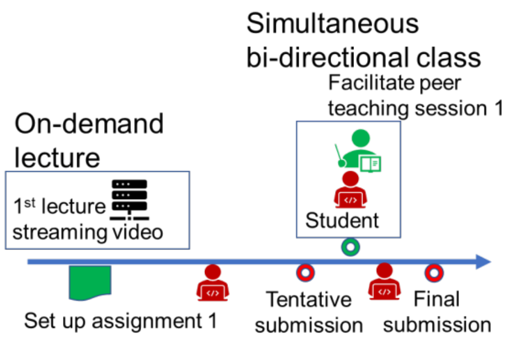

Fig. 2. Weekly schedule

The students were instructed to read designated sections of the textbook, review the assignments and watch the necessary parts of the on-demand lectures before the interactive class. They also submitted weekly assignments. They submitted a tentative assignment on the morning of the class and a final assignment two days after the class. The tentative submission served as evidence that the students had prepared for the class and did not require correct answers.

The 100-minute interactive class began with 20 minutes of instruction, followed by 60 minutes of peer teaching in 43 breakout sessions of four students each. The students then returned to the plenary session for 20 minutes of questions and answers. They were required to finish the final submission within two days of the class session.

2.2 Questionnaire

A questionnaire survey was administered to 176 students in one of the four classes. The students completed the questionnaire after the class. It contained a total of seven items: five questions about their class preparation behaviour and the benefits of peer teaching, and two questions about whether they preferred flipped classroom teaching or traditional classroom teaching and which format they preferred peer teaching to take place in.

Questionnaire:
I would like to ask you about your preparation for class. Please answer the following questions.
(1) How many minutes did you spend reading the textbook or other materials to prepare for each class?
(2) How many minutes did you spend watching the class recording to prepare for one class?
(3) How many minutes did you spend on the assignment to prepare for one class?
(4) Have you been actively involved in peer teaching?
(5) Has peer teaching been useful to you?
(6) Which do you prefer, a flipped classroom or traditional classroom?
(7) Which is the best way to implement peer teaching—in an online class, in a face-to-face class, or switching between online and face-to-face classes on a weekly basis?

2.3 Analysis

A correlation analysis was conducted on the responses of 128 students (out of the 176 students in the class) for whom both the questionnaire responses and grades were valid. Then, the data of 28 students (of the 128 students) with intermediate grades were excluded, and a comparison of student behaviour was made between the top 50 and bottom 50 students.

3 RESULTS

Table 1 shows the relationship between the students' class preparation and their grades. Compared to students with lower grades, the students who achieved higher grades spent more time reading the textbook (Question 1) and examining assignments as preparation (Question 3) ($p < 0.05$). On the other hand, there was no significant difference in the amount of time spent watching on-demand lectures (Question 2). There was a significant difference ($p < 0.01$) in the total amount of time spent preparing for each class, with the top performers spending an average of 192.4 minutes and the bottom performers spending an average of 153.4 minutes.

Table 2 shows the relationship between the students' behaviour in peer teaching and their grades. Both the high- and low-achieving students actively participated in peer teaching, but the high-achieving students engaged more actively ($p < 0.05$). There was no significant difference between the two groups in terms of the effectiveness of peer teaching. In the open-ended responses, the high-achieving students said that peer teaching helped them get answers to their questions and that they understood more by teaching colleagues. The low-achieving students only wrote that peer teaching answered their questions.

In response to the question about their preference for a flipped or traditional classroom, 60% of the high-achieving students and 36% of the low-achieving students chose the flipped classroom, while 22% of the high-achieving students and 30% of the low-achieving students chose the traditional classroom. The rest responded that they had an equal preference for the two approaches. As for the format of peer teaching, 52% of the top-performing students and 56% of the bottom-performing students reported that they preferred it to take place online, while 26% of the top-performing students and 28% of the bottom-performing students preferred a face-to-face approach. The remaining students said they would like alternating online and face-to-face weeks.

Table 1. Relationship between students' class preparation and grades

	Question (Answer in minutes)	Students with higher grades (n = 50)		Students with lower grades (n = 50)		p-value	
		Mean	SD	Mean	SD		
1	How many minutes did you spend reading the textbook or other materials to prepare for each class?	56.1	36.7	43.4	22.8	0.020	*
2	How many minutes did you spend watching the class recording to prepare for one class?	34.6	28.6	32.0	25.7	0.318	
3	How many minutes did you spend on the assignment to prepare for one class?	101.7	61.6	78.0	38.4	0.012	*
	Total	192.4	89.6	153.4	64.9	0.007	**

* p < 0.05, ** p < 0.01

Table 2. Relationship between students' behaviour in peer teaching and grades

	Question	Answer		Students with higher grades (n = 50)		Students with lower grades (n = 50)		p-value	
4	Have you been actively involved in peer teaching?	active	5	56.0%	90.0%	30.0%	80.0%	0.010	**
		somewhat active	4	34.0%		50.0%			
		neither active nor passive	3	6.0%	6.0%	14.0%	14.0%		
		somewhat passive	2	4.0%	4.0%	6.0%	6.0%		
		passive	1	0.0%		0.0%			
5	Has peer teaching been useful to you?	useful	5	44.0%	82.0%	42.00%	70.0%	0.38	
		somewhat useful	4	38.0%		28.00%			
		neither useful nor unuseful	3	6.0%	6.0%	24.00%	24.0%		
		somewhat unuseful	2	10.0%	12.0%	6.00%	6.0%		
		not useful	1	2.0%		0.00%			

* p < 0.05, ** p < 0.01

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STUDENT-DRIVEN LEARNING OF PROFESSIONAL SKILLS IN THE SUPPORT OF INTERDISCIPLINARY TEAMWORK

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***Keywords**: Interdisciplinarity, Project-based Learning, Student-Driven Learning, Engineering Education.*

ABSTRACT

Interdisciplinary project-based learning facilitates the development of a range of skills and knowledge through autonomous learning or an experiential educational structure. The ability to cooperate across disciplinary boundaries within a team environment is an inextricable component, and supporting the necessarily skills for doing so, via the deliberate development professional skills-training, is arguably crucial. As tutors may lack time or expertise to extensively scaffold interdisciplinary teamwork, the question is whether a minimally guided student-driven learning context in which students are left to decide on which professional skills to develop, can be effective, given the collaborative challenges students face. For this study, a trial was implemented to ascertain whether students would recognise the importance of and engage with, resources designed to foster professional skills in a collaborative interdisciplinary context. A variety of student-driven resources were implemented with varying degrees of success. Students were encouraged to use a team contract with the aim to delineate expectations and pre-empt strife. Professional skill resources on topics such as communication and conflict management were offered in order to enhance self-reflection and self-development. There was some indication that team contracts offer a safe condition to set expectations, but there was low interest in the student-driven courses aimed at professional skills. The results suggest autonomous modes of

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learning may not be appropriate for the development of such skills. The ability to motivate students to adopt the student-driven approach as well as prioritise time in their busy schedules, remains elusive. Details on the rationale of resources as well as recommendations for use are offered.

1 INTRODUCTION

Interdisciplinary (ID) project-based learning (PjBL) requires students from contrasting disciplinary backgrounds to collaborate on an interdisciplinary problem-solving task. In these contexts, interdisciplinary teamwork and professional skills are not always trained explicitly in university programmes. Rather, in line with the self-driven learning philosophy governing PjBL [1], it is often assumed that these skills will be developed through the process and experience of the group project. This is as groups confront tensions between conflicting ideas and epistemologies [2]. Some research has pointed out however, that interdisciplinary interactions can be more challenging than disciplinary ones, and that the development of collaborative and team skills i.e., should not be taken for granted [3]. Therefore, the need for professional skills training is becoming recognised as an important facet of tertiary education [4].

However, often due to time and staff constraints, many programmes are unable to support ID training beyond a few workshops. Even then, not all workshop-based initiatives are necessarily appreciated by students [5]. In this study, the aim was to ascertain whether autonomous learning of these skills can be effective. The experiment was undertaken at the University of Twente, where we trialled the effect of certain low-intensity initiatives, in two ID project-based courses, for bachelor students of different science and engineering backgrounds. These initiatives involved 1) the inclusion of a team contract, and 2) student-driven learning (SDL) resources supporting professional skill development. The details and objectives of the SDL resources are explained in *Table1.*

Table 1.: Student-driven Courses, Topics and Intended Learning Outcomes offered to Case study 1 & 2

Provided Resource	**Intended Skills**	**Intended Attitudes**	**ILO –** Students are able to…
Team Agreement *(Slides & example doc.)*	Defining & expectations Negotiation	Self & mutual respect Responsibility Accountability	… set team goals & desired behaviours into writing.
Non-Verbal Communication Guidance *(Slides)*	Self-evaluation Self-correction	Respect Confidence	… analyse own NVC habits, improve own comm. deficiencies.
Conflict Management *(Slides, role play prompts)*	Identify harmful behaviours Manage uncomfortable situations	Empathy Perceptiveness Resoluteness	… assess difficult situations, use considered response.
Teamwork Traps *(Slides)*	Assessment of status quo Challenging	Active Critical Reflective	… classify team behaviour, take necessary steps to avoid traps.

The trialled resources are consistent with the philosophy that students within PjBL should be responsible for making their own decisions regarding the development and management of their team relationships.

2 METHODOLOGY

2.1 Case study setting

To examine the effects of the uptake of SDL resources and their perceived usefulness to students, a two-case, mixed-method, descriptive study was undertaken. Student surveys, staff interviews and peer feedback were analysed. Design of materials was based upon IPT Metrics, a research based team assessment platform [6].

2.2 Case study details, instruments and sources

Participants: Two ID modules joined the study. Both cases had access to the teamwork resources, but only Case study 1 had access to project-related resources due to the co-ordinators preference, see *Table 4*.
Instrumentation: A digital survey was sent to all students of both modules, 123 responded. The survey consisted 5 agreement statements (Likert scales), and 3 open questions. Open answers from the student surveys and peer feedback underwent thematic analysis. *Materials used:* SDL resources were made available for self-study on the learning management site - Canvas.

3 RESULTS

Case Study 1: Interdisciplinary Engineering Module. (N=77)
Case Study 2: Interdisciplinary Computer Science Module. (N=46)
When surveyed on team function, around 70% of students in both groups were positive mid-way through their modules. At the end, most students in the CS1 group (79%) were positive. However, CS2 students were evenly split, although with a low response rate (N=10).

Team Contracts: Their use was encouraged by the module coordinators. 90% of students applied them. *Table 3* shows that at least a quarter of the users found them directly helpful. Positive written responses revolved around the advantages of starting the teamwork well by setting expectations, negative comments centred around them being time consuming or futile.

Table 3. Team Contract Usage Categories

Categories of answers	**CS1** Number (%)	**CS2** Number (%)
Positive response	18 (23%)	13 (28%)
Did not refer back to it	16 (21%)	3 (6%)
No need: good team functioning	13 (17%)	5 (11%)
Neutral/Negative	23 (30%)	20 (44%)

Examples of the comments on the team contract:

“Yes, it was a great icebreaker and good way to lay down rules without being bossy about it.”

“Yes but the contracts themselves are kind of pointless most if not all students don't really care about creating an extensive contract…”

SDL Resources: These were not well utilised. Less than one third of students engaged with them. The positivity expressed on the team functioning question, may mean well-functioning teams saw no need to engage with the resources.

Table 4. Student-Driven Professional Skills Resources

Categories of Resources	**CS1** Number (%)	**CS2** Number (%)
No	**65%**	**75%**
Yes	35%	25%
Project-Related Resources		
Presenting and Pitching	4	n/a
Deliverables	16	n/a
Brainstorming	9	n/a
Remote collaborative working	1	n/a
Teamwork/ Process-Related Resources		
Communication	5	9
Conflict Management	5	-
Teamwork Traps	-	1
"yes"	2	1

Examples of the comments on the SDL courses:

"Not really, we looked quickly into them but timewise wasn't really efficient to follow them all."

"Communication. The content was sound and logical but I didn't have a specific use case for them in the current project, however I may use them later along the line."

4 CONCLUSIONS & DISCUSSION

In this paper we set out to explore whether some minimally guided student-driven tools provide effective responses to ID collaborative challenges and professional skill development. We conclude while the team contract has some benefits, the self-driven courses were not perceived as useful or relevant by most students and thus not engaged with. In both cases, some student teams faced challenges related to different disciplinary backgrounds. Also, teamwork function took time to develop in many cases. In principle both the team contract and SDL resources were provided to students in order to manage such situations.

Team Contract: The mixed response with regard to the team contract, indicates utility for a certain type of student who can apply it as a means to pre-empt teamwork issues. When referring to the high levels of team functioning satisfaction it is possible that the team contract, even if not evoked again, played a role in establishing firm expectations and penalties for unacceptable behaviour.

Student-Driven Courses: These case study results provide evidence that student-driven interventions, geared towards enabling team or professional skill development, were not perceived as useful by most of the students. This suggests students did not recognise a payoff for developing these skills in order to improve team performance and ultimately their overall result, despite the challenges still faced by some.

The failure of this SDL trial may be partly explained by a few considerations. Firstly, although students from different backgrounds evaluated the courses differently in terms of task opportunities and role, students may not have recognized that their different levels of engagement were not only a function of course or problem design, but also a matter of collaborative or professional skill deficiency; something within their power to potentially improve. This points to the importance of articulating the relevance of such skills to students. [7] states that fostering SDL competence in formal educational settings may be necessary. Here, students were not offered support on their SDL journey. Rather, they were provided with a list of options from which they could choose according to their own identified need. Secondly, the lack of constructive alignment with regard to explicitly measuring team functioning meant that students had to rely on intrinsic motivation to follow these courses. There were no credits at stake, so were more prone to invest time on tangible endeavours. Finally, [8] cites lack of learner support as a demotivation for SDL; when there is no feedback or obvious reward for the effort expended, it becomes less motivating to learners.

As a result, there are various interventions instructors can make to encourage better recognition, by students, of the need to develop team-work or professional skills. For example, in order to enhance prominence, incorporating credits and the recognition of the teamwork process via constructive alignment of courses, may underline its importance for all.

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HOW DO ICT ENGINEERING STUDENTS EXPERIENCE ONLINE TEACHING AND LEARNING?

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Conference Key Areas: *Methods, formats and essential elements for online/blended learning, Social aspects and communication in online/blended learning*
Keywords: *Motivation, students' learning experience*

ABSTRACT

Due to Covid-19 pandemic, universities were forced to quickly shift from on campus operations to online teaching and learning. At Tampere University of Applied Sciences (acronym TAMK) online teaching was implemented with a few days' notice in March 2020. Since then, teaching has been organized mainly online. As online teaching and learning continues, concerns about students have grown.

The aim of this study was to explore TAMK's ICT engineering students' learning experience, academic success, wellbeing and studying motivation during Covid-19 pandemic. An online survey was sent to all ICT Engineering student at TAMK in March 2021. The survey focused on students' experience related to online teaching and learning. For designing the survey questions related to motivation factors, Pintrich et al. [1] Motivated Strategies for Learning Questionnaire (acronym MSLQ) was applied.

A total of 127 ICT engineering students responded to the survey. The results emerged concerns such as two-thirds of respondents experienced that their motivation to study has decreased during the academic year 2020-2021. Additionally, almost 50 % of the respondents experienced that 'I have done a less work with my studies during online teaching and learning than in the past' and 60 % felt that they haven't reached the same expertise during online teaching than they would have reached in face-to-face teaching. However, the respondents were mainly satisfied with the way in which online teaching has been implemented.

1 INTRODUCTION

When the Covid-19 pandemic started in Finland in March 2020, universities were forced to quickly shift from on campus operations to online teaching and learning. At TAMK online teaching was implemented with a few days' notice. University lecturers had a few days to build in their homes online teaching facilities and redesign their courses.

Since March 2020, teaching has been mainly organized online at TAMK. In many cases, there hasn't been time to evaluate the best pedagogical practices but just act and continue with teaching [2,3]. There haven't been time, enough expertise, or sufficient recourses in developing teaching staffs technological and pedagogical online teaching skills.

Before the Covid-19 pandemic, teaching mainly took place in classroom settings at TAMK's ICT engineering department. Many teachers taught traditionally, i.e., classroom sessions included teaching, mentoring, and doing various exercises or laboratory work depending on the course. Practically teaching through Zoom or Teams was not provided and only a few teachers, for example, used short educational videos to support teaching. With the pandemic, both students and university lecturers found themselves in a new situation.

At the time of writing this short paper, the Covid-19 pandemic continues. It is not yet known what the possibility is for organizing face-to-face teaching and what kind of regional restrictions there will be during the autumn 2021. However, it is certain that online learning will be continued to some extent, at least for the third- and fourth-year students. TAMK administration has also outlined that the amount of online learning will increase in the coming years.

As online teaching and learning continues, concerns about students have grown. This study aims to explore TAMK's ICT engineering students' learning experience. The following research questions are addressed:

1. How do ICT Engineering students experience remote learning?
2. What kind of study motivation do students have?
3. How do students experience their academic success?
4. How are the students doing?

2 METHODOLOGY

2.1 Survey

The study was conducted with an online survey during March 2021 and it was targeted to ICT engineering students at TAMK. The head of ICT engineering degree programme sent the link of the electronic survey via email to all ICT engineering degree programme's students.

The survey included both qualitative and quantitative questions. Most of the quantitative statements were constituted using 5-point Likert scale with 'don't know' option (1 = 'fully agree' to 5 = 'fully disagree') or (1 = 'daily', 2 =' weekly', 3 = 'a few times a month, 4 = 'rarely', 5 = 'not at all'). The survey mainly focused on engineering students' study experience during the pandemic. The survey consisted of items concerning students' learning experience, academic success, wellbeing, and motivation. Pintrich et al. [1] MSLQ was applied for designing statements on motivation. The survey contained also general information such as sex, background studies, year of studies, working in a job during current academic year and weekly working hours.

2.2 Sample

The study participants were students of ICT engineering degree programme at TAMK. A total of 127 students responded to survey, which means slightly under 40 % response rate. The majority of survey participants was male (77 %) and the minority female (20 %) or other (3 %). Before studies at TAMK, 54 % of participants had studied in high school, 34 % in vocational school and 10 % had double degree (both high school degree and vocational school degree). About one-third of the respondents were 1st year students. Table 1 shows the overall distribution of respondents' studying year.

Table 1. Distribution of respondents year of study

Year of study	Percentage
1st year	38 %
2nd year	23 %
3rd year	16 %
4th year	19 %
other	4 %

2.3 Analysis

The majority of the collected data is quantitative, and the results of the survey are described with descriptive statistics [4] including modes, medians, summaries of sample and distributions of variable. The used statistical method was chosen based on the data type.

3 RESULTS

This short paper reports the preliminary results of the study and more detailed statistical analysis will be carried out later. However, already at this stage, several concerns have emerged from the results. The results have been categorised based on research questions (see section 1).

3.1 Remote learning and academic success

Students' experience of the suitability of online learning for them varies. As figure 1 shows, at the same time almost half of the respondents agreed that 'online teaching suits me' (47 %, median = 3) and other half felt the opposite (46 %) (1 = 'fully agree' to 5 = 'fully disagree').

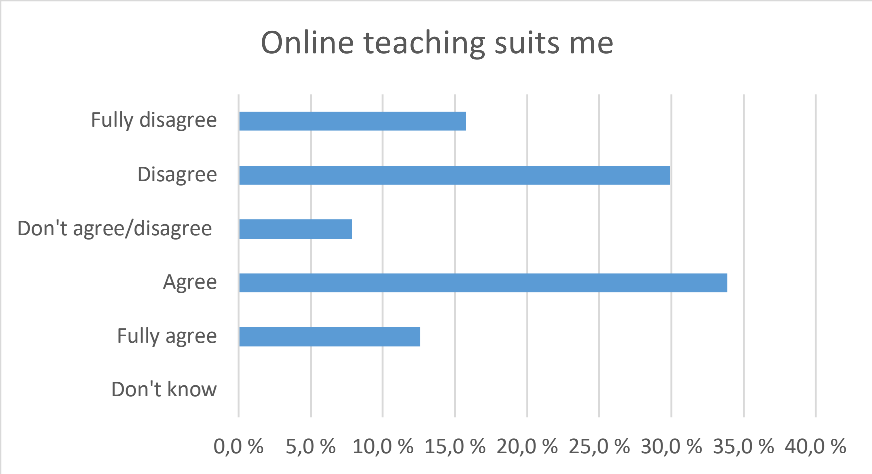

Fig. 1. Suitability of online teaching

Although about half of the respondents experience that online teaching is not suitable for them, only about one-fourth of the respondents reported, that their course grades have dropped during the pandemic. However, about 30 % of the respondents experienced that they would have needed more individual guidance during online learning. Figure 2 shows, how students compared their learning between face-to-face and online teaching.

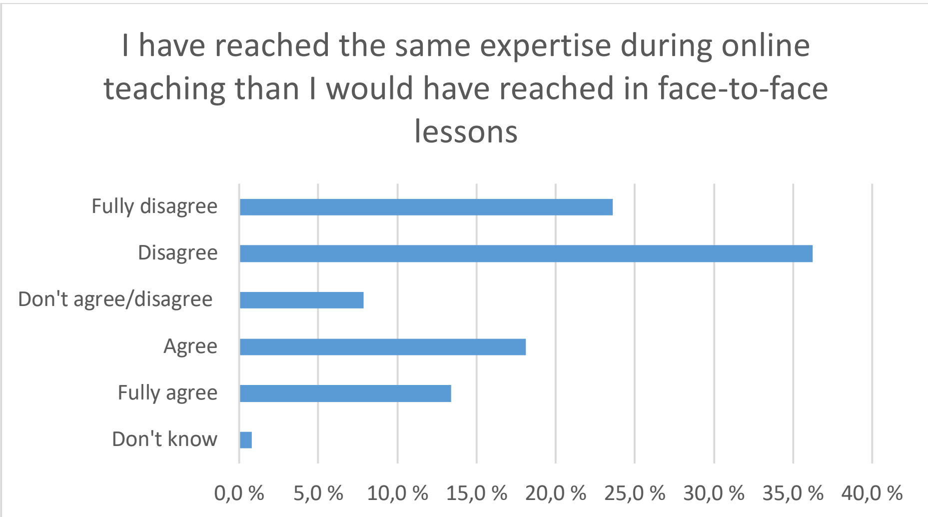

Fig. 2. Students' learning

Almost 60 % of respondents experienced that they hadn't acquired the same expertise during online teaching than they would have reached in face-to-face lessons (statement: 'I have reached the same expertise during online teaching than I would have reached in face-to-face lessons'; mean and mode = 4). The same amount of respondents experienced in general, that 'I don't learn as well in online teaching as I would learn in face-to-face lessons' (mode = 1, median = 2) (see figure

3). These results are inconsistent with the literature [5, 6] but the results may be explained by the fact that the courses at TAMK are not originally designed to be suitable for online learning. [5] explored the online leaning instructions designed and implemented for online learning needs using proper pedagogy and technology.

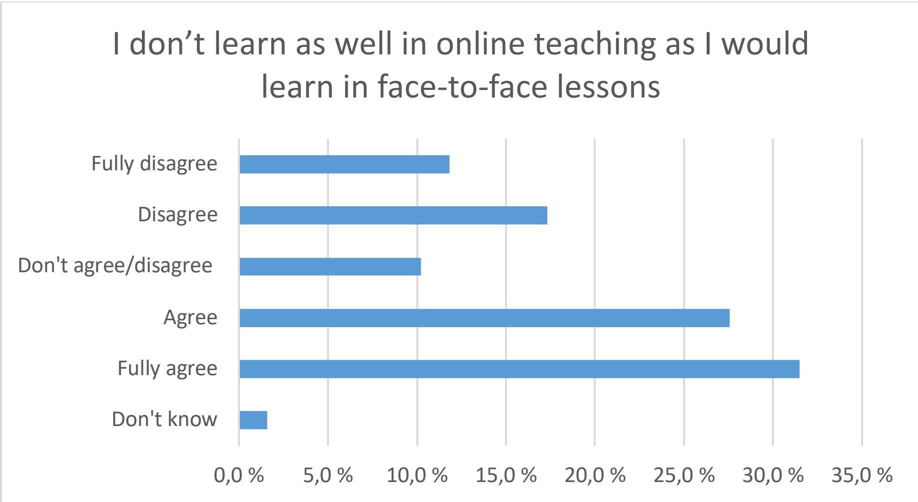

Fig. 3. Online teaching vs. face-to-face lessons

Almost 40 % of the respondents found the workload associated with online learning too great. From the perspective of students learning, these figures are quite significant. Although the students felt learning gap, the respondents were mainly satisfied with the way in which online teaching has been implemented.

Figure 4 shows the distribution of the preferred teaching methods. The respondents preferred the most face-to-face teaching and the combination of face-to-face teaching and real-time online teaching.

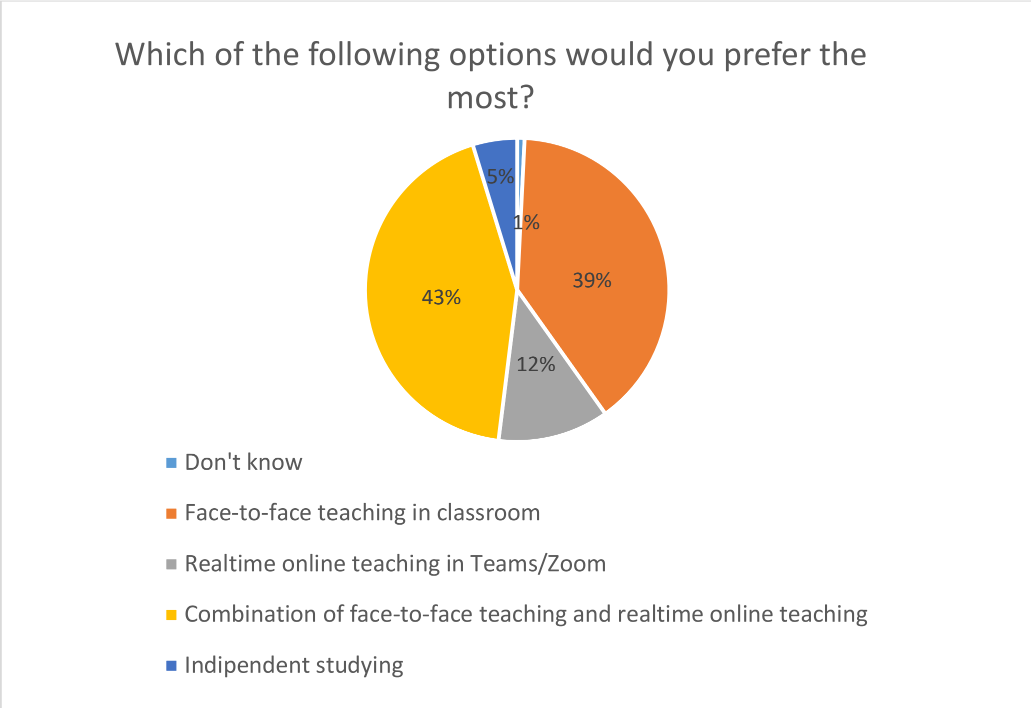

Fig. 4. Preferred teaching methods

3.2 Motivation

Two-thirds of the respondents (see figure 5) experienced that their motivation to study has decreased during the current academic year (mode and median = 2). Furthermore, almost 60 % of the respondents experienced that online teaching has reduced their study motivation (mode and median = 2). These figures are alarmingly high. Additionally, almost 50 % of the respondents experienced that 'I have done a less work with my studies during remote learning than in the past'.

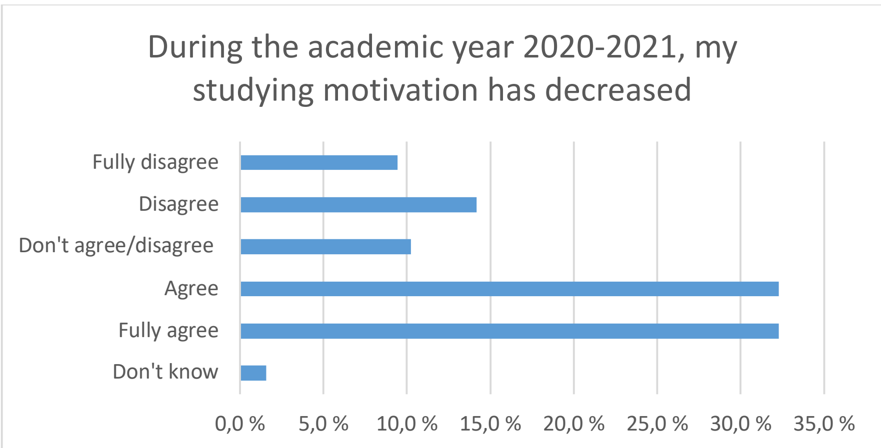

Fig. 5. Studying motivation

As many as half of the respondents feel that they do not make effective use of the time they spend studying. 37% of respondents felt that ‘if the course is difficult, I give up or do only the easiest tasks or study only the easiest things’. On the other hand, 95 % of respondents felt that ‘a nice teacher would increase my desire to learn’. This result is consistent with the literature [7].

3.3 Well-being

According to the responses, about one-third of the respondents feel themselves depressed and over 40 % of the respondents experience daily or weekly anxiety. These are quite high figures. One-fifth of the respondents reported they have utilized health care services to alleviate the anxiety caused by the Covid-19 pandemic. In addition, 57 % of the respondents have experienced challenges in the normal rhythm of their everyday life (e.g. she/he is awake later than usual or sleeps longer than before).

4 SUMMARY

The results emerged many concerns related to online learning. Based on the results, the biggest concerns are students’ lowering study motivation, learning gaps, and well-being challenges. This study provides a good starting point for developing these issues during academic year 2021-2022.

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"WE TREAT EVERYONE EQUALLY, BUT..." FINNISH ENGINEERING TEACHERS' PERCEPTIONS OF GENDERED DIFFERENCES IN GUIDANCE AND COUNSELLING

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ABSTRACT

Gender segregations in the fields of engineering and technology remain persistent. The number of women studying STEM in higher education is around 20 %, but there are varieties in these fields, i.e. both horizontal and vertical divisions. The segregation continues in working life as differences in career paths.

This study focuses on gendered differences in guidance and counselling in engineering higher education. The data consists of 14 interviews with university teachers and researchers responsible for counselling, guiding or supervising students in thesis writing, tutoring, and working life connections. We examine, 1) what kind of gender equality issues are attached to student guidance practices, 2) whether teachers recognize differences in male and female students' orientation and career expectations, and 3) what kind of gendered stereotypes are read in teachers' descriptions. We approach the data from Joan Acker's conception of gendered organizations, especially in terms of the construction of divisions of labor and the construction of symbols and images.

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Findings reveal that gender equality issues are not much acknowledged. Most interviewees considered guidance as a gender-neutral practice and gender mainly as irrelevant factor. At the same time, they identified some gendered patterns in students' performance and orientation, stereotypical characteristics attached to female and male students, and different expectations of technical skills. Student guidance and supervision plays important role in providing images of technology, its professions, and competences. To trace mechanisms that might have an impact on careers, it is necessary to increase gender awareness and to recognize unconscious bias behind gender-neutral ideals.

1 INTRODUCTION

Gender segregations in the field of engineering and technology remain persistent. A concern has been expressed for many years due to the situation that there are relatively few women who enter occupations in the natural sciences, engineering, and technology [1]. In Finland, the overall number of women studying in the fields of technology is 19 % (15 % in ICT). Women make one-fifth (22 %) of students in Master of Science in Technology and employers in technology companies. Within these fields, both horizontal and vertical divisions are considerable. Male-dominated fields in universities consist of mechanical, construction and electrical engineering, automation technology, physics, and IT (10–25 % are women), while relatively more women study in environmental and industrial engineering, material technology, chemistry, architecture and biotechnology and biomedical engineering (30–80 % are women).

The segregation continues in working life as differences in salaries, career paths, jobs, and positions. Women's career advance is somewhat slower compared to men, especially in transition phase from the middle management into highest management [2], while men dominate leadership positions in private sector and listed companies. Median salary for women with university degree in tech or engineering is 87 % of men's salary, mainly caused by different sectors and positions, but 5 % of the wage gap is unexplained [2].

While segregation and wage differential between men and women exists already during studies [3], it is important to observe study culture and practices, and possible gender bias in student guidance and counselling which may influence later careers. This paper is a part of an on-going development project Equal Career Paths – NOW[3] which aims to support and promote equal employment and career development of women particularly in the field of engineering and technology. The project observes causes and consequences of gender segregation and unequal career advance in Finland, targeting especially on transition phase from higher education to working life.

This paper presents early findings of the project research, and it focuses on gendered differences in guidance and counselling in engineering higher education. We examine, 1) what kind of gender equality issues are attached to student guidance practices, 2) whether teachers recognize differences between male and female students in their orientation and career expectations, and 3) what kind of

[3] Equal career paths for women – NOW -project is funded by European Social Fund (2020–2022).

gendered stereotypes are read in teachers' descriptions. The data consists of 14 interviews with university teachers and researchers responsible for counselling, guiding or supervising students in thesis writing, tutoring, and working life connections.

Guidance is understood in a wide sense as pedagogical methods and practices that ought to help students to identify their own knowledge, skills, and resources, evaluate the effectiveness of their practices, practice new habits and supports students' engagement and agency [4]. As a theoretical approach in the analysis, we utilize Joan Acker's [5, 6] conception of gendered organizations, especially in terms of *the construction of divisions of labor* and *the construction of symbols and images.*

2 METHOD

Thematic, semi-structured interviews with 14 university teachers and researchers were carried out in November 2020 through Zoom video meetings. Interviewees were selected upon their various experience in counselling, guiding and/or supervising duties from all four faculties which, in studied university, offer Master of Science in Technology degrees. Faculties and degree programs represent highly male-dominated fields but also fields with relatively higher number of women. Interviewees work at the faculties and units of Built Environment (Civil Engineering, Architecture), Engineering and Natural Sciences (Automation Technology and Mechanical Engineering, Physics, Materials Science and Environmental Engineering, Industrial Engineering and Management), Information Technology and Communication Sciences (Computing Sciences) and Medicine and Health Technology (Biomedical Engineering). They hold different academic positions with the titles of doctoral/post-doctoral researcher, university teacher, university researcher and professor.

Interviewees consist of six women and eight men, and their experience of active guidance varies from two to 20 years. Their guidance involves supervising bachelor and master thesis (often done in cooperation with companies), guiding different individual and group exercises and laboratory experiments, tutoring students, and following their practical trainings and internship in working life.

Interviews focused on three main themes: equality issues in faculties, perceived gender differences, and (in)equal practices in guidance and counselling. Interviewees were asked for instance to describe the visibility of equality issues in their units (e.g. trainings or discussions), how is the study culture for minorities, whether they have perceived any differences between male and female students and whether there are some key issues to develop regarding equality in guidance and counselling. The data were analyzed by a qualitative, thematic content analysis and quantification. In the first phase, relevant themes and subcategories for each research question were identified and the data was coded under each category. In the second phase, identified themes were classified based on the frequency of their occurrences and related to Acker's conception of gendered mechanisms in organizations. In the last phase, general descriptions of each theme were created with the illustrations from the original data.

3 RESULTS

1. Research question: *What kind of gender equality issues are attached to student guidance practices?* Findings reveal that despite various university level equality agenda and campaigns, gender equality issues are not much acknowledged nor debated in faculties. According to the data, engineering teachers are not familiar with the equality work in their university nor the implementation of equality plans. None of the 14 interviewees recalled noticed equality measures would have taken to action in their faculty.

Half of the interviewees (n=7) characterized that in their study environment gender is of no relevance or they have not paid attention to the matter. Most engineering teachers considered student guidance as a gender-neutral practice and did not recognize significant equality problems or different treatment of male and female students. Regarding their own guidance, counselling and tutoring duties, engineering teachers viewed students' gender as mainly irrelevant factor and highlighted their aim to treat everyone similarly. Guidance was described as a process where "we aim to find tools to the matter at hand, regardless of who is sitting on the other side of the table".

A few interviewees brought out some equality-related debates, mainly regarding observable gender divisions and the small number of female students particularly in highly male-dominated fields. In terms of role models visible to students, they referred to the low number of women as professors, tenure-track position holders, researchers, and doctoral candidates, while the share of female teachers is relatively higher in most studied fields. Visiting lecturers who represent high-level managers in companies are mainly men, but some interviewees have aimed at inviting female experts to highlight diversity in working life.

2. Research question: *Do teachers recognize differences between male and female students in their orientation and career expectations?* Interviewees identified some gendered patterns in students' performance and orientation, but little differences in vertical career expectations. On average, female students were described to succeed well in studies, they are motivated, demanding, and active to ask instructions, whereas among male students, there is more variety and higher number of those showing less ambition on excellent grades. At the same time, women were seen to feel more insecure, and to worry about their competence and thus needing for encouragement.

Proportionally high number of female students orientate themselves towards pedagogical studies to become qualified as teachers, whereas programming, for instance, attracts more male students. A few teachers also assumed women to be less interested in male dominated environments as construction sites, and more attracted to design, economics, and protection of buildings. Men were described to be more determined in early stage of studies in becoming managers. Descriptions of study choices and directions revealed also implicit valuation given to different competences, as for instance pedagogical orientation was characterized less important and out of "proper", core technology.

3. Research question: *What kind of gendered stereotypes are read in teachers' descriptions?* The data reveals stereotypical characteristics and different expectations of technical skills attached to female and male engineering students. Some interviewees pointed out cultural beliefs about women's weaker mathematical competence, and assumptions of less previous experience in technical skills. Such

descriptions reveal the idea of technical competence and knowledge as more natural to men, as shown in male the image of "a super nerd who is born with the keyboard in hand".

At the same time, female students were attached with the qualities of conscientiousness, accuracy, diligence, and keeping to the schedules while male students more often adopt nonchalant attitude towards studies. Women's tendency to take their performance seriously was related to their ways of showing emotions, and crying, which, for male students' part would be unexpected. In contrast to women's wish to handle everything, men were assumed to be confident about their interests and straightforward in focusing on the key issues.

Findings suggest that gendered differences in engineering higher education are constructed in relation to mathematic and technical competences and expectations, typical and allowed behavior, ways to approach and perform studies, and divisions of work.

According to Acker [5, 6] organizations reproduce gendered inequalities through various mechanisms. First, *the construction of divisions of labor* involves allowed behaviors, allowed locations in physical space, and allowed power, including institutionalized means of maintaining divisions in the structure of labor market. In the data, this was illustrated by role models available for students, representing the images of technical work and professions. Some gender typical choices are seen to guide interests and orientations of female and male students within and between the fields of study. Furthermore, attitudes towards suitable behavior for female and male students were read in teachers' descriptions, as well as expectations about technical understanding and skills.

Second*, the construction of symbols and images* involves ways to express or reinforce divisions between women and men, in the forms of language, ideology and dress. In the data, characterizations and comparisons shape certain images of engineering student and views of proper technology with its competences. As example of the latter, pedagogical knowledge or discussion about social roles or group dynamics is assumed to be of interest to female students but also viewed as unimportant.

From the perspective of everyday practices in guidance and counselling, gendered expectations and stereotypes stay easily hidden and unidentified. The data reveals that most engineering teachers have not considered gender issues or find them unproblematic. On the other hand, some interviewees identify the need to broaden the image of engineering and technology in terms of diversifying the role models visible to students, or to develop career counselling processes to become more gender aware.

4 CONCLUSION - FROM GENDER BLIND TO GENDER AWARE IN STUDENT GUIDANCE AND COUNSELLING

Findings indicate some contradictions between gender neutral ideals and gendered differences in engineering higher education. Student guidance is considered as a gender-neutral practice where gender plays irrelevant role, and most teachers have not reflected the issue. At the same time, they identify some gendered patterns in students' performance and orientation, stereotypical characteristics attached to female and male students, and different expectations of technical skills. These elements also serve as mechanisms that construct and maintain images of technology and divisions of work.

The field of technology is exceptionally gendered and segregated in Finland. Student guidance and supervision in engineering higher education plays important role in providing images of technology, its professions, and competences. To trace mechanisms that might have an impact on careers or hamper the equal advance of women in working life, it is necessary to recognize unconscious bias behind gender-neutral ideals. In this paper, we identified some perceived gendered differences and practices in student guidance and counselling, which is a step towards increasing gender awareness in engineering higher education, and to develop tools to reduce segregations in the fields of technology.

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EVIL – A HEURISTIC FOR ENGINEERING ETHICS EDUCATION

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ABSTRACT

In engineering ethics education, there is a range of decision-making models that help students, future engineers, to make comprehensive analyses of ethical dilemmas. In addition to decision-making models, heuristics can serve a purpose for simplifying and speeding up the analysis of ethical issues. In this short paper, I introduce the EVIL heuristic, which I developed in a textbook. The basis of the heuristic is Albert Hirschmann's three concepts of Exit, Voice, and Loyalty, complemented with the concept of Insubordination. It can be used in situations where an engineer faces wrongdoing by the organization, and where the only options seem to be to either "stay or go". I discuss this heuristic's benefits and drawbacks for engineering ethics education.

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1 INTRODUCTION

In engineering ethics education, there is a range of decision-making models that help students, future engineers, to navigate ethical dilemmas [2, 7, 10]. van de Poel & Royakkers' ethical cycle [10], Collste's decision-making model [2], and Lennerfors' synthetic model [7], all provide a step by step, often recursive approach, from problem formulations, to an ethical analysis, to action and reflection. They are all designed for ethical issues on both micro and macro level. Maner [11] would probably see these as heuristic models for analysing and solving moral problems, and in his paper he presents a large amount of such frameworks, and synthesises them into a 12-step heuristic model. Although such models are beneficial to moral reasoning and analysis, engineering ethics teaching can also benefit from some simpler heuristics.

Gigerenzer and Gaissmaier [4] define heuristics as "a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods." While Gigerenzer and Gassmaier see the benefits of heuristics, showing that they can be as effective as more complex forms of decision making, heuristics can also be seen as conducive to biased decisions [6]. Shah & Oppenheimer (cited in [4]) propose that one of the following ways of effort reduction is operative in all heuristics: (a) examining fewer cues, (b) reducing the effort of retrieving cue values, (c) simplifying the weighting of cues, (d) integrating less information, and (e) examining fewer alternatives.

In this paper, I do not study how people use heuristics, but rather introduce the EVIL (Exit, Voice, Insubordination, Loyalty) heuristic, which I developed in a textbook ([anon]). In my teaching practice, I have used variations of this heuristic to give a common problem: "what would you do if the organization you are working in is engaged in some unethical wrongdoing?" Some students would then say that they would quit their job, since they cannot keep working in a company that does that kind of wrongdoing. Some other students on the other side of the debate state that they need a job, so they would stay in the company. EVIL is a way to quickly devise some more granular strategies of action, at least in introductory sessions of engineering ethics. EVIL is a heuristic in the sense that it reduces alternative actions into four possible actions (type e in Shah & Oppenheimer, cited in [4]). However, it increases the complexity from the simplistic "should I stay or should I go?" to four alternatives. In that sense it is a mid-range heuristic which is used to find a middle ground between a complex decision making (such as the ethical cycle, autonomy matrix, or the synthetic model), and between a dualistic strategy. Through this creation of heuristic, it is possible to induce a new framing of problems for students, scaffolding their learning in engineering ethics.

2 EXIT, VOICE, INSUBORDINATION, LOYALTY

The basis of the heuristic is the three concepts of exit, voice, and loyalty, which were developed by Albert Hirschmann [5] to specify consumers' responses to the deterioration of the quality of goods. In other words, consumers exit (or stop buying the product), they voice their concerns, or they remain loyal and keep buying the product. Hirschmann's concepts have been used in a variety of fields, and introduced to engineering ethics [1, 3], as representing the choice that confronts an engineer when he or she faces wrongdoing by the organization. What this conceptual apparatus does, according to an essay which discusses Hirschmann's work 50 years after it was published, is that it allows us to take on a different perspective on an issue; it is something they "promotes understanding" [9]. Ossandon [9] discusses how Hirschmann combined "exit", which is derived from understandings of market competition, together with "voice" which is more seen as derived from politics, as a resulting from an experience of disappointment.

Boel Berner introduced exit, voice and loyalty into the Swedish engineering ethics literature in 1987 [1], when she discussed how an engineer could behave when facing a dilemma. Both exit and voice were seen as a representation of civil courage, while loyalty was not. Exit, she argues, namely leaving one's company, is perhaps not such a big sacrifice if the market is expanding and if the person is willing to relocate to another company, but in a small town, and for a person who is geographically rooted, it might be a significant sacrifice. Berner gives the example of an engineer who left a weapons producing company and rather took a job as a high school teacher. Voice is seen by Berner as a set of different responses, not just blowing the whistle to media. Rather, she writes that one can refuse to execute immoral orders, that one blows the whistle to union representatives or upper managers, and that one blows the whistle to outside stakeholders, for example the media. Loyalty is basically to follow orders.

I complement this with the concept of *Insubordination*, in other words to go against the organization if one's voice is not heard. In Jenny Chan's work on the harsh management regime at Foxconn, the employees have devised strategies to handle excessive work pressure, when they can not be loyal, nor voice their concerns, nor exit. Chan says:

> "The workers and interns are creative. They engage in different tactics of resistance. Sometimes, they just pretend that they are sick and play video games in the dormitory. But of course, they are discovered after one or two days; then they will be brought back to the assembly line. At other times, they deliberately make defective products, which slows down the pace of production." [8]

Similarly, this strategy is evident in popular culture. For example, in the movie *The Incredibles*, where one of the superheroes works in an insurance company. His manager does not want him to let the customer know how they can receive compensation for harm, in order to maximize profits for the company. The superhero agrees but between the lines he tells exactly how a client should get compensation, by saying: “Listen closely. I'd like to help you but I can't. I'd like to tell you to take a copy of your policy to Norma Wilcox on... Norma Wilcox, W-I-L-C-O-X, on the third floor, but I can't. I also do not advise you to fill out and file a WS2475 form with our legal department on the second floor” and so on [cited in anon].

I can notice through practical experience that students tend to pick up the EVIL heuristic, but I have not investigated its effectiveness for the learning outcomes of engineering ethics education. Anecdotally, in our engineering ethics course, a student wrote in an essay about the application of EVIL to a situation where a civil engineer faced a dilemma, in a war situation, where he was needed as a project manager to build a bridge to transport troops for a surprise ambush. Because of his values of pacifism, he wanted to hinder this project, but he could not do so either through voice or exit (fearing for his life). Rather, he engaged in a strategy where the other project members started to dislike him, and lose confidence in the project. He started to come too late to the meetings, and criticised others’ ideas even if they were good, just to slow down the project. Luckily for him, the project was cancelled due to an external reason, but this insubordination was a last resort.

3 CONCLUDING DISCUSSION

This short paper has presented the EVIL heuristic, which is a development of Hirschmann’s Exit, Voice, and Loyalty framework. It is a mid-range heuristic in the sense that it is aimed to both specify and reduce the number of options in a critical thinking process, but also to increase the number of options from “should I stay or should I go?” to four options. It could be used in introductory classes in engineering ethics and as a micro-insertion into discussions about dilemmas where an employee perceives wrongdoing in the organization.

But why is the acronym EVIL used rather than another arrangement of the letters E, V, I, and L? EVIL is merely used because it is a word which students tend to remember, and it coheres with how Hirschmann presented his concepts (E,V,L), but there is no priority that comes from the letters being arranged in a certain way. However, from the point of view of students and educators a particular order could be seen as representing a priority. EVIL could then imply that Exit would be a prioritized option when facing moral wrongdoing, followed by voice, insubordination, and loyalty. This predilection for Exit seems ill-founded. Another arrangement that I used before was LIVE, which had a more positive ring to it than EVIL, but then could be taken to imply that Loyalty would be the preferred option (and it led to some confusions about the pronounciation of the word). If a preferred order would have to be established, I would opt for one where Voice is the first option, and Loyalty is the last option, in other words either VEIL or VIEL. Given the heuristic memory effect of EVIL, I have opted for this, but when presenting EVIL to students one could play around with other ways of arranging the letters to explore prioritized kinds of action.

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IMPLEMENTING PEER FEEDBACK IN PRACTICE – A CASE STUDY

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Keywords: *peer feedback, formative feedback*

ABSTRACT

Formative feedback is well known as an effective learning tool [1] as it improves metacognitive competences and self-directed learning.

Peer feedback has been a learning activity used in higher education for many years and it involves feedback from one student to another student [2] . Peer feedback increases the amount of feedback for individual students and also strengthens the students' skills in giving and receiving feedback. However, peer feedback needs to be instructed and supported, for example by having rubrics and clear rules for how to provide feedback. One way to obtain this, it is to use the program Peergrade.io. The program Peergrade.io supports assignment submission and the feedback process itself. The system provides overview of the students'activity as well as their feedback process.

In this study, we investigated the implementation of peer feedback in an interdisciplinary course with focus on entrepreneurship. We discuss the theory behind peer feedback as a learning activity in teaching, discuss our findings from our case study and give suggestions for further use of peer feedback. We used the program Peergrade.io for peer feedback for evaluation of a portfolio based on the students' work with entrepreneurial methods. The data are reflections from the students after they had been giving and received feedback from fellow students.

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The results shows a positive attitude towards peer feedback and it was recognized as a good tool for feedback. However clear instructions and rubrics are important.

1 INTRODUCTION

Formative feedback is well known as an effective learning tool [1] as it can help students in developing self-knowledge and skills in assessing their own and other's contributions and thereby strengthen their metacognitive competences and self-directed learning.

Peer feedback can be an important alternative to formative assessment from the teacher as both giving and receiving feedback can promote the students learning, and the students become more aware of their own strengths and progress. Furthermore, peer feedback can also help to actively involve the students and engage them in the learning process.

Peer feedback involves the student evaluating a fellow student's work, ideally against a pre-defined standard like a rubric. A rubric is a guide that describes the specific criteteria for a specific assignment. Its purposes are to give the students informative feedback about their works in progress [3].The rubric can be defined either by the teacher alone or by the students together with the teacher. A rubric often contains both descriptions of the individual criteria and a level for division within each criteria.

Many benefits of peer feedback for student's learning have been described in the literature [4], [5]. However, peer feedback needs to be instructed carefully to the students and be supported for example by having rubrics. Furthermore, the students should be trained in giving and achieving feedback from fellow students [6].

Peergrade.io is an online platform to facilitate peer feedback sessions with students. The program Peergrade.io supports assignment submission and the feedback process itself. The system provides overview of the students' activity as well as their feedback process [7].

The peer feedback session in peergrade.io consists of the following steps:

1) Students submit their work online.
2) Students review each others work. The students give each other anonymous feedback through the rubric.
3) Students engage with their feedback. The students receive feedback from their peers, they react, discuss and engage with their feedback.
4) The teacher has a complete overview.

The purpose of this study is to investigate the implementation of peer feedback in an interdisciplinary course with focus on entrepreneurship.

We used the program Peergrade.io for peer feedback for evaluation of an individual portfolio based on students work with entrepreneurial methods. The data are reflections from the students after they had been giving feedback and received feedback from fellow students.

2 METHODOLOGY

The data was collected on a three week course held in August 2020, at the Technical University of Denmarks' campus in Sisimiut, Greenland. The students came from three different programs and were mixed in groups of 3-4 students. After the first week of the course the students handed in an individual report (portfolio). The individual report concerned the methods which the students had used and reflecet on upon using the methods (pros and cons, learning for next time etc.), where the maximum length of the report was set to five pages. The submission was done in the program Peergrade.io.

The peer feedback session consisted of four parts:

1) Introduction to peer feedback and introduction on how to give and receive feedback. A short introduction to what constructive feedback is and how to use the feedback afterwards was given.
2) The peer feedback session took place using the platform Peergrade.io. The rubrics consisted of four criteria. Two of them were standards (mention something your classmate did well and mention something your classmate could improve) and two were added (what to include more and what to reduce).
3) After the peer feedback session each student met with the teacher and reflected on the peer feedback session.
4) In the final report, each students reflected on the peer feedback session and results (learning).

Each student had two hours to read and to provide feedback to three fellow students. Afterwards each student received feedback from three other students and they had to respond to the feedback. Afterwards the teacher read the feedback and had a follow up meeting with each student.

At the end of the course, the students handed in a final report and part of the report consisted of a reflection part concerning the experience with peer feedback and what they had learnt from it.

3 RESULTS

Out of 15 students, 14 students submitted their report for peer feedback.

Part 1. Some of the students had tried to use peer feedback before, but for most of the students it was the first time. For all students, it was the first time they received an introduction on how to give and receive feedback. For all the students, it was the first time they tried to use peergrade.io program.

Part 2. All students gave and received feedback on their assignment. Most of the students gave feedback on two-three reports; a few only on two reports (decided by the Peergrade.io program). It was fluctuating how much text the student wrote as feedback.

Part 3. At the subsequent feedback session with the teacher, it was mentioned that it had been very useful to see how other fellow students had approached writing the report. It was noted that the report setup and other students' use of figures and tables was inspiring and gave rise to consideration as to how they could do so themselves in future reports. All students were positive about peer-feedback and the use of the program peergrade.io.

In the final report, the students reflected on what they had learned from the peer feedback session. The summaries from the final reports show a generally positive attitude towards peer feedback. It was described as being an eye opener in relation to learning from each other and thereby be able to improve one's own work.

Here are some statements:

- *"Positive to see how other students have approached the same task"*

- *"I gained new views into methods that I had not used myself"*

- *"By reading two other students reports and giving feedback on these, I gained insight into how the task could be solved in other ways than the one I had chosen. This provides inspiration as well as respect for the ellow students different competencies"*

Furthermore, it was mentioned that it is appreciated to receive feedback from several fellow students who are on the same level as oneself (students). Anonymity at Peergrade.io meant that honest opinions were given which might be difficult to say face-to-face. Anonymity also blurred cultural differences. A few students mentioned that they were less positive at the beginning of the peer-feedback session and more positive after they had tried to give and receive feedback.

The results from this study shows that both giving and receiving feedback are perceived positively and that the students can see the value in this. Furthermore, the platform Peergrade.io proved an effectively tool for peer feedback. The introduction to the peerfeedback session was appreciated but could be extended for example by showing some examples from other peer-feedback sessions.

4 SUMMARY AND ACKNOWLEDGEMENTS

By meeting with the students and hearing the students' descriptions of their own reflection in their final report, we gained insights into how the students' perceive peer feedback, and what worked for them and which challenges they experienced relating to peer feedback.

The Peergrade.io platform has proven to be a very useful tool for the peer feedback session.

This study is a small study which has provided some usefull results for optimitizing the peer feedback session. Further studies with more students are needed for more thorough investigation into the method and tool; and it would also be interesting to further investigate letting the students create the rubrics themselves as part of the peer feedback process.

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LEADERSHIP BEHAVIOURS IN VIRTUAL TEAMS TO ACHIEVE PROJECT GOALS

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Keywords: *Leadership education, virtual team, project-based learning, team formation development*

ABSTRACT

A systematic active learning leadership education programme for master's students has been implemented at the Graduate School of Engineering and Science since 2008. Leadership in this context refers to the skills that people can demonstrate at all levels, not just specific levels. After the spread of COVID-19 in the first semester of 2020, classes were remotely conducted. Project-based learning (PBL) activities used to practice leadership behaviour were also conducted in a virtual environment. In the PBL exercise, 17 teams tackled a variety of real-world issues related to local governments and businesses. The class for FY2020 focused on demonstrating leadership in achieving project goals with virtual teams. In the class, each team came up with ideas on accomplishing a project with virtual teams in terms of goal-achieving and team-maintaining behaviours. Based on these ideas, students set five rules for effective team management in the online version. Furthermore, for all team members to exercise leadership, each member identified their strengths and suggested to team members how they could contribute to the team activities. Finally, after confirming how to utilise the members' strengths to strengthen the team, students proceeded with the project. At the end of the project, the team showed increasing maturity in the team formation development stage. This paper reports on the content and results of specific discussions conducted in these classes to demonstrate leadership in achieving the project online.

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1 INTRODUCTION

Leadership education has been conducted for first-year students of the Master's programme at the Graduate School of Engineering and Science for over ten years[1] [2]. For FY2020, classes are forced to shift to online platforms to prevent the spread of COVID-19. In this regard, students form virtual teams and undergo project-based learning (PBL) [3] [4]. Learning is facilitated towards the formation of virtual teams to accomplish a project, where each member can demonstrate leadership[5]. The results of the survey confirm the improvement of the development stage of project team formation.

2 METHODOLOGY

2.1 Leadership Class Overview

Leadership education was conducted in 2 out of 14 sessions. Students applied leadership training in a PBL exercise. The three goals of leadership education were as follows: (1) to understand the principles of leadership, (2) to understand the mechanisms of effective online communication and (3) to exercise leadership in a virtual team.

2.2 Education Method

Online communication tools, such as Zoom, learning management system and Google Drive were used. Figure 1 presents the design of the online leadership class. An instructor provided lectures to all students in the Main room. In addition, the students were divided into groups for discussion and collaborative work (Breakout room). Students were assigned to two rooms, namely, the Main and Breakout rooms, under the direction of the instructor.

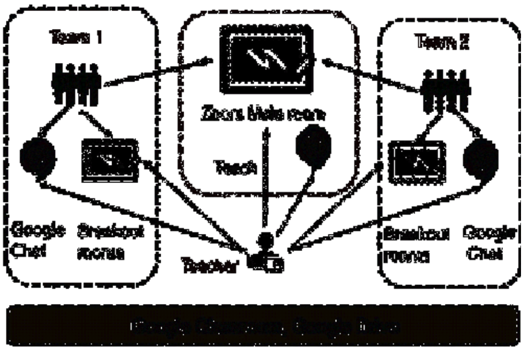

Fig. 1. Online implementation environment

2.3 Class Contents

In the first class, the instructor provided a lecture to the entire group in the Main room. Students learned the advantages and disadvantages of virtual teams, team building, online communication and leadership skills required for the project. The students were then divided into 17 teams with 5–6 students per team. Students formulated ideas on accomplishing the project in terms of goal-achieving and team-maintaining behaviours. Table 1 presents an excerpt of the results of the group work.

Table 1. Ideas for accomplishing the project

Goal-achieving behaviours	Team-maintaining behaviours
Confirming objectives	Speaking in a polite manner
Sharing of understanding	Responding to members' opinions
Maintaining a strict time schedule	Understanding the amount of tasks of others
Identifying issues	Utilising videos for online meetings

In the second class, lectures were conducted to enable students to recognise their strengths and skills in their area of expertise and utilise them for the success of the project. Moreover, they learned about the importance of drawing on the strengths of team members. After the lecture, the students worked individually and in teams to identify their strengths and to share them with other team members. They listed specific possible actions and discussed how such strengths can be used to help one another successfully conduct the project. Table 2 shows an excerpt of the results of the group work.

Table 2. Ideas for leveraging members' strengths for project success

How to utilise the strengths of each member to enhance the team's capabilities
· Identify skills that can be complemented by other members · Engage in tasks beyond one’s strengths · Work with the awareness of exercising one’s leadership · As a team, accomplish tasks that require a high level of skill, instead of designating such tasks to one member

2.4 Research Method

Using a 10-point scale, the students rated their team's stage of formation out of the four stages listed in the Tuckman model [6] (Table 3).

Table 3. Tuckman’s team development model

Forming	Storming	Norming	Performing
			High Productivity
Members lack knowledge of their roles.	A conflict in opinions and values occurs between members.	Team members examine effective processes for achieving goals.	Team members work together to achieve the goal.

If more than one stage was identified, then a numerical value was allocated and entered for each stage for a total of 10 points. Each person was evaluated once a week for six weeks.

3 RESULTS

The scores were summed for each stage per week for the 90 students to obtain a 100% stacked graph (Figure 2). A comparison of percentages by stage was then conducted. The forming stage continually decreased from 64.6% in the first week to 2.8% in the sixth week. The storming stage remained at 30% in the second, third and fourth weeks; however, it decreased to 19.5% by the fifth week and further to 8.0% by the sixth week. This indicates that it took a month to get through the storming stage. The proportions of the norming and performing stages increased per week. In the sixth week, the proportion of the performing stage exceeded that of the norming stage. The performing stage, which was 0.7% in the first week, eventually reached 51.8%.

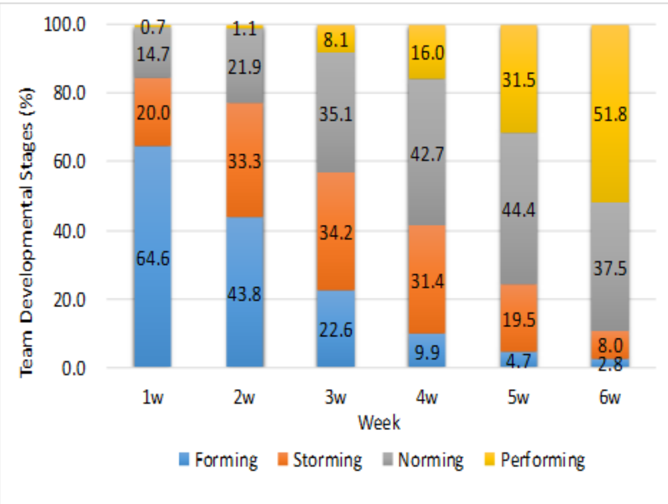

Fig. 2. Virtual team development in online project-based learning

4 CONCLUSION

In the first semester of 2020, the study conducted online leadership education in observance of the social distancing required due to COVID-19. The PBL exercise, which was set up as a demonstration of leadership, was also conducted online. The students aimed to accomplish the project as part of virtual teams with awareness of the unique strengths of each member. The students evaluated the level of formation development of their team over a six-week period. The results confirmed the development of team formation over time.

5 ACKNOWLEDGEMENTS

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DISCUSSION VISUALIZATION AND REFLECTION SYSTEM TO FACILITATE TEAM-BASED LEARNING

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Conference Key Areas: *methods, formats, and essential elements for online/blended learning*
Keywords*: Education Support System, Team-Based Learning, Text Mining*

ABSTRACT

Many universities have adopted collaborative learning approaches such as Project-Based Learning (PBL), where students work in teams. However, in collaborative learning, problems such as not developing appropriate conclusions within the time constraint or the conclusions deviating from the central theme occur. Based on recognizing these issues, we have developed a system that visualizes and analyses learners' discussions in collaborative learning in real-time and feeds back the results to the learners to encourage them to reflect on the results, leading to active and appropriate discussions. The system analyzes the number of words said by each learner per unit of time and the rate of frequent words in collaborative learning and displays this information on the learner's browser in real-time. We can use the system for ideas and meeting management by displaying the co-occurrence network diagram of frequent words and trends of words in a meeting. We have applied this system to collaborative learning in teams and evaluated its effectiveness and impact on team discussions. In the experiment for PBL II course students, the results showed that the scores of the four data representations were more than three, and 73.7% of students evaluate the system as helpful to the discussion.

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1 INTRODUCTION

1.1 Background

Many universities have adopted collaborative learning approaches such as Project-Based Learning (PBL), where students work in teams. However, in collaborative learning, there are problems such as not developing appropriate conclusions within the time constraint[1]. Due to the COVID-19 pandemic, online learning support should support active collaboration in such an environment. We also expect to improve the learning outcomes and learning environment by utilizing the digitization of education style. Initials Lastname2 et al. [2] developed a system to analyze and coordinate the discussion situation from nonverbal information. The system helps the team members estimate their roles and other learners' intentions objectively. Based on the research, our research questions focus on the following.
(1) How to analyze discussion contents in real-time.
(2) How to directly feedback the analysis results to the members.

1.2 Objectives

In order to further promote PBL activities, the objectives in this research are as follows.
(1) To build a real-time speech analysis system in which students can review and understand their remarks in the language information.
(2) To verify whether collaborative learning can be activated and improve the quality of discussion by visualizing and reviewing the speech and language information.
(3) To propose a system that can guide project teams to achieve satisfactory results quickly.

2 METHODOLOGY

2.1 Outline of the proposed system

We propose a prototype system that allows students to review team activities in real-time and transform them into better activities by visualizing their activities in real-time. Figure 1 shows the proposed system configuration diagram. Speech is visualized by texting the speech data and mining the text every short time unit. In addition, analysis results such as the number of words and the passage of frequent words are displayed on the browser immediately. We can use the system in two situations: to promote discussion activities, and the other is to improve the quality of discussion. The former can promote the increase of speech by visualizing PBL work progress and setting the target value. In the case of exceeding the target value, the second way can visualize the divergence/convergence tendency and frequent words. It can also promote the review according to the needs of learners.

2.2 Real-time performance of the system

Firstly, the transmitted voice data is textualized in real-time using the Google cloud platform(speech API). Secondly, we analyze the text-file output by Google Apps script through the automatic execution of the text-mining tool called KH coder[3]. Lastly, we show the latest analysis result on the browser. In the prototype system, errors and processing delay did not occur except in minimal utterances.

2.3 Representation of analysis results

Figure 2 shows four visual representations of the analysis results from the KH coder. In order to support facilitation, it shows the quantity of speech defined by the number of utterances per minute in Fig.2(a). We set a target value in advance if the utterances exceed the target, reminding students to improve discussion quality.Fig.2(b) shows the trend of divergence and convergence of dialogues. We set a reference value of divergence and convergence boundary. If the number of words exceeds this number, there is a convergence tendency; on the contrary, there is a divergence tendency.Fig.2(c) shows the time changes of the frequent appearance words. It helps students create valuable ideas and opinions. The diagram networks of the co-occurrence words in Fig.2(d) show the current discussion topics.

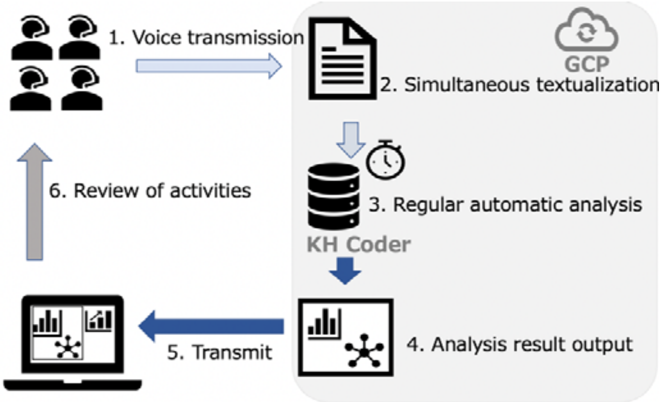
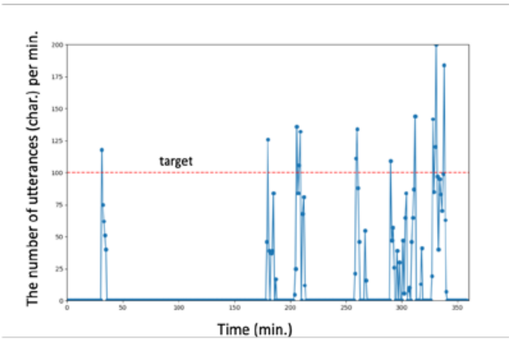
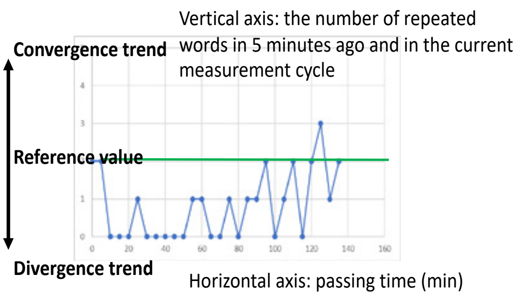


Fig. 1. System configuration diagram



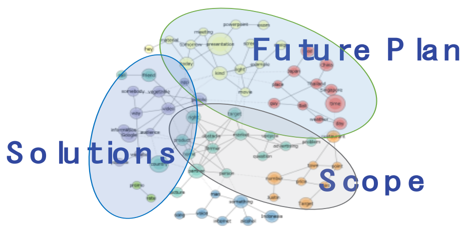
(a)*The number of utterances per min.*



(b) *Convergence and divergence tendency*

2	animal	5	place
2	college	3	part
2	park	2	college
2	Prima	2	increase
2	project	2	today
2	student	1	Commission
2	video	1	dad
1	amusement	1	decision
1	arrow	1	Discovery
1	Arrow	1	face

(c) *Frequent appearance words in every 5min.*



(d) *Diagram networks of the co-occurrence words*

Fig. 2. Representation of analysis results

3 EXPERIMENTS

3.1 Experimental conditions

We carried out to apply the proposed system to two PBL courses and evaluate the system's effectiveness. One PBL course called "PBL I" was conducted with the theme of "creating social-friendly applications." Seven third-grade students (two groups in total) were the subjects. We obtained the data of the first two days in the process of these decisions. After the PBL I, we slightly modified the system to reduce the processing time and represent more preceise graphs. Another PBL course called "PBL II" was the international PBL which tries to propose solutions and prototypes given by enterprises and governmental offices. Sixty-seven students consisting of 40 overseas students and 27 Japanese students organized nine groups in total, and we obtained the data for the first three days. After the experiments, we conducted questionnaires surveys to evaluate the usefulness of the system and its impact on the team discussion promotion.

3.2 Experimental results

Figure 3 shows the details of the four data representations. As a result, for PBL I, (a),(b),(c) representation obtained scores between two to three, but that of (d) is a little bit lower than others. After slight modifications of the system, the results for PBL II were improved in all the representation data, and their scores were more than three. It suggested that real-time processing and effective representation improves the performance of the system.

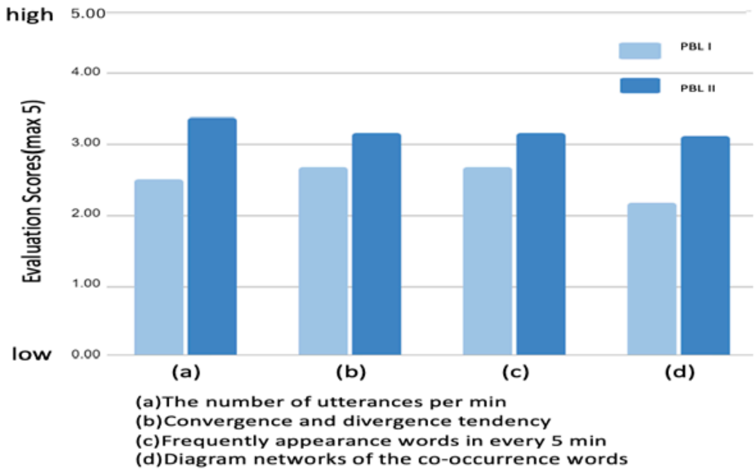


Fig. 3 Questionnaire results of the effectiveness of the four data representations.

In the questionnaire about the system's usefulness, 50% of the respondents in PBL I said that the proposed system was helpful to the discussion, and 50% of them said that they would like to use it in the future. Moreover, for the PBL II students, the questionnaire results showed that 73.7% of the respondents said that the proposed system was helpful to the discussion, and 68.4% of them said that they would like to use it in the future.

4 CONCLUSION

We proposed a system that visualizes and analyses PBL discussions in real-time and feeds back the results to the students to encourage them to reflect on their activities. For PBL II students, the results showed that the scores of the four data representations were more than three, and 73.7% of students evaluate the system as helpful to the discussion. In the future, we will consider the new application method to decide more flexible and specific evaluation criteria and add a new function to improve the reliability and practicability of the system.

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UPSCALING A CHALLENGE-BASED AND MODULAR EDUCATION CONCEPT (CMODE-UP)

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Conference Key Areas: *Challenge based education, Methods, formats and essential elements for online/blended learning*
Keywords: *Challenge-based learning, Modular education, Systematic literature review, Instructional design framework*

ABSTRACT

In 2019, a course at a Dutch University of Technology was redesigned towards challenge-based and modular education. The course was received positively by students and their learning outcomes (grades and engagement) increased compared to previous years. This redesign was quite intensive, and case-specific. It did not deliver a specific set of design principles that can easily be used to redesign other courses within the university or even other universities. Therefore, a follow-up project was started, that aims to deliver a framework to scale-up the course redesign tested in the previous study (CMODE; Challenge-based Modular On-demand Digital Education). This framework will be designed using practical principles and will be evidence-informed. The project consists of three stages: (1) informal interviews with key actors at our university, experienced in studying and/or designing modular instruction, a systematic literature review on challenge-based education and modular instruction; (2) a test of the design principles that were developed using the interviews and literature review; and (3) a test of the CMODE-up framework that was built on the results from the second stage, using think-out-loud protocols. In the current study we specifically focus on the first stage. A first look at the already existing literature around challenge-based education and modular instruction shows us that both concepts have been around for a long time in higher engineering education. Since education has become more and more digitized (and the development of MOOCs), it appears that the concepts have taken a quick increase in relevance. However, both concepts have only been studied minimally in relation to each other. We deem it thus highly relevant to first build a clear and proper view on both concepts, the strengths and weaknesses, and where both (can) meet. So that anyone who has intentions like ours - to implement both in higher education - can do this in an evidence-informed manner.

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1. INTRODUCTION

In this paper, part of a project is presented that aims at presenting a framework to design challenge-based, modular education courses in engineering education. Merks et al. [1] have described a course redesign focused on making a course challenge-based and modular at Eindhoven University of Technology. In order to help teachers within that and other universities to redesign their courses as well, or in other words, to scale up the work done by Merks et al. [1], an evidence-based framework for challenge-based and modular education is essential. The project (CMODE-up) consists of three stages: (1) the development of a preliminary set of design principles for challenge-based modular education, resulting from (1a) informal interviews with key actors at our university, experienced in studying and/or designing modular instruction, (1b) a systematic literature review on challenge-based education and modular education instruction; (2) the development of the CMODE-up framework after a test of the previously developed design principles; and (3) a test of the CMODE-up framework, that was built on the results from the second stage, using think-out-loud protocols. This paper specifically focuses on stage 1 (both a and b).

Modular education or modularization as a concept, has been around in higher education since Harvard University initiated an elective course system in the late 1800s [2]. Accordingly, the set curriculum was replaced and the students were given the freedom to decide and take courses in the program that matched their learning needs. Since then, many educationalists have adapted a modular perspective to education, but throughout time, modular education has taken different meanings; e.g. many studies refer to modularization as it was first used at Harvard University, other studies mean that within a course different modules can be defined and students go through these modules in chronological order, or they even choose themselves what modules they take and in which order [2]. The latter type, where the modules are independent of each other and nonsequential, can be considered the most ideal type of modularization, since it offers students the autonomy and flexibility to follow the modules as a mix and match program, while still ending up with regular certification [3]. Following a modular course structure, students achieve success in multiple course modules as well as create connections between these modules [4]. Key features in all these perspectives on modularization are flexibility, frequent feedback, self-paced learning and adaptations to individual students' needs [5]. For CMODE-up, we are interested in modular course structures, regardless of whether the modules are independent and nonsequential. In research, the modular perspective to course design has its roots in learning theories such as programmed instruction, and student-centered pedagogies [6, 7].

1.1 Modular course design

The higher education literature presents design and development of modular course structures. An example course design focused on maker education. The researchers required some of the modules to be mandatory but also left the rest of the

modules to be chosen by the students upon their interests and learning needs [8]. Another course was developed with a modular approach for mechatronics engineering students. The course modules combined theoretical knowledge and learning activities for the students to apply what they learn as they create solutions to the design challenges at hand [9]. In line with the framework of challenge-based learning (CBL), several educational modules were designed that included course learning outcomes and the learning experiences. The modules were designed to facilitate mastery of the content and the skills that the students would need to finalize the challenge [9].
The CMODE framework by Merks et al. [1] is another example of the movement towards modular education for higher engineering education. In this redesign, a traditional course was restructured into several theory modules, centered around a challenge that was also 'modularized' into deliverables accompanying the theory modules. Testing this redesign showed that dividing a single CBL course into modules with specific learning outcomes and learning activities can lead to positive student learning outcomes.

To take on a modular approach to course design, multiple aspects in higher education need to be considered: a) the educational program to be modularized, b) the students and their background (e.g., prior knowledge, needs, interests), c) teacher preparedness, d) learning and instruction, and e) organizational support [2]. Given the lack of an empirically-grounded framework targeting higher engineering education, the iterative development of a framework can provide a valid structure for designing courses with a modular approach. This study aims to present design principles to be used in an evidence-based framework for modular course design.

2. METHODOLOGY

2.1 Stage 1a: Informal interviews

Interviews were conducted with 13 professionals who have experience with modular instruction in higher engineering education contexts at Eindhoven University of Technology. All interviewees were contacted using personal networks. The interview questions addressed interviewees' experiences in designing modular courses for higher engineering education. The interviews questions include: "1) What are your experiences in modular instruction in relation to higher engineering education? and 2) In what ways is modularity extending CBL and higher engineering education further?" The researchers' field notes are used during data analysis [10].

The researchers carefully read the fields notes taken during the interviews several times. As a result of a descriptive analysis [10], general categories were created to summarize the findings.

2.2 Stage 1b: Systematic Literature Review

Content analysis method was adopted to conduct the systematic literature review [10]. Multiple searches were conducted in the databases: Ebsco, Web of science, Scopus.

The keywords used to locate the articles included: “engineering education”, “challenge-based learning”, “modules”, “modular courses”, and “content modules”. These keywords were used in different combinations to locate as many appropriate articles as possible. The search was limited to articles published in peer-reviewed journals between 2000 and 2021. Books, book chapters and conference proceedings were not included in the search. The removal of duplicates decreased the located number of articles from 545 to 486. Of the 486 unique articles, titles and abstracts were studied using exclusion criteria: a) studies that do no not target higher engineering education, b) publications such as commentaries, reports, short documents, c) studies not written in English, and finally d) studies that either report modules as software or device (e.g., protein module, solar module, modular simulators) or discuss modular approach only in their recommendations. If one of these exclusion criteria was applicable to an article, the article was excluded from further analysis. Application of these criteria decreased the total number of articles to 201. A further examination was later completed using inclusion criteria. Only the articles that at least one of the two criteria applied to were included: a) explained modularization of a course, curriculum, or a program in a higher engineering education context and b) described how the modules were created.

Later in this stage, the authors individually examined the retained 103 articles using codebooks. The codebooks included the themes and the codes based on their total occurrences found in the data. Use of codebooks facilitated the organization of the review findings [10].

3. RESULTS

3.1 Stage 1a

The informal interviews have provided an overview of what higher engineering education and modular education look like at Eindhoven University of Technology, at the moment. Table 1 provides an overview of the range of practices and perspectives at TU/e regarding these concepts. From the interviews it already appeared that even if a university like TU/e has a vision to have more challenge-based and modular courses, design of such courses differs a lot, depending on the perspective the course designer has on these concepts.

3.2 Stage 1b

Using two codebooks, the authors coded all articles included in the systematic literature review. Frequencies and the percentages have been calculated for all themes and codes. The first codebook illustrated the descriptive characteristics of the articles; year, location, engineering discipline, classification of module (e.g., learning module, instructional module), sources for module design, and teacher contribution. The frequencies were calculated separately for articles that reported on modules in programs, and for articles that reported on modules to be integrated in courses. The second codebook included the design aspects to create modules for higher engineering education courses. The identified codes included learning outcomes, student feedback, self-pacing-status, focus of modules, delivery of modules, pedagogical framework, and instructional sources.

Table 1. Categories that surfaced in the interviews

Categories	Description
Higher engineering education context	Challenge-based, design-based course contexts
Structures that resemble modularity	Structures that lie somewhere between traditional courses and modular courses, the course is not entirely modular but students are highly encouraged to personalize the instruction and learning by other means
Degree of modularity	The variety in modular course structure; the courses allow multiple degrees of sequence, flexibility, choice and individualized instruction for the students
Characteristics	The benefits and limitations of modular courses for higher engineering education
Instructional principles	Conceptual background; how the course is structured (e.g., steps followed, interdisciplinarity, alignment to the design challenge, assessments)
Computer-assisted learning	The value and role of digital platforms in modular course structures
Roles	The roles of teachers and students in a modular course structure
Teachers	Teacher preparedness and the importance of teacher professional development
Organizational aspects	The institutional vision towards modularity in higher engineering education, existing and planned support

4. NEXT STEPS

Completion of Stage 1a and Stage 1b resulted in a set of design principles, that in Stage 2 are being tested with five professionals and teachers within Eindhoven University of Technology in order to come up with the initial version of a framework for instructional design for challenge-based modular education. In its current form, the set of design principles are represented with two documents: 1) 10 instructional design steps and 2) a brief teacher manual with the best practice articles identified from the literature to represent each design step. Later, in Stage 3, the initial version of the framework will be validated with think-aloud interviews. The think-out-loud tasks will be based on the initial version of the framework and on helpful sources on cognitive interviewing, higher engineering education and modular course design [5, 11].

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MOTIVATION FOR UPPER SECONDARY SCHOOL MATHEMATICS THROUGH WORKING LIFE CONNECTIONS

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ABSTRACT

This concept paper presents an ongoing project with the aims of motivating upper secondary school students to study mathematics, communicating the importance of mathematics in different occupations to them, and persuading especially the girls to keep their options open for continuing their studies in mathematics-intensive fields, such as engineering. The basic idea of the project is to connect the upper secondary school mathematics syllabus to concrete applications of mathematics in different occupations. This is done by three means: 1) providing mathematics teachers exemplars of different occupations and working life scenarios, 2) building an online course on working life mathematics for upper secondary school students and 3) training university student ambassadors, who visit upper secondary schools and talk about the need for mathematics in different study fields and their experiences of studying mathematics in the tertiary level education.

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1 INTRODUCTION

The Finnish labour market is among the most gender segregated in Europe [1]. A central part of the explanation for this phenomenon is the strong gender segregation of educational choices at the tertiary level, which, in turn, is connected to the gender segregation of subject choices at the secondary level.

Nowadays, girls constitute a majority of Finnish upper secondary school students and generally get better grades in their matriculation exams than boys [2]. One exception to this is mathematics, which boys choose more and where boys typically outperform girls in the exam [3]. All students have to choose either a long or a short syllabus in mathematics. Students choosing the long syllabus have to take a matriculation exam in mathematics, but for the students taking the short syllabys the matriculation exam in mathematics is optional. Research has shown that the competence level in mathematics of those students who only complete the minimum number of courses remains at the level they have achieved during the compulsory basic education [4]. Choosing the short syllabus in mathematics and not taking a matriculation exam in mathematics is more common among girls than boys [3]. Hence, at the end of upper secondary school, the average competence in mathematics of girls trails boys by approximately one year [4].

Yazilitas et al. [5] discovered that in the Netherlands girls often choose science and mathematics at the secondary level to keep their options open for the tertiary level studies. In Finland, the upper secondary school subject choices seem to be more exclusive, and girls commonly make choices which rule out the possibility to study for example engineering at university [2]. Instead, girls' subject choices—psychology, health education, and religion—often relate to the wish to study educational sciences, humanities or health sciences [2]. The fact that mathematics is needed also in these disciplines is not very widely acknowledged among upper secondary school students and can result in struggles in tertiary level studies, for example, when a nursing student needs to pass the exam in medical calculations.

Contextual framing of mathematics problems is a commonly proposed means to increase students' interest in mathematics. It does not come without problems [6], but the use of engineering problems in the upper secondary school mathematics teaching has been shown to increase students' perception of practicality and usefulness of mathematics [7], and the utility value of mathematics has been noted not to decrease students' intrinsic motivation for mathematics [8]. Feelings about mathematics have been noted to impact the engineers' career choices heavily [9]. Illustrating the task value of mathematics in school is commonly suggested by engineers as a means to engage young people with mathematics [9]. It has proven to be effective in increasing also engineering students' interest in mathematics [10].

This paper presents a project where the upper secondary school mathematics syllabus is amended and supported with concrete applications of mathematics in different occupations. The aim of the project is to motivate upper secondary school students to study mathematics and communicate the importance of mathematics in different occupations especially to girls. The rest of this paper first introduces the central elements of the project and then discusses the insights we have gained during this project.

2 PROJECT "TyöMAA"

The project started in spring 2019 and will finish in summer 2022. The project activities consist of three lines of action: 1) creating teaching material for mathematics teachers, 2) building an online course for upper secondary school students and 3) training university student ambassadors.

2.1 Material for teachers

The material for teachers contains mathematical exemplars of different occupations and working life scenarios. The problem illustrations extend over several occupational areas, such as engineering, business, physiotherapy, nursing, tourism and hospitality. They have been collected in a free, open source GeoGebra software, which allows several helpful features for teaching, such as graphical illustrations or 3D demonstrations [11]. The material produced in the project is structured according to the mathematics syllabus to support the findability of relevant exemplars. The material is not yet final, and it is constantly being developed. During academic year 2020-21 there were ten teachers piloting the material.

2.2 Online course for students

The objective of the developed online course is to support students' mathematics learning throughout the course of upper secondary school. After gaining access to the course, the students can relatively freely choose the way they operate in the course as well as the timing of their studies. The study time is not limited, so the students can proceed in the course with the same pace they study the different mathematics courses in upper secondary school. The online course also provides an excellent platform for revising for the matriculation exam.

The course was planned in cooperation with upper secondary school teachers, and the course structure follows the mathematics syllabus. The course operates on a Moodle platform and uses a computer-aided assessment package STACK for the realization of the exercises. More detailed information about the course can be found in [12]. The first students started the course during summer 2020. At the end of spring 2021, there were 20 upper secondary school students (14 girls, 5 boys and 1 other, gender identified from name) enrolled on the course.

2.3 Math ambassadors

Math ambassadors are university students whose role is to motivate the upper secondary school students and to inform them about the need for mathematics in different occupations. Ambassadors visit the upper secondary schools and give about a 30 min talk, which covers the introduction of mathematical aspects in several occupations and study areas (health care, business, engineering, tourism and hospitality, arts, social work, education and psychology), as well as their personal experiences of studying mathematics at the university level. Ambassadors are also present in the online course during certain consultation hours and answer upper secondary school students' questions on chat.

The first five visits by the math ambassadors were conducted in autumn 2020. Based on immediate feedback from the teachers, the upper secondary school students found the ambassador visits interesting and encouraging.

3 DISCUSSION

We are continuously collecting feedback on all the activities with feedback forms linked to the online course (students) and GeoGebra-material (teachers), but so far the feedback has been scarce because of the limited number of users, a relatively short user experience time, and the COVID-19 pandemic. Further feedback from the teachers will be acquired in a national workshop in autumn 2021. Although the pandemic may momentarily decrease the upper secondary school teachers' and students' interest in different kinds of online tools, we believe that in the long run, the 'forced' online learning experiences during the pandemic lower the threshold for engaging in these kinds of activities and increase the attractiveness of online resources, such as the GeoGebra material and the online course developed in the project. The current numbers of students enrolled on the online course suggest that the course is more interesting to girls than boys, which can help reduce the currently strong gender segregation in education and occupations.

Our work has shown that both GeoGebra and STACK provide good tools for building mathematics exemplars and problems contextualised in working life scenarios, but without too much simplification or 'sanitising', which is feared to obscure their efficiency in supporting the learning of mathematics [6]. We also believe that conveying the same message about the need for mathematics in different occupations through all the three means provided by the project will have an effect on the upper secondary school students' actions when choosing the subjects to be studied at the secondary level as well as the studies they will pursue in the tertiary level education. However, this belief needs still to be verified, and we are currently thinking of possibilities to study this issue further during and after the project.

After the project finishes, the GeoGebra material will be freely available for all the interested teachers, the online course will become part of the regular open university offering at LAB University of Applied Sciences, and the visits of math ambassadors will continue to be organised by the local science and technology education centre. Hence, all the activities will continue and also provide a venue for a more comprehensive research on the effectiveness of the actions than is possible during the project lifetime.

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FLUID DYNAMICS PROJECT LABORATORY – CONVERSION TO AN ONLINE COURSE WITH INTERACTIVE 3D MODELS TO ENHANCE LEARNING SUCCESS

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ABSTRACT

The Technische Universität Berlin offers the annual orientation program MINTgrün/STEMgreen for prospective students. The department of Fluid System Dynamics participates with a fluid mechanics project laboratory, which connects hydraulic turbomachinery with the sustainable use of resources and the role of renewable energy to our society. In winter semester 2020/21, the project laboratory was thematically extended. The module now deals with the working principle and design of hydraulic pumps, in addition to the established wind and water turbines. Due to the COVID-19 pandemic, the laboratory was shifted online and enhanced with digital teaching concepts to create new learning experiences.

The project lab´s goal is to introduce students to multifaceted aspects of pump-related engineering and social challenges. In groups of four to five, students are given the opportunity to design a water pump by using typical engineering software. To recognize approaches to a solution, necessary knowledge from the field of fluid

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mechanics is provided, which is supplemented with relevant content of project management. Interactive 3D models were developed and used to illustrate technically complex components and to encourage independent online learning. In addition, students are introduced to classic engineering tools to solve problems. The individually designed machine parts are then 3D printed and tested on a specially developed test rig. In the process, relationships to other engineering disciplines are continuously established and discussed.

1 INTRODUCTION

1.1 Outline of the MINTgrün/ STEMgreen orientation program

The MINTgrün/ STEMgreen program was established in 2012 at the Technische Universität Berlin. The intention of this two-semester orientation program is to give prospective students the opportunity to explore various topics and areas of interest to subsequently make a well-founded choice of study. Topics of the MINT area are mathematics, computer science, natural sciences and technology. The gained theoretical knowledge is supplemented by practical laboratories. One of these labs is the fluid dynamics project laboratory, which is led by the fluid system dynamics department.

1.2 Composition of the fluid dynamics project laboratory

The one semester project gives students the opportunity to gain practical experience in the field of fluid machinery. In addition to the established topics, such as wind and water turbines, the design and construction of a pump impeller has been added to the portfolio. At the beginning of the project, the students learn to create a project-accompanying schedule from the field of project management. This is followed by an introduction to the necessary theoretical principles in the field of fluid mechanics. Simultaneously to the familiarization with these basics, an introduction to the required software programs takes place. The time schedule and the necessary calculations are made with MS Excel. The subsequent impeller design as a CAD model is developed with SolidWorks, which the students receive a two-week introduction for. The created models are then 3D printed and tested at the department on a test rig. However, due to the pandemic, the use of the test rig is only possible in small groups and depending on the local COVID-19 incidence. Therefore this part could not take place in presence in the last semester. At the end of the project a final presentation and a project report of the respective groups are mandatory.

2 METHODOLOGY

2.1 Transition to an online format

As a result of the COVID-19 pandemic, the fluid dynamics project laboratory has been converted to an online format. Lecture content is delivered in Zoom meetings. In these digital lectures, students have the opportunity to discuss the content together and ask questions. Following the lectures, students move into a group work phase. Zoom offers digital group workspaces, so called break-out sessions. In these sessions, the individual groups can work on their projects and exchange ideas with the project supervisors. In comparison to past semesters, which is explained in detail in [1], the structure of the project was adapted. Scientific writing and presentation skills are already introduced halfway through the project. From this point on, the students present their respective group status in short interim presentations. The aim is to stimulate the exchange between the students and to reduce the distances that have arisen due to the online format. Table 1 presents the adapted schedule of the project lab.

Table 1. composition of the fluid dynamics project laboratory

Duration	Topic	Student assignments
- two sessions	- introduction - project management	- project introduction - group organisation - timeline planning with MS Excel
- four sessions	- fluid mechanics - turbo-machine - impeller design	- fundamental and advanced calculations with MS Excel - comprehensive impeller design
- two sessions	- CAD (computer aided design)	- software introduction - basic 3D modelling - impeller designing
- two sessions	- scientific writing - Presentations	- guidelines for scientific writing - Introduction in MS Word/ Power Point - interim presentation and report
- two sessions	- define boundary conditions for student´s own impeller - 3D printing impellers - test rig setup	- each group calculates and designs a distinct impeller - post-processing of impeller models - test run on the test rig
- one session	- presentation - report	- final report and presentation

During the introductory phases in the subject of fluid mechanics and fluid machines, complicated relationships used to be illustrated very well using a large number of fluid machines and impellers in the laboratory of the department of fluid system dynamics. For the use in online formats, interactive 3D models were developed as an alternative.

2.2 Compilation of interactive 3D Models

In order to be able to present complex content as clearly as possible to students in online formats, more suitable solutions were sought. In [2] possible concepts using 3D models to support interactive learning methods for students are discribed. After a short evaluation the software program Sketchfab was chosen. Sketchfab is, according to its own specifications, a 3D publishing tool with which models can be accessed via any browser. Sketchfab is already used by various universities and museums to provide 3D models of teaching content or exhibits. For example, the University of Dundee`s d'Arcy Thompson Zoology Museum has created a digital compilation of various species using Sketchfab [3]. Furthermore, a positive impact of 3D models used in teaching in the field of medicine can be found in [4], where not only the influence of web-browser models, but also virtual reality models were compared.

Implementing Sketchfab models into an existing course on the learning platform of the Technische Universität Berlin (ISIS) is very intuitive. When interacting with the provided models, students have the possibility to freely scale and rotate them. Furthermore, annotations can be added directly to the models. Fig. 2a shows a model of an impeller with a partially cut-out shroud. Through the cutout, students can gain insight into the otherwise hidden blade channel. In addition, five annotations have been added to this model: shroud, hub, blade, leading edge and trailing edge. With the help of Bender, a freely accessible software program, animations can also be added to the model. For example, the rotation of an impeller in a housing can be shown this way.

Fig. 1. Radial impeller with partially cut-out shroud

3 RESULTS

In the course of the teaching transformation due to the COVID-19 pandemic, a conversion from presence to digital formats was developed. The evaluation of the students took place in a final feedback meeting. Classroom sessions were converted into Zoom sessions and Zoom break out sessions, which were very well received by the students. Even after completing all tasks, most students used this platform to discuss the further course of the project. The cooperation in the groups worked extraordinarily well. In the feedback discussions, the 3D models created were also rated as very helpful. None of the students had any problems with interaction or access. Based on this assessment, further 3D content will be gradually developed and made available in the coming semesters.

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EXPLORING PROFESSIONAL INTERESTS OF COMPUTER AND ELECTRICAL ENGINEERING FRESHMEN

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ABSTRACT

The fields of electrical and computer engineering are subjected to constant change regarding their domain knowledge. Technologies, programming languages, environments, and development approaches change reflecting industry needs and formal education programs. But it is not just what needs to be known that influences this change. It is also the interest of electrical and computer engineering students. Some of the factors affecting students' decisions about their profiling during their studies are their intrinsic motivation and interests, their career and pay prospects, but also hard limits like enrollment caps on a study program or availability of a potential mentor. This paper explores the interests of two consecutive generations of electrical and computer engineering freshmen regarding their future professional focus. Students' assignment was to choose and research a topic they would be interested to work on during their studies and find a potential mentor who could supervise their work. The answers collected from more than 600 students per generation regarding their chosen topic of interest were clustered to identify topics of most or least interest as well as changes in those topics between years. The interests that students have expressed are reflective of their perception of popular electrical and computer engineering topics like artificial intelligence or mobile app programming. Students' reported interests are discussed as information that can be useful for faculty-level decision-making, either to try to affect students' perceptions and interests for certain topics and study programs or to plan for restructuring.

1 INTRODUCTION

Emerging technologies like artificial intelligence, artificial reality, and data mining are introducing many changes to related industries and it is not surprising that electrical and computer engineering professionals are in high demand. It is estimated that only the artificial reality market will be worth around $60 billion by 2020 [1] and that the combined value of the artificial reality and virtual reality markets together will be worth $209 billion by 2022 [2]. Many countries, therefore, have recognized the need for educating future engineering professionals and have introduced measures to increase interest in STEM fields. Such outreach programs occur both in primary [3] and secondary education [4], [5], as research has suggested that general interest or previous experience with related topics is a frequently mentioned reason for studying electrical and computer engineering [6]. Still, predicting or learning about students' professional interests is also important after they get enrolled in a studying program. Mismatched enrollment caps on a study program or unsustainable (lack of) interest in specific engineering disciplines can yield undesired outcomes regarding the number of future engineering professionals. They can also affect a university's decisions to end some study modules or introduce new ones. It is, therefore, important to gain insight into students' interests after they enroll in an engineering program as well. In this paper, the first results of ongoing research of professional interests of first years' students at the University of Zagreb, Faculty of electrical engineering and computing are described. The reported results are based on the self-reported data from the 2019/2020 and 2020/2021 generations of students.

2 METHODOLOGY

2.1 Assignment context

The data reported in this short paper were collected within the *Communication skills* course, a first-semester course concerned with communication skills relevant for future engineering professionals. The final course assignment worth 30% of the overall course credits requires students to create a two-minute video presentation about a topic they would like to work on during their studies. The chosen topic must be related to the faculty and students are also required to find a potential mentor for their work. The mentor must be a member of the faculty who either teaches a course related to the topic of interest, has that topic listed under their areas of expertise at their personal university webpage, has already mentored students on similar topics, or is listed at the university webpage as a collaborator on at least one scientific project related to that topic. Students are instructed not to contact their potential mentor since they are doing this assignment for practice and to start thinking about their professional interests. Students are also instructed to make their topic as specific as possible and to avoid too general topics such as *machine learning* or *data mining* without a specific application. The submitted video should contain a brief introduction to the chosen topic, a description of its importance, the link to the potential mentor, and, if possible, an idea of how the author wants to contribute to it.

Students' answers containing the proposed assignment topics and the name of a potential mentor were collected using Moodle and exported for analysis. A total of 650 and 672 topic/mentor pairs were submitted in the academic years of 2019/2020 and 2020/2021, respectively. To get an overview of students' interests, submitted topics were read by course lecturers and main topic categories were defined within the two main studying programs: computer engineering and electrical engineering. Approximately 50 categories were derived based on students' submitted topics and those categories were further generalized to reduce their number and to increase the number of included topics. For some topics, it was difficult to assess where does the contribution lies, *i.e.* which category should a topic be assigned to. For example, in the development of a specific mobile application or in the development of an electrical sensor device that will supply it with data. More than one category could have been assigned to a topic in that case, but this happened relatively rarely. Finally, only the categories with at least 10 entries either in 2019/2020 or 2020/2021 were included in this report.

3 RESULTS AND DISCUSSION

The results of the analysis for both years are displayed in Fig. 1.

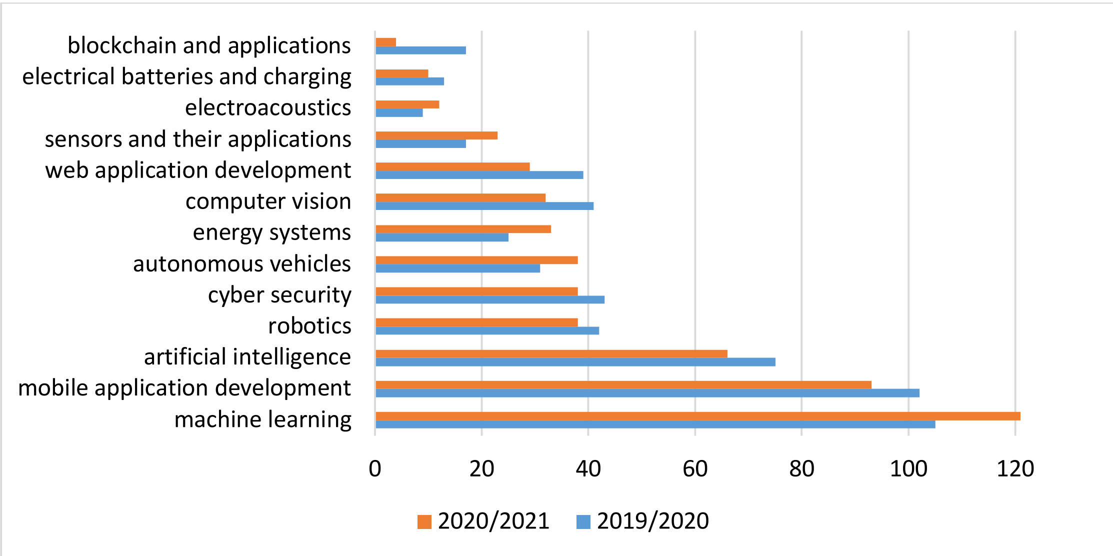

Fig. 1. Most common topics for two generations of students

Based on the results displayed in Fig. 1, several topics have emerged as most common in both academic years, specifically: machine learning (especially for games and detection/classification problems), mobile application development (especially learning and everyday apps), and artificial intelligence (typically in games, recommender systems, autonomous vehicles, and drones navigation). It seems that approximately 45% of students have an interest in one of those three topics. This is not surprising given the hype associated with artificial intelligence which generally includes machine learning and computer vision. Mobile and web applications, on the other hand, are ubiquitous today and students probably expect that that demand will continue to thrive, making their development a well-paid job. Robotics (including the design of humanoid robots, robot arms, and drones) seems to be the highest-ranked topic related to electrical engineering. Other notable topics in that category include electrical vehicles, energy systems, and sensors and their applications. Still, those four topics related to the electrical engineering study program have only been selected by approximately 20% of students. Those results are also consistent with an already noted decrease in enrolment of the electrical engineering program at the Faculty. Interestingly, categories like artificial reality, bioinformatics, or quantum computing all fall below the 10 entries threshold in both generations of students although they seem to offer challenges that will be very relevant in the near future. Those topics might offer additional opportunities for students or will remain underrepresented due to the popularity of artificial intelligence and machine learning.

4 CONCLUSIONS

This paper presents the first results of a work in progress aiming to document the interests and the changes in the professional interests of engineering students before and after they start an engineering degree. The acquired data suggest a larger interest in computing-related topics associated with artificial intelligence, machine learning, mobile application development, and robotics but at the same time underrepresentation of other relevant and generally popular topics like bioinformatics or artificial reality. If those trends show to be constant across generations of students, additional advertising, or outreach programs for such topics early during the studies might help students develop an interest in them.

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STUDENT ATTITUDES TO PROFESSIONAL SKILLS TRAINING: ARE THEY MORE DIFFICULT TO LEARN IN A UNIVERSITY CONTEXT THAN TECHNICAL SKILLS?

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ABSTRACT

Here we explore undergraduate perceptions of different skills in two large-scale programmes in Australia and the UK. We have preliminary findings from an on-going study on the ways in which students believe they can best develop professional skills. We take a qualitative approach to a single optional, open-ended question at the end of the survey, which asks for "…any other comments". Just over 12% of a total of 1097 survey respondents filled out the question. We explore the themes through the lens of William Perry's (1981) schema of intellectual development with the addition of the concept of epistemic frames. We suggest that Professional Skills and Technical Skills may be perceived by students from different epistemic frames. Whilst students may develop more sophisticated epistemologies in relation to some areas of their study, they do not always transfer these framings to Professional Skills.

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1 INTRODUCTION
1.1 Study and Aims

In recent decades there has been a drive to prepare undergraduate students for professional practice, often with the inclusion of professional skills training in engineering curricula [1] [2] [3]. Professional skills usually encompass such skillsets as teamworking, communications, leadership and management, entrepreneurship, independent (and lifelong) learning, critical thinking, creativity to name a few. All are composite attributes and skills that are hard to define, dependent on context, and tend toward lifelong development, features that lead Knight (2007) to describe them as ‘wicked competences’ [4].

Here we report preliminary findings from a larger study that seeks to understand student perceptions of how they learn technical and professional skills. The drive to understand more, particularly about students attitudes to training in professional skills, was instigated by diverse responses to professional skills provision in two univerisities that interweave problem-based learning (PBL) activies, with skills training and more traditional forms of engineering tuition.[5] Each institution takes in a large cohort of undergraduates in excess of 750 students annually and provides a number of two-hour taught workshops to support skills development that run alongside work experience or university projects. At UCL skill support workshops are concentrated in the first two years of the degree programs, while in University of Sydney (UoS) activities are spread throughout all undergraduate years.[6][7]

In order to probe the reasons for the wide range of student responses to professional skills training, we have conducted a quantatitative survey consisting of 6 structured questions, that ask participants about where they have developed or believe they should develop different competences, from technical to professional. Here we focus on an optional, open-ended question at the end of the survey, which asks, “Do you have any other comments on the competencies and skills you have (or haven’t) learnt at University, or anything else that you might be helpful to us in understanding your views and experiences?”. We included this question in order to tease out some of the attitudinal qualities that students hold regarding their educational development. Here we treat these questions qualitatively. Our aim is to gain a more nuanced understanding of the quality of students’ views and experiences that underlie the wide variation of responses to university professional skills training.

1.2 Background

“What can you do with such unaveragable judgements as ‘This course has changed my whole outlook on education and life. Superbly taught! Should be required of all students!’ and ‘This course is falsely advertised and dishonest. You have cheated me of my tuition!’?”. [8 p76-77)

So begins William G Perry’s explication of a schema for intellectual development. It was natural then, to look to Perry in the midst of similarly divergent responses to our own professional skills training provision. Using qualitative data from unstructured interviews recorded over a number of years, Perry devised a four-stage model of epistemological development in young adults. Each one of Perry’s stages is characterised by a typical attitude to knowledge. At one end ‘Dualism’ describes a position in which knowledge is either right or wrong, good or bad, but it is known by Authorities (eg: teachers, experts) that are external to the self. From here uncertainties begin to creep in, others have different opinions, even Authorities have different opinions. ‘Multiplicity’ describes a stage in which a diversity of opinion and values is acknowledged, but it is in areas where Authorities don’t yet know and opinions are all equal. ‘Relativism’ is a point at which opinions can be backed by evidence, sound argument, data, logic or rhetoric or not. Knowledge is relative and contingent. Now it is possible to use critical reasoning to make judgements between useful and worthless opinions. Finally, ‘commitment’ describes the individual affirmation of particular opinions, values and viewpoints achieved via the awareness developed through relativism. At this point, the student is able to think in ways that mirror the Authority and is able to construct knowledge internally.

A number of studies in engineering education have utilised Perry’s schema to explore student development and find ways to support it. Research on student development in the context of PBL, project-based learning (PjBL) and design-based learning is generally very encouraging in demonstrating the value of active learning in supporting and promoting intellectual development [9] [10] [11] [12] [13] [14]. (For simplicity in this short paper, we use the term PBL to refer to all PBL, PjBL and design-based activities.) Other work that looks specifically at student perceptions of their progress in developing a number of professional skills has shown the value of experiential pedagogies and active learning in supporting growth, most notably Beagan et al (2019) report positive results [16]. Itani and Srour (2016) also report positive results, finding that senior undergraduates value their training in professional skills as a result of understanding their importance in industry. Yet they found some of the value that these students attributed to these skills was partly due to their aspiration to enter managerial or administrative careers in which engineering was not a core acitivity [15].

The majority of studies (eg: [9],[10],[12],[13]) that utilise Perry's schema treat it as a progressive, uni-directional model in which individuals adopt one epistemological position at a time, working from the simplest to the most complex. Other authors, most notable Elby (2010) and Elby and Hammer (2010), have argued for a more nuanced view of a fragmented epistemology, in which it is possible to hold many different models of knowledge at once [18] [19]. So, it may be possible to hold dualistic views in one context (a lecture perhaps) but to move toward relativism when cued by the context of PBL activities. Gainsburg (2015) cites several studies that demonstrate the influence of context and knowledge domain [11] on epistemology. What this signifies is that progression in one knowledge domain, does not necessarily signify progression in all domains.

In addition, Schaffer (2009) introduced the idea of epistemic frames [19]. A frame is a filter through which individuals can make sense of experience [20]. Like a camera view finder it limits what is observed, or how a situation is interpreted. Individuals may shift their frame dependent on their context. An epistemic frame drives what is noticed as knowledge, and influences beliefs about the way knowledge is developed and validated. This may be important in the context of professional skill development given that professional skills are inherently more multifarious and subjective than some technical topics. If students approach this kind of knowledge with the same epistemic frame with which they understand engineering principles, then they may not notice professional skills as knowledge at all.

2 METHODOLOGY

Just over 12% of a total of 1097 survey respondents filled out the final open question at the end of our survey. Participants were undergraduates from years 1-4 of their degree programmes, about half the total came from each institution. They were invited by e-mail to take an on-line survey containing 6 structured quantitative questions and 1 open-ended question.

We analysed 133 responses to the question "Do you have any other comments on the competencies and skills you have (or haven't) learnt at University, or anything else that you might be helpful to us in understanding your views and experiences?" Treating this data as qualitative data, we used an approach based on an inductive 'grounded' theory [17]. Our initial reading revealed highly divergent responses from very positive to very negative of the kind that are city by Perry (above). Using Perry as inspiration, we developed a set of themes that relate to the way these students understand epistemic Authority. From the first set of codes we were then able to detail finer grained categories representing sub-themes that feature recurrent qualities within the data.

All responses reporting negative effects of the pandemic were placed within a single code which was excluded from other codes. Any other responses that fitted into more than one theme were coded more than once.

3 RESULTS

Table 1 shows the frequencies of codes emerging from the final coding of 133 responses. Just under a quarter of the student responses revealed a positive attitude to their learning or experience. These comments ranged from simple affirmations such as, "All good" to more revealing comments such as "[Projects] …helped a great deal in making it understandable as to why we have to learn certain things." However, two thirds of the sample presented negative views on student experience and learning. These breakdown into two themes, the largest and most complex of which includes student attitudes toward epistemic authority. These sub-themes represent common epistemologies across the cohort.

Given this is a qualitative study, the number of positive versus negative comments is not a significant finding, what is more interesting is the fact that negative comments across the two different cohorts contained some markedly similar qualities.

4 DISCUSSION

Many students reported that professional skills could only be learned in the workplace, for example - "There is no way to consistently equip students with such a toolkit from drilling theory into their heads. Squeezing your way into the workplace and learning from there experience is the best way to gather such knowledge in my opinion." For this student the 'true authority' for professional skills is in industry *and* these skills cannot be learned with theory. It is not clear whether this students frames theory as something that happens in university, but it is quite likely. In addition, this response highlights another main theme in which students perceive professional skills as emerging from experience or practice. For example, "I feel its a lost cause to try to formally teach professional skills and its best to just put students in situations where these skills can be developed naturally." The first example cites learning from experience as the way to develop knowledge of professional skills and the second response takes it one stage further and believes these skills develop naturally given the right context (which is not formal teaching). Here professional skills are in an epistemic frame in which authority (university teachers and lecturers) is unhelpful, the only authority is experience or practice.

Table 1: Codes and Frequencies by % of Total Number of Responses

High Level Code	Frequency High Level % Total (n = 133)	Detailed Codes		Frequency as % Total (n = 133)
There is something Wrong with the Authority	56.4	True Authority is in Industry	Professional Skills	10.5
			Technical Skills	3
		Authority is Unnecessary	PS* is Only Learnt by Practice	12
			PS Cannot be Taught	3.8
		University Authority is Deficient	Professional Skills	37.6
			Technical Skills	15
		University Authority has Wrong Balance	More PS is needed	3
			More TS* is needed	4.5
Complaints and Demands	9.8	Complaints and Demands	Professional Skills	6
			Technical Skills	4.5
Development has Occurred (authority uncontroversial)	23	-	-	23
Pandemic issues (excluded from other codes)	12	-	-	12

* PS Professional Skills, TS Technical Skills

Many more students fell into a theme in which the university authority is in some way deficient. For example, one student describes professional skills training as “overall very disappointing because important learning opportunities such as conflict resolution and motivating teams to work together and succeed were overshadowed by a reluctance by staff to take affirmative action to address real issues.” Conflict resolution and motivation are both explored in this student’s curriculum, but the student apparently in a dualistic frame sees teaching staff as faulty for not being authorative. This may be because the teamwork topics are covered in the context of a lecture, where the Authority show stands at the front and has all the knowledge. Yet, this knowledge was required by the student in a (different) PBL context. Whilst PBL scaffolds and cues may encourage the shift to a frame of Relativism, or even Commitment (see [12]), the teamwork support which was covered in a less active setting is still seen through a Dualistic frame.

A second student demonstrates a similar frame shift, “The problem is with the larger client projects, I am sure they are really helpful and really develop our professional skills but they are the most frustrating modules to complete. Due to some team members not caring about the module, client difficulties, not clear objectives.” The fact that dealing with difficult team members, clients and fuzzy objectives *are* professional skills has not occurred to this student. In this case, the deficiency is in the project, not specifically in the teaching staff. Nevertheless the frame is still somewhat dualistic, perhaps representing Perry’s description of a transition from Dualism to Multiplicity. Although the student acknowledges that professional skills develop within the context of the project, s/he has not been able to locate authority within the self. Authority is external, somewhere unfound and the cause much frustration.

A good example of the shift to Multiplicity is described by a student who divides knowledge in the following ways:
“The Sciences teach logical and rational thinking and is frequently associated with IQ, which is what most engineers are supposed to be good at (as maths is a core competency). In order to effectively teach professional competencies, interdisciplinary degrees that include arts, commerce and law subjects should be offered as these subjects are not maths based, are about people and require writing arguments from a multitude of perspectives and at times with no right and wrong answers. Unfortunately, the STEM way of thinking and the Arts/Commerce/Law way of thinking is almost always mutually conflicting, and some people might end up hating it, but it must be taught, as much as it is a pain in the neck to think in two different ways.”

Perry may describe this tactic as an avoidance or deflection of development. The realisation that knowledge is multiplicitous, contingent and/or constructed can cause much anxiety and he identifies various strategies, unconscious on the part of the individual, to hang on to the simple Dualistic notion of right or wrong and an Authority who knows which is which. What is inferred by this student is that the sciences are are more Dualistic than the Arts and that s/he values the Sciences for this. Mulitiplicity in Arts, Commerce and Law is a ‘way of knowing’ that apparently conflicts with logical, rational science and for this student Multiplicitiy is clearly problematic. This may be a core issue for these students for whom the introduction of a highly relativist domain such as teamwork is provokes anxieties about having to think in different ways.

Finally, Perry describes a small number of students who deflect their own development by retreating to a Dualistic frame, or escaping with strong expressions of alienation. This small group he says, often lash out with “childlike complaints and demands” [8 p91]. We picked up a few responses in this vein ourselves. One student described professional skills training as “an unpleasant experience” while another reported “over pressured students prepared to lie cheat … and basically do anything to achieve high marks…” and “lazy incompetent teachers more interested in their own research and ticking teaching expectations”. There is little to add to such a comment, except to feel some comfort from the fact that Perry reports similar responses from his own students.

This short paper raises the concept of epistemic frames as an influence on the ways in which student respond to professional skills training in our institutions. Some students who see this training as a negative addition to their programme may find it hard to incorporate professional skills in the same epistemic frame with which they see engineering. Engineering is factual, correct and logical, while professional skills are hard to define, fuzzy or ‘wicked’. The issue of Authority has been productive in the sense that it is mostly in relation to professional skills provision that these students find fault with Authority. It is notable that the frequency of negative responses to professional skills is higher across all of our codes with the exception of Complaints and Demands. We tentatively suggest that our high level and second level codes may represent epistemic frames and our job now is to further explore these framings with our students to confirm (or not) their existence.

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INVERTED ONLINE TEACHING TO MINIMIZE CONTACT IN PRACTICAL COURSES

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Conference Key Areas: *Lab courses and projects in online/blended learning • Changes beyond Covid-19*

Keywords: *practical courses • physics • blended learning • online assessment • inverted classroom*

ABSTRACT

Inverted online teaching flips the classical method of online teaching, where students are taught at home by teachers in the lecture hall. In inverted online teaching the students come to the university and are connected to online supervisors. The students work at the experimental setups while cameras transfer the experiment during a video conference. The teachers observe and comment the student's actions. Core elements are 1. the shared screen, 2. the image of several mobile cameras and 3. the audio connection.

We carried out such a concept in the summer semester 2020 during practical courses and in Winter 2020/21 during supervision of Bachelor students. Additional instructional videos were offered explaining details of the experiment. Discussions and the final presentation of the results during a seminar were conducted online. In that sense students profit from university equipment while contacts are minimized.

1 INTRODUCTION: BLENDED LEARNING AND ONLINE TEACHING

During the Covid-19 pandemic home-lab experiments substituted closed laboratories and experimental classes. On the other side labs like the advanced practical courses in physics at Martin-Luther-Universität Halle-Wittenberg decided to offer experiments

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in presence of the students with a concept for the minimization of infection risks. Bachelor- and Master students must not be supervised online only in experimental subjects. When having students in the university other techniques need to be explored that allow for secure standards during a pandemic.

Online conferences became standard tools that formed our communication in 2020 and 2021. Teaching undergoes a transformation due to the digitalization. However, this is not new. The implementation of digital teaching into general higher education is understood as blended learning or online teaching since 20 years [1,2] and the idea of the flipped/ inverted classroom developed [3-9]. Stanford, UC Berkeley and the University of Michigan were the first offering own online teaching portals promoting blended learning as the future of the web 3.0.

Improved blended learning concepts extract the optimal and/or most advantageous elements from online teaching concepts leaving disadvantageous elements behind. Digital teaching does not necessarily need to substitute presence teaching [10-14]. We used blended learning elements during the Covid-19 pandemic substituting particularly those parts of practical courses with most personal contact like e.g. the accompanying seminar talks and discussion of experimental results aiming to work without both, without contact and without a loss of teaching quality. The flip was done partially, targeted to the desired learning outcome [15-18].

2 THE CONCEPT OF INVERTED ONLINE TEACHING

In the future, the requirements for online teaching and online communication will further increase. It is one of the basic skills of students to visualize, discuss and decide problems online. Therefore, it is necessary to share and communicate experimental problems which are difficult to access online in a suitable format. The idea of inverted online teaching helps students to work with the experimental setup but discuss the experiments on the internet via audio-visual equipment. In addition, experiments are made operable via remote access and students are supported with teaching videos. Inverted online teaching inverts the classical method of online teaching, in which students are taught at home by teachers in the lecture hall.

2.1 Elements of inverted online teaching.

During inverted online teaching the students sit directly at the experiments in the university and several cameras film the setup (see Fig. 1). The teachers observe the student's actions and can correct them, measured data can be discussed on shared screens. A suitable holder for the cameras allows the students to show details with good picture quality to the educators and move the camera freely between different elements of the setup. We use the open source software OBS (Open Broadcaster Software®) for the organisation of the different cameras on the shared desktop (see Fig. 1). Video conferences before and after the experiment are done with BBB (Big Blue Button®).

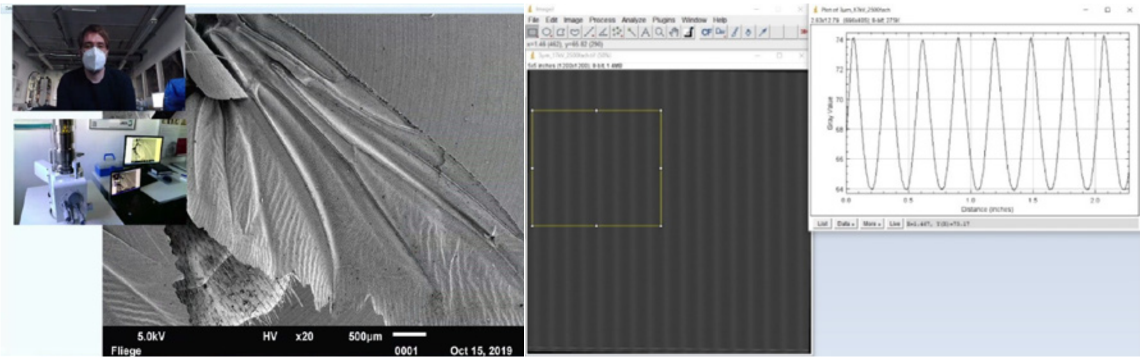

Fig. 1 example for inverted online teaching of the scanning electron microscope with camera and microscopy images (left side) and evaluation of the achieved resolution (right side).

Shared screen information and the shared camera are discussed in online conference style. This enables full supervision of the experiment and the evaluation without the physical presence of the teacher. The aim is a constant online presence. The concept enables more support with less effort and less physical contact.

Instruction in the software for recording or evaluating the measurement is done with short instructional videos and is then practiced online together. The videos are all hosted on the Youtube® channel of the experimental class [19]

2.2 Remote Experiments

A second line of inverted online teaching is the identification of selected experiments that can be done remotely. At the moment, we have set up Hall effect with a LabView® program that allows for the complete data acquisition, heating of the sample and measurements of current, voltage, temperature and Hall-voltage via Teamviewer®.

3 RESULTS AND EVALUATION

3.1 Online Seminar and Poster Presentation

We had very positive feedback from the students regarding online presentations during the seminar and poster presentations as part of their exam in the master´s practical courses. 90 % of the students did not have problems to follow the presentations. However, we realized less activity during the online presentations as compared to the activity during the seminar in the lecture hall.

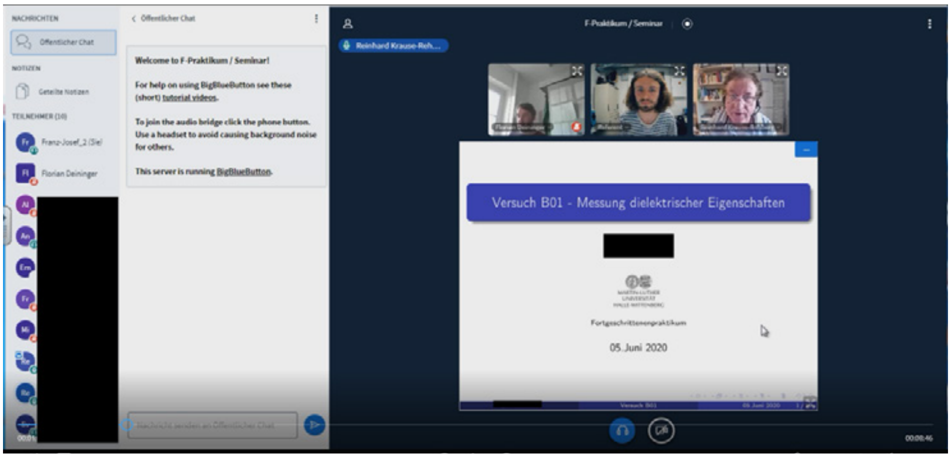

Fig. 2 Online Seminar and Online Poster Presentation during the practical courses.

3.2 Online Communication during experiments

The online communication during the experiments was not yet fully exploited. In spite of the fact that contact to the supervisors via video conference was established some students and supervisors preferred regular personal contact. The steady online conference to supervise the experimental work of the students was mainly executed during the supervision of Bachelor theses or with experienced students. At presence (July 2021) we conduct teaching pupils following the concept of inverted online teaching with some selected pupils and/or students working on the electron microscope and supervisors as well as the rest of the study class observing the experiments from home or from school.

3.3 Evaluation results

The evaluation clearly showed that the students appreciated highly the possibility to work in the laboratory in presence. It even turned out that students agreed with the new structure of the advanced laboratory and the master´s practical courses but they refused further digitalization of the practical courses. A complete digital practical course was refused by 80% of the students in contrast to the fact that 92% of the students did not have technical problems.

On a rating scale from 1 (very helpful) to 4 (not helpful) the students rated the available online documents and exchange of materials and protocols via email with best mark (1.3), however, this element was not new at all. The video conference and additional supporting teaching videos were rated with 1.6. In a range from 1 (very good) to five (very bad) the mixture of online components and presence experiments were rated with 2.0 however the didactical quality was only rated 2.4. This mark was considerably better than the rating of a completely digital experimental classes. The suggestion of pure online experiments was rated 4.0 (refused) with few exceptions (a few students rated the idea 1 or 2). The biggest advantage was seen in time flexibility and the biggest disadvantage was judged the feeling of being isolated from other students in the class.

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INTERDISCIPLINARY CHALLENGE-BASED LEARNING: SCIENCE TO SOCIETY

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ABSTRACT

There is a growing recognition that the world's emerging complex problems require perspectives from multiple disciplines to be properly addressed. For higher education, it is imperative to develop well-rounded graduates with both a depth and breadth of knowledge and skills to integrate perspectives across disciplines. A mixed-methods study was conducted to describe the implementation of an interdisciplinary module with students from nine bachelor programs across science, engineering and social sciences who worked on a challenge-based learning assignment. This module involved external partners setting the 'challenges', and the student groups worked on devising an interdisciplinary solution. For students, multiple available options for support such as tutors, lecturers and challenge partners were found to be an enabling factor. At the same time, the minimally structured learning activities, and ambiguity of expectations were the limiting factors. At the staff level, the lack of cohesion within the teaching team and minimal support for guiding student groups were limiting factors. In terms of collaboration in the groups, students recognized the role of the other disciplines, improved their communication, and integrated disciplinary knowledge at varying levels.

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They faced difficulties such as an unequal distribution of workload and disciplinary differences, causing tension. Lastly, the key competencies developed in the module were perspective-taking, communication, collaboration, reflection, and confidence in existing skills and knowledge. Main recommendations for improving the module are scaffolding support for students, developing the interdisciplinary teaching team, and guiding the challenge definition process.

1 INTRODUCTION

Interdisciplinary (ID) education aims to help students in learning how to address complex real-world problems [1][2]. Interdisciplinarity stands out in its integration of multiple disciplines triggered by a shared problem that spans across disciplines, thereby necessitating collaboration [3][4]. ID education can be facilitated through active learning pedagogies coupled with student collaboration, and an iterative process designed with milestones and scaffolds [5]. Building further on the concept of ID education, challenge-based learning (CBL) is specialized for diverse teams working on solving real-life problems in a systematic method [6]. In CBL, instead of being provided with a problem, students must define a challenge from general authentic problems shared by industry partners, and are encouraged to work with peers, teachers, and external partners to devise a solution [7].

This research is a descriptive case study conducted on an undergraduate interdisciplinary minor, Science2Society 'From Idea to Prototype' at the University of Twente. The module adopted the CBL approach to facilitate ID education for students from nine different disciplines across applied and social sciences. Since the context includes very distant disciplines, the results can encourage and guide broader ID education with CBL. This study aims to examine the following research focus areas about the implementation of ID challenge-based education in this module: 1) perceived value of this module, 2) support for staff and students, 3) interdisciplinary group collaboration, and 4) competency outcomes.

2 METHODOLOGY

2.1 Module

The module aimed to engage students from multiple disciplines to collaborate and address real-world challenges in diverse fields of Energy, Health, Learning, and Robotics that require an interdisciplinary approach through the integration of knowledge from different domains. It is a 15ECTS module organized across 10 weeks for 3rd year Bachelor students to develop scientifically and practically grounded prototype(s) addressing the challenge. The students worked in heterogeneous groups on a challenge for an external partner (e.g. Energy Transition towards Gasless Domestic Heating & Cooking for City of Enschede). Students were introduced to various scientific disciplines to develop a shared background knowledge to address the given challenge. The content was focused on Design, research and other skills were supported through specific workshops open to all students of the course.

2.2 Case study design

Participants: Students from nine study programs and staff involved in the implementation of the module across different roles were the participants (Table 1). Also, challenge providers (3) representing the partner organizations were interviewed.

Table 1. Participants

Students (48)	Staff (17)
1. Psychology (18) 2. Mechanical Engineering (11) 3. Industrial Design Engineering (8) 4. Technical Medicine (2) 5. Chemical Science and Engineering (2) 6. International Business Administration (1) 7. Electrical Engineering (1) 8. Computer Science (1) 9. University College ATLAS (1)	1. Guest lecturers responsible for facilitating the workshops/lectures. 2. Module coordinators responsible for organization and coordination. 3. Process tutors responsible for guiding the student groups. 4. Challenge facilitators responsible for liaising between the challenge providers and the groups. 5. Educational specialists who guided the design of this module

Instruments: An online survey (89% response rate) was used to collect self-report data from the students about their experience in the module. In total, 15 questions were presented with ten closed-ended five point Likert scale questions and five open-ended questions to gather qualitative comments. The closed questions were adapted from Lattuca's measures of ID competence [8], and previous ID education studies [9][10][11][12]. Semi-structured focus group interviews were conducted with 7 students to zoom in on their experience. Individual semi-structured interviews were used to understand the perspectives of 17 academic staff involved in the module. The interview scheme consisted of 10 questions focused on their experience in the module, and opinions about student collaboration and competency outcomes. Furthermore, observations and document analyses were performed to understand the support structures, intended competency outcomes and collaboration experience.
Data analysis: The quantitative data from the survey were analysed in IBM SPSS 24. Qualitative data from the other sources were thematically analyzed using Atlas.ti 9 following phases of thematic analysis [13]. Triangulation was key to interpreting the data to identify convergence, complementarity, and dissonance among the findings for relevant research questions [14].

3 RESULTS

Perceived Value: Overall, staff members valued ID education positively (See Table 2). The exposure to authentic problems, and working with students from other disciplines were shared as strengths of this module, as illustrated in this interview fragment:

> *“I think having the challenge provider was very nice because they (students) got to interact with the real-life company or a case….The interdisciplinary team is again a huge strength. So being able to work with people from different fields and get to know how to speak to people from different fields.”*

Students' responses also point to a better understanding of the challenge due to ID, relevance for the future, and higher motivation due to authentic challenges. The following comment by a student exemplifies this aspect well:

> *“(In previous projects) I often had the feeling that we are working several weeks on one problem and then we come up with a solution. But nobody cares about the solution because it’s just on your paper and you get a grade and that's it. And with the (challenge provider), we can actually do something that they can use. So, you are more motivated to work because, you know, they really want to use it.”*

Table 2. Highlights reported by staff (n=22)

Highlights	**Occurrence**
Enhanced competencies	11
Relevancy for future profession	10
Broadened perspectives	9
New insights from other fields	4

Support: Staff were satisfied with the organization and communication within the module and expressed their interest to be more involved. Lecturers proposed improved alignment of the lectures and other learning activities with the intended outcomes. Challenge facilitators shared their interest to join the lectures and workshops to be aware of the educational aspects. Process tutors appreciated the CBL workshop they received and shared that they would like more clarity on their responsibilities for guiding the student groups. Module coordinators suggested that professional support for guiding ID education would be beneficial for all.

Students appreciated the availability of multiple options for support in this module, and they were largely positive towards the support they received. Planned support was in the form of *content* support from lecturers and challenge providers, *supervisory* support from process tutors and challenge facilitators, and *infrastructural* support through the learning management system of the module and a working space for weekly meetings. All participants specifically pointed out the involvement of the challenge provider for contextual support as an enabling factor. Besides, the group members supported each other. On the other hand, one of the limiting factors was the lack of alignment between the learning objectives and learning activities in the module. Also, the staff pointed out the lack of material and challenge-specific resources in the module as a potential limitation for students. Students, brought up limited interaction with other groups, struggles with group formation and finding the ideal composition, and suggested additional support for group work.

Collaboration: Collaboration was largely driven by dividing tasks within the ID group based on disciplinary expertise. It was also unanimously noted that the contribution to the project varied among the disciplines involved in a group (See Table 3). Next, the aspect of differing perspectives across the disciplines and some prejudice about students of other disciplines was noted. Students highlighted the learning resulting from collaboration, communication struggles among different disciplines, and difficulties in making decisions as a team. Examples of comments about collaboration from students:

> On different approaches: *“We all have different approaches .. the psychology students’ approach is more like scientific. So, you start with working on your theory and you start working on the analysis of the problem…. The engineering students’ approach is more practical, they wanted to start right at the beginning with the prototyping and everything.”*

> On communication: *“Sometimes, if we have a certain idea, it's hard for others to understand what you mean with it. So, the other Industrial Design students understand but like a Computer Science student doesn’t understand what exactly you mean. And it's difficult to explain what you mean and then have some kind of discussion and then try to figure out.”*

Table 3. Student responses about the nature of collaboration in their group

Nature of collaboration	Percentage
We divided the tasks based on our expertise	87%
We formed sub-groups to tackle the challenge	77%
We worked on tasks individually and coordinated our work in the meetings	46%
We engaged in group work most of the time and shared our expertise	36%
Students of certain disciplines had more or less work in our project	28%
We all had an equal role in the project	26%

Competencies developed: The competencies developed through the module were determined based on the intended learning outcomes and what was anticipated by the lecturers, and what was perceived by the students and the staff who worked directly with the student groups. The overall key trends are collaboration, communication, confidence in self and their disciplinary knowledge, reflection, and perspective-taking. The following is a comment by a student about perspective taking:

“Not having 'tunnel vision’ on the problem by only looking at it from your own discipline. I learned to look at it from multiple perspectives”

4 CONCLUSIONS & DISCUSSION

Value: Staff members and students predominantly shared a positive attitude towards this unique module [15][16]. Students are motivated by working on authentic challenges [6][17]. Moreover, the involvement of external challenge providers is vital as it deepens the rationale for ID education and allows for diversity in solutions [18][19].
Support: The workshop for the process tutors was regarded positively and is aligned to the theoretical recommendations for training supervisors [20]. Staff’s prior experience in ID is an important factor as previous studies have shown that ID experience can increase investment and ability to guide students [21]. However, the lack of cohesion among the staff team can hinder ID collaboration as staff’s role-modelling of valuing other disciplines and integrating disciplinary perspectives is essential [22]. Limited training for staff is concerning as previous studies have highlighted the need for training staff on supervising interdisciplinary teams and guiding students towards integration and open-ended problem solving [21].
The module demands the students to be self-directed in their learning with limited guidance. Although the intention is to develop students’ professional competencies and self-regulation through this design, it is important to note that scaffolding is crucial in supporting the transition from learning with well-defined expectations to self-directed ID group work [5][22]. Previous studies in ID have reported students pointing out lack of support [19] and asking for more checkpoints for feedback [22]. However, a fine balance must be reached in terms of structure as too much structure can negatively impact ID collaboration. Therefore, instead of prescribing the approaches or outcomes, students may be supported by including activities that encourage ID teamwork and guide integrated problem-solving [15].
Collaboration: Students from many disciplines in ID education can work together and acquire new skills. Although there are differing levels of integration, evidently the students prefer to bring their own expertise leading to disciplinary division of tasks. Previous studies have been critical of this approach as it can prevent integration between disciplines [23]. Linked to this, there was unequal contribution as certain disciplines did not have as much to add from their disciplinary knowledge. Managing and distributing workloads among disciplines in groups are common problems in interdisciplinary contexts due to unequal disciplinary grounding and sequential order of involvements of the disciplines [24]. Also, communication problems occur due to the use of significantly different vocabulary among disciplines. This necessitates simplifying and articulating one’s ideas [24][25]. Struggles with decision making can be attributed to inherent differences in theory, methodologies, and epistemologies across disciplines

and causes difficulties for students to navigate learning in ID groups [4]. This adds to the need for scaffolded support.
Competency outcomes: The competencies of communication, collaboration, reflection, perspective-taking, and confidence in prior knowledge, were improved based on student and staff perceptions. Students developing the competencies of drawing connections to prior knowledge and between disciplines is notable. The skill of seeing connections across disciplines is a key interdisciplinary skill and a starting point for curiosity, respect, and openness related to the appreciation of other disciplines [8][4]. Competency development in students can be attributed to both the interdisciplinary and challenge-based learning elements of the module which offer them the opportunity and demand to expand their repertoire of skills.

RECOMMENDATIONS

Based on the findings of this study, recommendations to further strengthen this and other interdisciplinary modules are relevant. Firstly, scaffolding tools can help support and understand group processes [27], discourse frameworks [26], reflective dialogue for assessments [5], and process management methods such as Scrum [28]. Moreover, milestones with planned feedback moments aligned to all the learning objectives can help streamline the student team process. Secondly, developing the teacher team in how they can support the student groups to collaborate and effectively integrate their disciplines in response to the challenge. Thirdly, ensuring constructive alignment between all the learning objectives, activities and the assessment. Fourth, introducing peer assessment for the dual benefits of getting groups to leverage their peers for support and sharing innovative practices (e.g. group processes or involving stakeholders). Lastly, the recruitment of challenges can be improved to ensure that the external partners are aware of their expected involvement and needs of group composition. As the onus of defining the problem from the challenge description is on the students, they need support to ensure disciplinary perspectives are balanced.

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DISCIPLINE MATTERS OR DOES IT? DISCIPLINARY DIFFERENCES IN PERCEPTIONS TOWARDS ENTREPRENEURSHIP

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Keywords: *Disciplinary difference, Attitudes, Entrepreneurship education, Competence development*

ABSTRACT

Entrepreneurship education (EE) is no longer limited to business school, but it has been introduced across campuses to different disciplines. The effects of EE on entrepreneurial attitudes have varied across studies, and discipline is one factor that has been suggested to play a role in student's disposition towards entrepreneurship, because culture and norms are also present in discipline-specific cultures, not just at the university level. This suggests that students from different disciplines tend to hold different dispositions towards entrepreneurship, which in turn has an impact on the effect that EE has on students. Thus, this research examines the question: do students start in different starting boxes in entrepreneurship courses.

The data consists of 218 students from multiple disciplines taking an online Introduction to Entrepreneurship -course in Finland via an online questionnaire. The results show that the average level of entrepreneurial intentions and attitude towards entrepreneurship differ between disciplines (engineering vs. non-engineering), having

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a business minor and gender. These results are further examined via fuzzy-set qualitative comparative analysis (fsQCA), which shows a difference in drivers of entrepreneurial intentions across disciplines, gender, and business minor. These results contribute to the EE literature by showing how different students start from different starting boxes in terms of perception of entrepreneurship, i.e. their disposition towards entrepreneurship differs across disciplines, minors, and gender. These results have implications for EE in the context of different disciplines by highlighting the contextuality of EE. The results also seem to suggest that it is worth exploring whether engineering students need specifically targeted entrepreneurship education, or more generally: should subjects suitable for many different fields be taught in a tailor-made way for students in different fields?

1 INTRODUCTION

Entrepreneurship education (EE) began in the field of economics, but recently it has also gained a foothold in the teaching of technical sciences. The effects of EE on entrepreneurial attitudes have varied across studies, and discipline is one factor that has been suggested to play a role in student's disposition towards entrepreneurship [1]. This is due to culture and norms, which are also present in discipline-specific cultures, not just at the university level [2]. Entrepreneurship education is defined as a specialized programme designed for developing awareness of the career options for entrepreneurs [3]. Regardless of the discipline, in the knowledge-intensive university context, knowledge taught and learned shapes the student's perceptions of what entrepreneurship includes and what entrepreneurship can offer for them. All this suggests that students from different disciplines tend to hold different dispositions towards entrepreneurship, and further, towards EE. The prior research has also shown that the effect that EE has on the change in student's entrepreneurial intention differs depending on a study major; the effect was larger among technology students than other students [4]. Surprisingly, although the prior research has shown that pre-educational entrepreneurial intentions and cultural, contextual, and personal variables [1] shape the outcomes of EE, there seems to be a lack of research focusing on the starting level of attitudinal factors towards entrepreneurship.

Based on the above, we propose that the connection between a discipline and the effectiveness of EE should be studied further. Keeping in mind that entrepreneurship has numerous real-life manifestations and assuming that EE is related to career planning, the strengths of students in different subjects may lead to different roles in entrepreneurship. This implies that students do not start entrepreneurship courses from the same starting points, but rather have different views towards entrepreneurship.

In this paper, we look for the differences that major subjects (engineering vs. other) bring to EE by utilizing the theory of planned behavior and causal complexity. First, the theory of planned behavior suggests that a person's behavior is a result of the combination of intention and perceived behavioral control [5]. Entrepreneurial intentions are shaped by three factors: attitude towards the behavior, social norms, and perceived behavioral control. The higher the level of these three factors is, the more likely a person is to have a high level of entrepreneurial intentions. Second, causal complexity, on the other hand, proposes that different factors contribute to a presence of an outcome and these combinations of factors can differ [6]; [7]. This suggests that students from different disciplines may have different drivers for entrepreneurial intentions, thus highlighting the contextuality of EE. This theoretical background enables us to build on the prior literature, and address the following questions: do all students start their entrepreneurship study journey from the same starting box? If differences are found, what are the explanations?

2 METHODOLOGY

2.1 Data collection

The data was collected using an online questionnaire as a part of a national-level web-based introductory course in entrepreneurship in Finland. These students represent several universities and multiple disciplines. The survey was sent to 290 students, who signed up for the course. Out of these students, 239 students responded to the questionnaire, and after removing incomplete responses and those denying the use of their data in research, 218 full responses were obtained (response rate of 75.2 %). The majority of the respondents (86.8 %) are under 35 years old. Female students account for 44.5 percent of the respondents (males 55.5 %). More than half (57.1 %) of the respondents have been studying in the university for three years or less. The majority of the respondents (76.4 %) have a family member, a relative or a friend who is an entrepreneur. However, only 7.7 percent currently belong to, or have been a member of a student entrepreneurship club, while 10.0 percent have work experience from a start-up and 15.5 percent have started a company.

2.2 Research methods

The measurement scales were adopted from the literature. Entrepreneurial intentions were measured via 7-point Likert scale developed by Liñan and Chen [8]. The scale consists of six items ranging from totally disagree to totally agree. Summated scale was formed based on the results of factor analysis (Cronbach's alpha=0.95). Similarly, perceived behavioral control and personal attitude were measured via a 7-point Likert scale adopted from Liñan and Chen [8]. The personal attitude scale ranges from strongly disagree to strongly agree, while the perceived behavioral control scale varies from completely agree to completely disagree. Summated scales were formed based on the results of factor analysis (Personal attitude: Cronbach's alpha=0.92, Perceived behavioral control: Cronbach's alpha=0.92). Social norms were measured via two scales reflecting the normative and descriptive nature of social norms. The normative social norms (Cronbach's alpha=0.81) were measured via a 7-point Likert scale adopted from Liñan and Chen [8], while the descriptive social norm (Cronbach's alpha=0.68) was adopted from the same scale by asking whether entrepreneurship is considered as an acceptable career option among family, friends and school mates.

Discipline was measured by asking the respondents what their major/discipline/field of study is with an open-ended question. This was then coded to respond to major fields of study, namely business, education, engineering, health sciences, arts and humanities, information technology, law studies, life sciences, physical sciences, and social sciences due to the imbalanced distribution of groups. For the analysis purposes, the measurement scale was dichotomized (1=engineering sciences, 0=non-engineering). Additionally, gender (0=female, 1=male) and business minor (0=no, 1=yes) were controlled for.

The data were analyzed via fuzzy-set qualitative comparative analysis (fsQCA). Fuzzy-set QCA focuses on an examination of causal complex relationships [6] by combining in-depth insights and generalizability, and the way an outcome is generated by the number of conditions [9]; [10]. Conditions refer to the input variables that are associated with the presence and/or absence of the outcome. In this paper, conditions include gender, discipline, minor, and the attitudinal drivers of entrepreneurial intentions, while the outcome is entrepreneurial intention. Fussy-set QCA bases on fuzzy logic, thus enabling an examination of degree in membership (fully-in, cross-over point, and fully out). The process of QCA is as follows: 1) dataset is calibrated (ranging between 0 and 1), 2) necessity and sufficiency of conditions are examined, 3) truth table is formed, and 4) systematic minimization is run to find configurations for a given outcome [11]. Following the recommendations of the prior literature, [12]; [11] the consistency threshold is set to 0.8, the proportional reduction in inconsistency (PRI) threshold is set to 0.6 and the minimum number of cases is defined as 2. Totally fuzzy and relative (TFR) calibration technique was used to accommodate the categorical nature of the data [13]. The results reported in this paper base on the intermediate solution, which utilizes logical reminders. To minimize the chance of untenable assumptions, contradictory simplifying assumptions were excluded from the minimization.

3 RESULTS

The results of the mean comparison show that the average level of entrepreneurial intentions and attitude towards entrepreneurship (ATB) differ between engineering science students and other students ($p<0.1$). Additionally, having a business minor matters to the disposition towards entrepreneurship ($p<0.05$; $p<0.1$). Similarly, males have higher average entrepreneurial intentions and ATB than females ($p<0.1$). This suggests that there seem to be attitudinal differences towards entrepreneurship.

To investigate this further, fsQCA was used in two steps. First, the necessity of conditions was examined. A necessary condition enables the existence of an outcome and has a consistency score equal or above 0.9 [6] and PRI equal to or above 0.6, and coverage of 0.6 [14]. The results of the fsQCA analysis show that there are five possible necessary configurations (See Table 1). To examine this further, a necesssry condition analysis was run. The results show that ATB is the only single necessary condition for high entrepreneurial intentions (effect size =0.22)

Table 1. Results of fsQCA analysis for high entrepreneurial intentions (outcome)

Necessary receipts										
~PBC + ATB	0.93	0.62	0.71							
PBC + ATB	0.94	0.63	0.72							
ATB +~SNn	0.94	0.61	0.71							
ATB+~SNd	0.94	0.62	0.71							
Conditions	1	2	3	4	5	6	7	8	9	10
ATB	●	●	●	●	●	●		●	●	●
PBC	●			○	●	●	●			●
normative SN	●			●				●	●	●
descriptive SN	●	●			●		●	●		
Engineering science		●	●	●	●	○	●		○	○
Business minor			○		●	○	○	○	●	○
Male			●	●		○	●	○	○	
Consistency	0.93	0.91	0.85	0.96	0.93	0.93	0.86	0.91	0.88	0.91
Coverage	0.46	0.30	0.20	0.21	0.13	0.15	0.12	0.16	0.05	0.20
Unique coverage	0.04	0.03	0.03	0.01	0.01	0.03	0.01	0.03	0.02	0.01
Solution consistency	0.88									
Solution coverage	0.76									

Notes: ~ denotes a negation of a condition (not high); ATB=attitude towards the behavior, PBC=perceived behavioral control, SN = social norms; black circle (●) denotes presence of a condition, white circle (○) denotes absence of a condition, empty space denotes that a condition is irrelevant for the receipt. Numbers on the top refer to each receipt (combination of conditions).

Second, the sufficiency of conditions was examined. The results show ten (1-10) distinct receipts that are associated with a high level of entrepreneurial intentions. These receipts differ in terms of drivers for entrepreneurial intentions as well as gender, discipline, and business minor. There is only one receipt (1), in which gender, discipline, and business minor do not play a role. In half of the receipts (2-5, 7), students are studying engineering sciences, while in three receipts (6,9,10) they are studying non-engineering fields. In most receipts, ATB is present, while only in one receipt (1) all four drivers of entrepreneurial intentions are present. Additionally, only in two receipts (1,8) both descriptive and normative social norms are present. Thus, the results highlight the multiplicity of factors and combination of factors shaping the level of entrepreneurial intentions. Based on the receipts, we propose two non-discipline specific groups of students (entrepreneurially minded and acceptance seekers), five engineering-specific groups of students (acceptance seekers, entrepreneurially spirited, capability laggers, business experienced, and confident acceptance seekers), and three non-engineering specific groups of students (confidently entrepreneurially minded, experienced entrepreneurially spirited, and entrepreneurially minded). This suggests the need to take into account personal differences, when designing EE courses.

Next, the negative outcome, namely low (non-high) entrepreneurial intentions, was examined. The results in Table 2 show 11 distinct receipts that are associated with low entrepreneurial intentions. In most receipts, ATB is missing, and even through in three receipts (5,6,10) perceived behavioral control is present that does not help to overcome the lack of attraction towards entrepreneurship. Additionally, only in one receipt (10) both normative social norms and descriptive social norms are present; however, even these cannot compensate for the lack of attraction towards entrepreneurship (absence of ATB). All receipts differ in terms of gender, discipline, and business minor, thus highlighting the difference in students' backgrounds. Based on the receipts, we identified two non-discipline specific student group (convinced non-entrepreneurs and non-entrepreneurial capability laggers), three engineering-specific student groups (capable non-entrepreneurs, non-entrepreneurially oriented, and accepted non-entrepreneurially oriented), and six non-engineering-specific student groups (non-entrepreneurs, not-accepted non-entrepreneurs, accepted capability laggers, conflicted capable, attitudinally influenced, and unwillingly capable).

Table 2. Results of fsQCA analysis for low entrepreneurial intentions (outcome)

Condition	1	2	3	4	5	6	7	8	9	10	11
ATB	○	○	○		○	○	○	○	○	○	○
PBC	○	○	○	○	●	●				●	○
nSN	○	○			●		○	○		●	
dSN			○	●	○	○	○		●	●	●
Engineering		○	○	○	○	●	○	●	●	○	
Business m.	○		○	●		●	○	●	●		○
Male	○	○		○	○			●	●	●	○
Consistency	0.93	0.94	0.92	0.96	0.90	0.94	0.93	0.94	0.88	0.91	0.93
Coverage	0.13	0.17	0.16	0.21	0.14	0.15	0.14	0.14	0.05	0.20	0.19
U. coverage	0.01	0.02	0.02	0.01	0.04	0.04	0.02	0.02	0.02	0.05	0.01
S consistency	0.89										
S coverage	0.66										

Notes: ATB=attitude towards the behavior, PBC=perceived behavioral control, nSN = normative social norms, dSN=descriptive social norms, business m.=business minor, U. consistency=unique consistency, S consistency=solution consistency, S coverage=solution coverage; black circle (●) denotes presence of a condition, white circle (○) denotes absence of a condition, empty space denotes that a condition is irrelevant for the receipt. Numbers on the top refer to each receipt (combination of conditions).

4 SUMMARY

The results of the study suggest two issues. First, discipline, having a business minor ,and gender with different combinations are present in 90 percent of receipts associated with high entrepreneurial intentions. Similarly, different combinations of discipline, gender, and having a business minor are present in all receipts associated with low entrepreneurial intentions. This is further reflected in the taxonomies: there are five engineering-specific taxonomies that are associated with high entrepreneurial intentions, while only three non-engineering-specific taxonomies are identified. Conversely, there are six non-engineering-specific taxonomies connected to low (non-high) entrepreneurial intentions, while only three are engineering-specific. This suggests that attention should be paid to the student's entrepreneurial background when designing an EE since these contextual factors seem to matter.

Second, it seems that high entrepreneurial intentions are more likely to be found among engineering students than among non-engineering students, while low entrepreneurial intentions are more likely to be found among non-engineering students rather than among engineering students. This seems to be partially explained by the difference in attitude towards entrepreneurship and perception in behavior control. Engineering students seem to perceive entrepreneurship as a more attractive career option than other students and they seem to believe they possess the skills and knowledge needed for entrepreneurship more than other students. Additionally, the absence of social norms in the case of low entrepreneurial intentions seems to add to the situation.

Based on these results, a taxonomy for student profiles can be formed, which enables contextualization of EE for non-discipline-specific, engineering-specific, and non-engineering-specific student groups. However, currently, EE seems to be one size fits all solution, although the results of this research seem to indicate differently. Similarly, recent research on entrepreneurial intentions has suggested a motivational difference [15], thus further highlighting the need to contextualize EE. These above-mentioned results seem to suggest that further studies are needed to clarify the phenomena behind variations in EI and further, the potential need for more targeted EE. The results suggest that it is worth exploring whether engineering students need specifically targeted entrepreneurship education. These findings raise some questions. Should subjects suitable for many different fields be taught in a tailor-made way for students in different fields? And further, would it be possible to develop a measurement tool based on the taxonomy developed in this study to find the optimal EE starting box for each student.

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Workshops

ordered alphabetically
by first author

COMPARING INSTITUTIONAL STRATEGIES FOR ENGINEERING ETHICS EDUCATION IN REGIONAL, NATIONAL AND EUROPEAN CONTEXTS

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Conference Key Areas: *Ethics*
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ABSTRACT

This paper describes, at raw-data level, the results of a workshop at SEFI 2021 on “comparing institutional strategies for engineering ethics education in regional, national and European contexts”. It uses the curriculum typology of Goodlad. The results indicate the diversity of answers at the European scale for the ideal, formal, perceived and operational curriculum. Although there were some first contextual differences noticeable, the set of answers was too small to give an in-depth analysis, but it opens up a promising area for future research.

1. INTRODUCTION

Given the complex nature of engineering practice, artefacts and issues addressed by engineers, the provision of a solely technical engineering education is no longer sufficient for preparing graduates to provide services to the broader public. It is of crucial importance for engineering programmes to include ethics in their educational offer. The significance of professional ethics for engineering has been formalized beginning with 1989 in global accords, with the Washington Accord stating that graduates are expected to “apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice” (International Engineering Alliance, 2014). The emphasis of global accords on ethical and societal considerations in the practice of engineering is considered to have led to the establishment of engineering ethics education as a mandatory accreditation requirement in signatory countries, which in turn was linked to an enhanced presence of ethics in the engineering curriculum in signatory countries [1]. At the same time, in many other national engineering education systems, professional ethics is not required for a degree, particularly beyond undergraduate degrees.

Based on existent studies and anecdotical evidence, there is a deep fragmentation of curricular approaches of Engineering Ethics Education [2]. The fragmentation and variation in how engineering ethics education is conceptualised and implemented is manifest along five major lines of enquiry: related to the goals of engineering ethics education, the method of implementation, the teaching and assessment methods employed, as well as in the coverage of issues [3].

There is a clear need to have more information on how this variation plays out at the geographical level as well on the reasons behind the differences in how ethics is implemented in different national contexts. Along with this, numerous challenges impact the implementation of ethics at the institutional level exist. The major challenges range from ensuring a systematic implementation in the engineering curriculum to staff expertise or balancing the insertion of ethics alongside other curricular elements. These challenges are often rooted in budgetary pressures, limited institutional resources for hiring instructors with an expertise in this area, insufficient space in the curriculum and lack of guidance [3: p16].

It is thus of high importance to analyse the contextual (institutional, regional, national, European) reasons behind this lack of emphasis on ethics education in engineering at the undergraduate and graduate level, as well as to map the individual or institutional views on the aims and purpose of engineering ethics education [should aim at]. The analysis should include skills needed in industry or valued by society, as well as the supporting arguments for the importance of ethics education.

The SEFI Ethics Special Interest Group therefore decided to organise a workshop as a first step to address this imperative. The aims of the workshop were (1) to map the institutional strategies for engineering ethics education considering the variety of regional and national contexts that make up the European engineering education landscape; and (2) to identify future next steps.

This workshop report describes the workshop set-up, provides the first results at raw-data level, and indicates possible next steps.

2 BACKGROUND

2.1 Institutional strategies for engineering ethics education

Several studies focused on the institutional strategies for engineering ethics education point to the uneven or deficient manner of implementing ethics (e.g. [1], [4], [5]). The study by Colby and Sullivan [4: p.330] analyzing 100 programs offered by 40 engineering schools in the United States revealed that few schools have “instituted systematic programs to educate for this broad sense of professional responsibility”. At the graduate level, Filush and Barakat [5]’s study covering most of the geographical areas of the United States showed that only a very small percentage of universities had a full course or a subject of a course pertaining to professional ethics. These numbers reflect a deficit in the students' education on how to perform in a professional setting. In Ireland, a study analyzing the implementation of ethics in 23 engineering programmes highlights the unsystematic manner of implementing ethics, which is often regarded as a curricular “add-on” [1].

2.2. Goodlad

As a framework for the workshop on institutional strategies for engineering ethics education, we used the curriculum typology by John Goodlad [6]. This typology focuses on the role of the institution alongside the role of the teachers and the learning outcomes of the students by distinguishing different representations of a course or curriculum: the intended, implemented and attained curriculum. It is therefore useful also in engineering ethics education redesign [7]. First, a course is described by its intentions. Course designers and other stakeholders develop their ideals when thinking about the aims of the course (e.g. [8]). During the design process, course designers will make these ideals tangible by using their views of students 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. Next in the process, teachers will interpret the intentions based on their own perceptions. They do this based on the characteristics of the students, previous teaching experiences and contextual factors (e.g. [9], [10]). These perceptions will also affect the teachers' operationalization of the actual teaching and learning (e.g. [11], [12]). Finally, based on their backgrounds, earlier experiences and interests, students, but also others involved, will experience the course in a certain way and deviate in their learned outcomes [13], [14]).

Table 1. Overview of curriculum representation and form with explanation (based on [2]).

Representation	Form	Explanation
Intended	Ideal	Vision (rationale or basic philosophy underlying a curriculum)
	Formal	Intentions as specified in curriculum documents and/or materials
Implemented	Perceived	Curriculum as interpreted by its users (especially teachers)
	Operational	Actual process of teaching and learning (also: curriculum-in-action)
Attained	Experiential	Learning experiences as perceived by learners
	Learned	Resulting learning outcomes of learners

In the workshop, we focussed the intended and implemented curriculum to generate knowledge on the interaction between the institute and the individual teacher.

3 METHODOLOGY

3.1 Workshop structure

The workshop took place online on Monday September 13th 3:15pm-4:15pm CEST. Twenty-two participants were present during the entire session. They came from

Estonia, Finland (2), Germany (2), Ireland, the Netherlands (2), Norway, Portugal, Romania, Russia (2), Switzerland (2), United Kingdom (3), and two from outside Europe (East Asia and Sub-Saharan Africa). The workshop structure consisted of a welcome, intro of the model (10'); individually answering the questions and looking at answers of other participants (15'); break-out discussions in which participants were asked two questions ("Which differences, similarities, remarks or recommendations would you like to formulate?" and "Do you have comments or ideas of improvement for the questionnaire?") (20'); wrapping up in plenum discussing overall views; and inquiring about interests in next steps (15').

3.2 Questionnaire

In the questionnaire, we focussed on the "perceived" curriculum, as we ask teachers. But we also ask for (perceived) links with the ideal, formal curriculum on one hand and the operational on the other. Questions were deliberately formulated in an open way to probe aspects that teachers would see as important. We formulated: "The following questions are about how you perceive the discussed topics. Give answers to the following questions in your own words for as far as you know about it. Answer the questions in general, as a rough average of your engineering ethics education as a whole."

Table 2: Goodlad curriculum forms and related questions

Level	**Question**
Ideal	*What is the vision of your institute regarding engineering ethics education?
Formal	*How is ethics articulated in your institution's vision or objectives?
Perceived	*What do you personally try to achieve in your ethics education? *How do your technical colleagues see (the role of) engineering ethics education?
Operational	*What is according to you the most striking at your university in the way engineering ethics education is organised? (% of total program, number of students, what are the topics, support for experimenting, free choice for you or obligation, political influence or pressure, sufficient training, …)

For the reporting of this workshop, we provide below our own intuitive observations and do not develop further methodologies to interpret the results. Participants provided their informed consent to use the results to further redesign the research and the questionnaire. In the reporting, although important for the discussion on contextual factors, we deleted countries to respect the participants' privacy in the reporting of this workshop.

4 RESULTS

4.1 Ideal Curriculum

To the question "What is the vision of your institute regarding engineering ethics education?", four groups of answers emerged. Few respondents indicated they did not know. A few indicated the vision on ethics is mainly related to accreditation. About half of the group indicated there is little or no elaborated vision at their university. The other half explained some of the particular visions. (See table 3)

Table 3: Ideal curriculum answers.

What is the vision of your institute regarding engineering ethics education?
Actually, I do not know this.
Related to meeting NATIONAL benchmark statements
Competencies required by the national degree ordinance
Ethics is not something that is frequently mentioned as a priority or strength of the school.
Unclear vision. SDGs are very important. Not per se a clear view on what "responsibility" means
None at this moment. A discipline worth ignoring. We hope to change this state of affairs.
The institution's official mission and vision refers to the importance of ethical education for engineering students, taking into account the impacts and challenges of the future.
That all students receive support to learn to develop an 'ethical perspective' on engineering and technology
Implemented in a dedicated course of professional practice (1st year, all student groups) & across the curriculum, in policy courses, design courses, work practice and as a mandatory section of the BA report
Ethics and responsibility are considered as capabilities in order to make informed and morally well-justified decisions. These capabilities should be taught right from the start in engineering programs.
Typically, engineering ethics is divided between the mandatory disciplines (Bachelor Programs: Intro to Sociology (module "Professional Culture"), Intro to Philosophy (module "Ethical Theory"); Master Program: Philosophy of Science and Technology). A special course of Engineering Ethics is only included in a limited number of the recently accredited programs (e.g. Computer Sciences).

4.2 Formal Curriculum

To the question “How is ethics articulated in your institution’s vision or objectives?”, some state it is not or cannot be articulated. Most respondents refer to values that the university wants her students to have, like responsibility, integrity, openness, and respect; or they refer to important societal aspects as sustainability and diversity. One respondent’s university explicitly refers to digitalisation. (See table 4.)

Table 4: Formal curriculum answers

How is ethics articulated in your institution's vision or objectives?
It is ***not a part of*** our institution's vision/objectives.
As of now, the capabilities mentioned are not covered at all and are only about to be introduced as optional. The institution with which I am affiliated with ***is not in a position to make such teaching mandatory.***
So far ***insufficiently operationalized*** from the national degree ordinance

Sensitize to the ***responsibility*** of the engineer
Sustainability and Gender Equity are named as strategic priorities for the school and we have a vice president responsible for these themes.
Through university values - 3 of which are ***confidence, integrity, responsibility***; our university "motto" is 'for the Common Good'; our new strategy (2030) is aligned to the ***UN SDGs****;* desire for open access publishing.
as ***responsibility towards people and the environment,*** following the ***profession's standards*** of conduct
That our education should contribute for ***humanity*** and for a ***better future***, for ***sustainability***, for ***openness*** and ***respect***
The vision includes educational goals around ***societal impact*** including ethics but ethics does not look very not pro-eminent in it
The expected educational outcome is "commitment to social ***responsibility***, ***sustainability*** and ***diversity***"
Our mission as a school is to: "Develop the next generation of engineers through ***relevant skills*** and life-long education to bring ***practical solutions to eco-societal problems***". The ethics is reflected in mentioning the impact to society. Relevant skills & life-long learning, reflects due ***diligence*** and ***responsibility*** as a professional.
It was only this year that the need for ethical education was debated in a body of the institution (in the pedagogical council). The debate was held with professors and students and resulted in a recommendation that, when there was ***any remodelling***, the curricular plans would include ethical education. Currently, the curriculum plans for several engineering degrees are being remodelled, however, only the curriculum in electrical engineering has included ethics training in its curriculum.
It is one of the ***learning objectives*** of all curricula.
All bachelor programmes are offered ethics educations by the Ethics department as part of our modular education
We have a ***CDIO*** based learning outcomes syllabus where ethics is included.
Companion on the path of a ***digital future***

4.3 Perceived Curriculum

To the question "What do you personally try to achieve in your ethics education?", some refer to the content of ethics courses or to understanding ethics itself and its relevance. Raising ethical awareness is mentioned by several respondents, as are moral or critical thinking and ethics for the design process. One respondent referred to the ethics of care in education. One respondent referred to ethics as a personal development. (See table 5.)

Table 5: Perceived curriculum answers

What do you personally try to achieve in your ethics education?
Include at least some ethics related content in the course I'm responsible for, mostly through topic specific ethics questions.

Students develop an ***understanding*** of how ethics can/ should influence the practices of engineers. Students develop the ***self-confidence*** to be able to advocate for ethical practice in their work and study.
a ***broad understanding of ethics*** (ethics as sustainability, policy, design, community engagement, safety a.s.o), awareness of considering the perspectives and characteristics of different groups in the design and decision-making process of engineering
Articulate the ***relevance*** of ethics to our students (it's not their favourite topic)
appreciation of the application of the principles.
Taking into account the short time I have for this training (about 7 hours) I try to raise ***awareness*** of the importance of professional practice with ethics and the ethical dimension of engineering (at a macro-ethical level).
raise ***awareness***, ***change attitudes*** is what I hope for, but I remain "humble"
To make students ***ethically aware***.
I try to develop an ***ability for moral thinking***. To give students a moral tool-box: theories and concepts that are useful in their professional and day to day activities.
I try to enable students to analyze and ***consider moral questions*** in a self-determined way that is also well-founded in ***critical thinking.***
Focus on ***practical ethical reasoning***; search for the "***existential pleasures of engineering"***
Train ***skills*** in making ***judgments*** including ethical aspects
The ***ability to identify ethical issues in complex situations*** and be ***able to reflect*** upon them and address them. Considered particularly relevant in relation to sustainability issues and so called wicked problems.
Student can ***recognize the ethical issues*** and ***seek for support*** internally or externally
Part of technological design, not derivative to it
To get students to think and ***include ethical thinking as part of the design process***
Provide engineers in innovation projects with methods that enable them to ***evaluate and select their product ideas against an ethical, social and sustainable background***.
I ***separate pedagogy (ethics of care)*** from the ethics that students should develop as a consequence of ***participation in the learning activities*** (dual imperatives of dominant global forms of ethics and local contextual communalism approaches to ethics)
To ***develop ethically minded engineers.*** I try to do that in the group design-build-test CDIO projects where they need to consider ethical design of their products and this is also reflected in their assessments as well.

4.4 Operational Curriculum

To the question “What is, according to you, the most striking at your university in the way engineering ethics education is organised? (% of total program, number of students, what are the topics, support for experimenting, free choice for you or obligation, political influence or pressure, sufficient training, …)”, some respondents indicate it is not or not enough represented. Many respondents refer to the "embeddedness" of ethics in the curriculum. A few comments seem to target the organisation of the ethics program, such as based on CDIO or imbalances in different parts. Two respondents indicated ethics as a controversial topic, in providing it as a university or as a subject teachers want to avoid. (See table 6)

Table 6: Operational curriculum answers

What is according to you the most striking at your university in the way engineering ethics education is organised?
Ethics is ***so far not yet covered*** in engineering education at all.
It is ***not really organised***. Some programmes (life science) include required courses. All have optional courses (mostly taught from philosophy perspective - not engineering) and some teachers integrate a bit into technical courses. But there is no strategic overview/ oversight.
Very little time and is not integrated across the curriculum in each year. Have it in first year and final year.
Right now ***completely underrepresented***. We, SUB GROUP, try to integrate Engineering Ethics into the Curricula.
Opportunity to be more ***embedded*** is missed.
The fact that it is not ***part of the curriculum***.
divide specialized local ***'professional' ethics*** courses and a ***general ethics*** course
Very few courses have ethics integrated, those which do seem to mainly address research ethics (mostly from a practical point of view, e.g. doctoral courses)
Decentralisation. Unclear how different engineering programs include ethics
It is embedded into the large ***CDIO*** team-based projects (the design-build-make projects) where we run 4 throughout their degrees
Uneven divide: Large part (13%) of bachelor, but nothing in masters; A lot of room and finances for ***experimenting, support and training.***
It is totally a ***free choice*** for us; our approach so far is about academic integrity.
All students address ethical issues from year one, but these ***sessions are too 'light touch'.*** I suspect they are not getting enough support to internalise the tools they need to think through ethical issues
too few people that feel comfortable teaching ethics/number of students and given the emphasis put on ethics in the vision statement
The need for ethical training ***is a very controversial topic*** that raises a lot of opposition: in some cases, because teachers think it is not necessary, others because they think it is totally ineffective, others because it steals space to teach technical-scientific content and others because they consider that ethical education should be included in the curriculum just to "feel good", but for that a discourse is enough and structured training with specific time and content is not necessary. In COUNTRY there are ***no official indications or recommendations*** either from the government or from the entities that oversee higher education institutions or engineering. This leads to a vacuum in this area which leads to a residual presence of ethical education in engineering courses.

The university has a philosophy department, but this ***does not affect engineering studies***. In engineering ethics is not covered systematically in all curricula. It is compulsory for all in doctoral studies, but addressed just occasionally by earlier courses. New master's course includes a slice of ethics in computer science and electrical engineering.

4.5 Remarks on the questionnaire

As to the question “Do you have comments on the above questions if they would be used in a European-wide questionnaire?”, most respondents had no comments. Some respondents mentioned the individual perception of these institutional questions.

5 SUMMARY

The report of the workshop is a very first step. We are aware that the set of teachers participating in an SEFI Ethics Special Interest Group is very biased and that our questions give personal views of institutional issues. Nevertheless, it gives us first ideas of what possible answers to the questions can be and if the questions themselves are understandable.

We mapped the answers to the four questions. This gives first impressions of what people can answer. It already indicates the diversity of answers at the European scale for the ideal, formal, perceived, and operational curriculum. Although there were some first contextual differences noticeable (e.g., the role of national influence in UK and Norway, for example), the set of answers was too small to give an in-depth analysis. We therefore refrained from dealing with this here.

Participants showed interesting in continue to work on this. If you are interested in participating as well, feel free to contact g.bombaerts@tue.nl.

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ETHICS EDUCATION FOR ENGINEERS, CREATING OPEN EDUCATIONAL MATERIALS

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ABSTRACT

We propose a workshop on creating Open Educational Materials for teaching ethics to engineering students, based on a project encouraging the reuse, creation and open publication of Case-Based Exercises within a community of ethics and philosophy of technology scholars in the Netherlands.

1 INTRODUCTION

As ethics education has become an integral part of the engineering curriculum, universities of technology in the Netherlands have increased their load of ethics classes to students coming from all engineering disciplines (on BSc, MSc, and PhD levels). An important instrument in this form of teaching is the Case-Based Exercise (CBE), in which the students tackle ethical questions by studying a specific application of technology (the case) by using various theoretical frameworks. Often these exercises are situated in a context of Design for Values or Responsible Innovation.

Usually, CBEs are created by the teachers themselves and shared only incidentally and locally (within departments) with other teachers. To increase sharing and reuse of CBEs within Dutch universities and beyond, we initiated a project whose aim is to create an initial collection and the online infrastructure for the open publication of CBEs[1] , which can then be opened to contributions of national and international partners and the wider circle of scholars teaching ethics to engineering students worldwide.

It takes a considerable editorial effort to modify the description of a CBE that a teacher can use in her own teaching to the point where it can be used by another teacher, since a lot of tacit knowledge needs to be made explicit. To help teachers bridge this gap, we have developed a toolkit, consisting of a template specifying all relevant aspects for documenting a CBE, a set of learning outcomes, descriptions of educational activities (that can be used as inspiration), and glossary of ethical terms.

2 SETUP OF THE WORKSHOP

The workshop is targeted at anyone interested in teaching ethics to engineering students through CBEs.

2.1 Aim

The workshops aims to introduce the participants to the toolkit method of building up CBEs, by having them apply it to create a CBE of their own during the workshop. This hands-on training will allow teachers to learn how to design a CBE as an open educational resource and, ultimately, to stimulate the open sharing of educational materials among universities.

2.2 Format

Where possible, we will provide the toolkit materials to the participants before the event. In the workshop participants work in small groups (break-out rooms), where each group is asked to start building a CBE intended to be taught in an ethics/

philosophy of technology course for engineering students. They will go through the following activities (time indications assuming a 60 minute workshop):

1. The workshop conveyors introduce the project and toolkit to the groups (10 minutes).
2. Each of the groups starts building a CBE from scratch, using the toolkit and choosing a story they would like to focus on, resulting a first sketch for a new CBE, facilitated by the workshop conveyors (30 minutes)
3. Groups exchange sketches and give feedback on each others work (15 minutes
4. Wrap up (5 minutes)

3 DESCRIPTION OF THE WORKSHOP

The workshop was attended by 12 participants. The workshop convenors introduced them to the task, creating a CBE, and the main tool supporting it: the stepwise construction of a CBE out of a story, introducing the topic, followed by a series of steps, each posing a set of questions to be answered by the students, using a suitable educational activity. A step can have multiple “inputs”, results from previous steps or materials provided by the teacher, and has a tangible “output”, e.g. a list of stakeholder and their values, a list of arguments for and against an option for action, requirements for designing a device, etc. A template for applying this construction was provided as an online form.

The participants were split into three groups (Zoom breakout rooms), each tasked with creating a CBE. In every group one member was appointed to fill in the online form as a record of the group’s design process. For each group, one of the workshop convenors was present to provide instructions and guide the process where needed. Discussion on thecase design also brought out wider issues entailed by the creation of open-source educational materials in ethics.

In group 1, the participants proposed a CBE based on one of their research, namely concerning an ethical issue encountered by engineers in day to day life. Based on interviews with engineers in various companies, the participant noticed that the ethical problems are not so much about ethics of technology or design, but about what he called “HR issues”, namely workplace conflicts arising from insufficient communication and from not involving the engineers in the sales process. The case proposed singled out such a problematic moment, namely when an engineering team needs to deliver a project in unrealistic time because the sales team promised something unfeasible to the client. The engineers are then faced with the choice between doing an imperfect project, asking for more time, or failing to deliver it on time. All choices are considered problematic for the future of the engineers in that company. In group 1, we discussed the options that the students had to choose from and we discovered that it was too simplistic to attribute responsibilities and assign blameworthiness. Rather, in choosing the goal of moral sensitivity and moral deliberation, we proposed some pedagogical activities that entailed first that students do a role play of how the decision was made (to oversell their capacity) and then, after students had decided who was to blame, to allow them to role-play a time-travel: if students could go back in time, what moment would they choose where they could intervene? What kind of interventsions would they enact? We also discussed how the students should be encouraged to see the problem as systemic – namely one of company procedures and approaches – instead of trying to attribute blame to single individuals.

Group 2 started from a technology, assistive robots in elderly care. One of the group members performs as a musician in elderly homes, and from his experience music plays an important role in the well-being of elderly people, including those with ailing health, especially when the music is from their younger years and they can make requests to the musicians. This became the topic of the CBE: design a robot that can interact with elderly people and play music for them. The first step in the exercise is to investigate both the opportunities and dangers in the use of such a robot, addressing questions like: How can the robot be used assist to increase quality of life? Can it be adaptive to support different health needs? How much control do the end-users/patients have – are they activilty involved and being encouraged to positively engage. The second step in the exercise was to engage in “negative design”: thinks of all the ways in which such a robot could be designed for unethical uses, for instance: could the robot’s algorithms manipulate the mood and play music that has a desired outcome for others, e.g. make the elderly more docile for the care home owner? The third step is to collect requirements, preferences and constraints for the design of the robot, taking the outcomes of steps 1 and 2 into account. Here the discussion turned to participatory design methods, which could help to incorporate the relevant values into the design, but might be difficult to apply with some stakeholders in this context, in particular elderly suffering from dementia.

Group 3 chose to take the challenging topic of cryptocurrency/ blockchain. This turned out to be an adequate choice, as the workshop members knew some things about it, but not as much as engineering students might. As such there was a clear distinction between empirical knowledge and ethical reflection. The members decided to start from a single impression: an image of a house in a wintery landscape, where the snow had disappeared around the ceiling and walls of the house – because inside, cryptocurrency was being mined. From the impression of this image, the following steps were quickly conceived. The group chose to create a set-up for a structured, plenary discussion about the (dis)advantages of this new, disruptive technology. In principle, blockchain-technology could inspire an entirely new economic system by excluding the middle party currently fulfilled by banks. Although Venezuela has recently made bitcoin an official currency in the country, this kind of development has not been seen in many other instances. Furthermore, the consequences of such a transition cannot be predicted. These kinds of deliberations were gathered in statements for the discussion. Finally, roles for students partaking in the discussion were defined to enable a structured debate.

4 RESULTS

All groups were able to use the construction method for case-based exercises presented in the workshop, and commented favorably on it during the exchange of experiences at the end of the workshop. Given the time constraints, it was not possible for the groups to finish the CBE they started to design. The workshop conveyers have offered to help the participants to develop their sketch into a full-fledged exercise, and publish it exercise as Open Educational Material in the project's online collection[2].

A finding across groups was that participants really appreciated designing a CBE in a group compared to doing this by themselves, as is common practice. Discussing one's idea with others brings out many more possible directions in which the CBE can be developed, both in terms of the story and in terms of the ethical issues that one would like to address. This wealth of options brought a second issue to the fore. In designing an exercise, there is a tendency to start developing the idea without first deciding on the learning outcomes. This makes it difficult to ensure that the educational activities chosen for answering the questions in each of the steps contribute to the goal of the exercise. Achieving alignment between the activities and the desired outcome of an exercise is easier when the learning outcomes are established before designing the steps.

Overall, the workshop achieved its goal of introducing the participants to the toolkit method of building CBEs. By making the construction of exercises explicit and piecemeal, we managed to show that creating open educational materials is an achievable goal for many ethics teachers.

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[2] To be found online here: https://edusources.nl/communities/62f26a9c-d593-49a5-9330-f4a71a1fd370/

MATHEMATICAL COMPETENCIES AND BLENDED EDUCATION: HOW TO BUILD A RESILIENT COURSE?

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ABSTRACT

1 INTRODUCTION

1.1 Background

To educate future competent engineers, it is crucial to adopt teaching and learning approaches that support students in dealing with highly complex problems [1]. One strategy is to enhance service mathematics in higher engineering education by shifting from outcome-centered to competence-centered approaches [2]. This strategy is examined and adopted in a large-scale innovation programme of mathematics education (PRIME) at TU Delft to design effective service mathematics courses in higher engineering education.

As mathematics is at the core of engineering education, we will, in this workshop, explore how to create a viable and resilient educational model for developing mathematical competencies, described in the Framework of Mathematics Curricula in Engineering Education [2, 3]. Additionally, we will discuss how the development of mathematical competencies can be facilitated by leveraging technology in blended and remote learning environments. The aim of this workshop is to start a process via a living document which serves to share and create material and expertise in teaching, learning and assessing the mathematical competencies.

1.2 PRogramme of Innovation in Mathematics Education (PRIME)

In 2014, TU Delft piloted PRIME with the aim of redesigning service mathematics education for engineers by employing the blended learning cycle principle: Prepare, Participate, Practice. The main goals of PRIME are academic success, transfer, and student engagement [4]. Over 20.000 engineering students in 45 courses are being taught in PRIME each year.

1.3 Framework of Mathematics Curricula in Engineering Education

The report of the SEFI mathematics working group on the Framework of Mathematics Curricula in Engineering Education advocates the acquisition of mathematical knowledge in engineering education through consideration from the broader perspective of acquiring mathematical competencies at desired levels. [2]. Niss [5] (p. 6/7) defined mathematical competencies as “the ability to understand, judge, do, and use mathematics in a variety of intra- and extra-mathematical contexts and situations in which mathematics plays or could play a role”. Alpers et al. [2] argued that mathematical competencies can only be obtained by their application in engineering contexts and courses, and by stimulating active student involvement. Examples of how learning activities in PRIME support the development of mathematical competencies as a part of the Engineering curricula have been shared in the workshop.

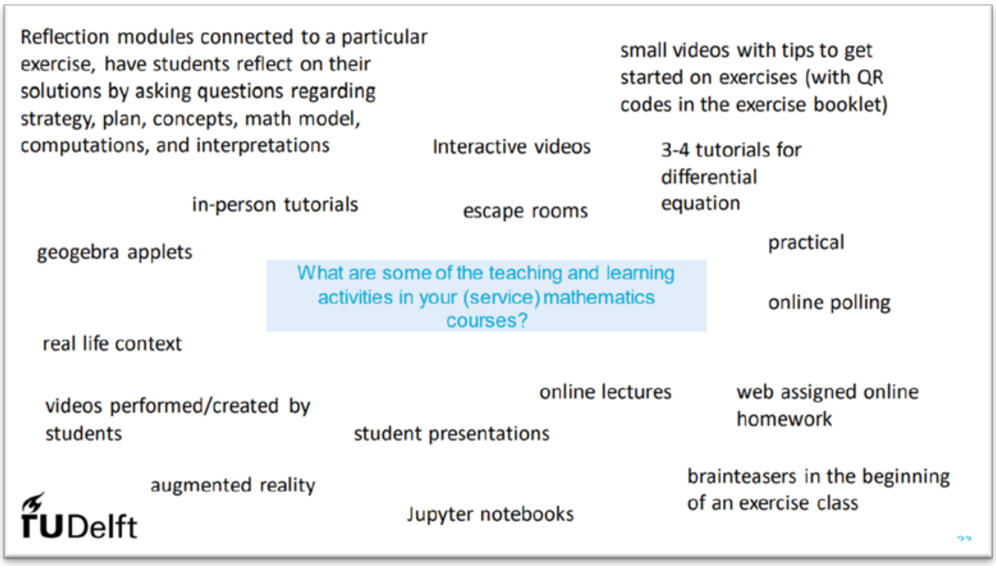
2 WORKSHOP METHODOLOGY

Prior to the workshop, a small survey study assessing mathematical competencies was conducted with 22 (73%) math lecturers teaching in PRIME. The survey was adapted and made available for participants after the workshop. Reading materials and links were also provided in advance, but no preparation was required from workshop participants.

During the workshop, the presenters provided an overview of the blended approach in PRIME and invited the participants to share some of their course activities (see Figure 1).

Figure 1

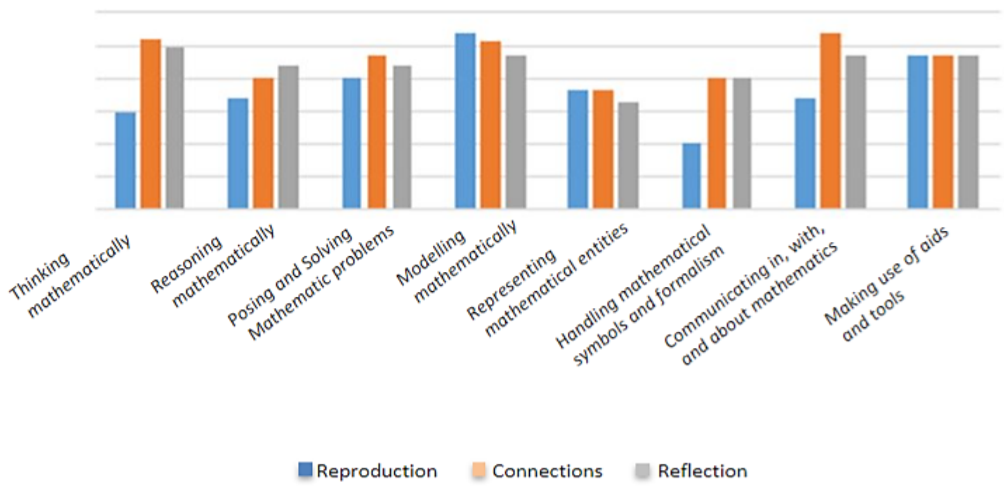
Ideas Shared in Brainstorming Session



In addition, the mathematical competencies theoretical framework [2] was introduced and key conclusions from the small survey study in PRIME were shared with workshop participants (for an example, see Figure 2).

Figure 2

Math Lecturers' Relative Assessment of "Application Examples in Lectures" as a function of Mathematical Competencies across three levels of transfer: Reproduction, Connections, and Reflection



Lastly, a description of the RULES_MATH project (https://rulesmath.usal.es/) was presented. In the final workshop session, participants shared experiences on fostering mathematical competencies, first in breakout rooms and then in a plenary session. The discussion was prompted by two questions: "How do the activities in your courses support the development of mathematical competencies?" and "How do these activities align with the three levels of transfer?". During the discussion, a living document with examples, thoughts, and ideas on effective teaching and learning materials was initiated.

At the end of the workshop, participants were expected to experience the following outcomes:

- Reflect on how their math courses support engineering students in developing mathematical competencies
- Share how course activities in different universities support students in developing mathematical competencies
- Discuss how service mathematics courses and activities can be designed to optimize learning outcomes associated with mathematical competencies

3 WORKSHOP RESULTS

The brief presentation at the beginning of the workshop provided participants with insights into the activities developed in the context of PRIME and the study that was conducted to assess how different activities may support students in developing the eight mathematical competencies with regards to varying extent of transfer (i.e., reproduction, connections, reflection). Using the zoom annotation tools, participants shared the teaching and learning activities that they use in their service mathematics courses. Figure 1 shows participants' ideas from the brainstorming session. The ideas were used as a starting point for the discussion in the breakout rooms. During the breakout session, participants elaborated on the activities that were shared and discussed how these different activities contributed to the development of mathematical competencies for engineering students. Based on the discussion, participants gained an understanding of the various teaching practices at other universities and reflected on their own course designs. A few important themes surfaced from the small group discussions:

- Students need opportunities for reflection and mathematical thinking. This can be facilitated by providing students with better forms of feedback so that they can learn from mistakes.
- Problem-driven activities can serve as a starting point for students to think about how to better apply what they have learned and enhance mathematical modelling.
- There is a need to support students in critical reflection and to stimulate metacognition.

The discussions in the workshop led to a collaborative living document where we envision that teaching and learning ideas and best practices carried out in the universities can be compiled and shared across universities. (For more information on the living document, please contact the corresponding author.)

4 FUTURE DIRECTIONS

Ideas from the workshop led to two initiatives.
Firstly, the survey study assessing mathematical competencies conducted with math lecturers teaching in PRIME will be extended to math lecturers at other universities. The study aims to examine how math activities in different universities support the development of mathematical competencies and whether there are differences in lecturers' perceptions of mathematical competencies.
Secondly, a living document is created to facilitate sharing of resources and ideas across universities. This document serves as a dynamic and collaborative working space for practitioners in service mathematics to contribute, inspire, and connect.

Having concluded the workshop with deep reflections and generous sharing of activities and ideas for service mathematics courses by participants from different universities, the general sentiment is that ongoing discussions and sharing are needed to build a community of knowledge and practice around mathematical competencies. Furthermore, the strategic shift from outcome-centered to competence-centered approaches in higher engineering education is necessary for ensuring that students are equipped with relevant competencies to become competent future engineers.

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INTEGRATING GENDER AND INCLUSIVITY INTO RESEARCH PLANNING

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ABSTRACT

Attaining equity across genders is still a challenging concept in many facets of society, but successful engineering for a diverse population requires inclusivity. Engineering teams, engineering design processes, engineering research and output can all improve when gender is considered, and when principles of inclusivity and equality are applied. Gender equality training, guided by research-informed toolkits, can promote positive actions, and encourage institutional change. This paper reports the outcomes of a workshop offered at the 2021 SEFI conference, introducing participants and readers alike to a toolkit for integrating gender-sensitive approaches into research and teaching. The toolkit, developed by Mihajlović Trbovc and Hofman, helps academics integrate gender dimensions into their research and teaching – at undergraduate, graduate and doctoral levels – and into new projects and curricula.

1 INTRODUCTION

Gender equality is one of the core values of the European Union and is embedded in the 5th Sustainable Development Goal in the United Nations' 2030 Agenda for Sustainable Development. Promoting gender equality and diversity in science has been also one of the six priorities in strengthening the European Research Area. Achieving equality across genders, while addressing their diversity, is still challenging in many domains of our societies, and it is particularly crucial in engineering for a diverse population. To progress gender equality, the European

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Commission has been supporting implementation of actions in universities and research centres to promote equality and to dismantle gender stereotypes. Gender equality training, guided by research-informed toolkits like the one by Mihajlović Trbovc and Hofman [1], can promote positive actions, and encourage institutional change. This paper introduces readers to the toolkit, its purpose, and some of its core features, and it reports the outcomes of a workshop offered at the 2021 SEFI (European Society for Engineering Education) conference designed to help participants apply the toolkit to better integrate gender-sensitive approaches into their research and teaching.

2 INTRODUCTION TO THE TOOLKIT

The toolkit discussed at this workshop presents four steps to integrating gender-sensitivity into one's academic work. It involves: (1) designing gender-sensitive research content; (2) applying gender-sensitive methodology; (3) producing gender-sensitive results; and (4) achieving gender-sensitive outcomes in the teaching process. It was developed by Jovana Mihajlović Trbovc and Ana Hofman, via a project funded by the European Commission: "Gendering the Academy and Research: combating Career Instability and Asymmetries" (GARCIA, www.garciaproject.eu). Its purpose is to help academics envision and enact more inclusive projects and curricula by integrating gender dimension into various aspects of research and into teaching at undergraduate, postgraduate, and doctoral levels.

Gender-sensitive research considers gender as a variable in all steps of a research project while striving for equitable participation in research among genders (male, female, transgender, transsexual, etc.). It helps make research results more relevant for society. Using a gender-sensitive approach encourages researchers to consider and utilize more sensitive research methodologies in general—and the process of considering gender may open new interdisciplinary research questions. It can enable researchers to write more competitive research and funding proposals. Integrating gender sensitivity into one's research conduct also tends to build a more gender-sensitive academic work environment overall [1].

The research approach considers gender differences—such as how men and women might be differently affected—at all stages of the research process from conception to communication of results. Gender differences, which often lie under the surface and remain unrecognized and unnamed, but they need to be considered and this toolkit helps researchers think about what, when, and how to probe such issues.

Gender-sensitive teaching considers and supports students of all genders, integrating more diverse histories, voices and perspectives into course material and discussions. Gender needs to be considered with regard to class conduct and class content, with inclusion of readings and publications that use a gender-sensitive approach and homework assignments that require reflection on the gender-dimensions of a subject. It is important to provide equal opportunity to staff of all genders across disciplines, attract and retain diverse students and teachers.

3 OVERVIEW OF THE WORKSHOP

Most participants in this SEFI event engage daily in both teaching and research. To support equity, our workshop at SEFI aimed to help these engineering educator/ researchers reflect on ways gender is relevant to their research projects as well as their teaching practices. Workshop participants practiced applying the toolkit under three scenarios:

1. Designing gender-sensitive research/curriculum content
2. Applying a gender-sensitive theoretical or methodological structure
3. Producing gender-sensitive outcomes

The workshop was opened by the session coordinator, Professor Shannon Chance, and the Chair of SEFI's Special Interest Group (SIG) on Gender and Diversity, Dr. Inês Direito. Their welcome was followed by a presentation of the toolkit by its lead author, Dr. Jovana Mihajlović Trbovc. Then the attendees broke into small groups to apply and practice using the toolkit, using Google Jamboard (https://jamboard.google.com/) as a collaborative tool to generate and capture ideas for subsequent discussion. The workshop culminated with a response by Dr. Mihajlović Trbovc to comments posted to the Jamboards. In this way, Dr. Mihajlović Trbovc provided a re-cap of the individual group outputs, extending our understandings with practical suggestions for engineering education research.

2 RESULTS

The breakout groups in this workshop focused on three specific aspects of the toolkit: (1) how to design gender-sensitive research content; (2) how to detect stereotypes and biases; and (3) how to apply gender-sensitive theoretical or methodological structures. Regarding each topic, workshop participants generated new ideas and insights specifically relevant to engineering education research. Below, we integrate ideas from the toolkit and view these in relation to engineering education research and practice. Ideas presented below therefore originate from two sources: (a) the toolkit itself and (b) annotations made on to pages of the toolkit by workshop participants using Google Jamboard.

2.1 How to design gender-sensitive research content

The question of how to design gender-sensitive research content is step one of the toolkit, and it has to do with identifying the research question and generating research questions that are gender-sensitive. This step requires considering gender dimensions throughout each planned phase of the research (posing the initial idea, formulating the research question, designing aims and objectives of the research, applying methodologies, and presenting outcomes and results). The toolkit provides valuable prompts, such as: Can you formulate the research question with both women and men in mind? Can you think of how men and women relate differently to the research question? Does your project have to do with structural aspects of society, such as decision-making, law and public policy? It's important to consider how the roles and positions of women and men differ in the realm you're studying and if genders are equally represented in various aspects—such as decision-making, access (e.g., transportation, mobility, use of infrastructure), income, and ownership (e.g., property, land).

The toolkit recommends that, "if your project tackles the private lives of individuals, think of how women experience life situations differently from men" [1, p.30]. Be aware that women and men can face different challenges (related to, for instance, voting, parenting, consumption, career paths) and consider how this might influence your results and findings. Are participants in your study influenced by their society's dominant roles and narratives, pressures and expectations—in the way they think, behave and respond to questions?

As the default lens often ignores gender, such prompts are important in helping us see, name, and address what normally remains invisible. But are they applicable in all research disciplines? We think they are applicable at some level in nearly all research, and we challenge you, the reader to probe this as carefully as possible. For centuries researchers have assumed their research was gender-neutral, and this has had detrimental, and very often measurable, results [2]. Consider how many women have died while driving over-medicated because dosing was designed with larger, male-sized bodies in mind, and how many more have died in vehicular accidents because car safety belts were designed without regard to women's typical body sizes and types. From cell behaviour to the design of ingredients, products, buildings, and infrastructure, gender makes a difference. At all these levels, women have historically been ignored, which resulted in them being treated as 'atypical' or 'inferior' [3]. Even apps to track health have omitted basic health issues faced by all women. Revealing a huge blind spot, Apple released a health tracking that had no capacity for tracking menstrual cycles. The toolkit helps researchers avoid such omissions. It urges us to consider, when defining research problems, the way male and female bodies and chemistries might differ. It advises that, when reviewing literature, we take time to search for gender-sensitive studies and literature related to the study topic and assess where gender aspects might remain implicit.

Workshop participants who looked specifically at this step noted we should take care not to inadvertently attribute women's (interview or survey) responses to their gender. Participants agreed it is important to adopt a gender lens, and to also be mindful of the non-binary gender spectrum—being careful not to force people into boxes, particularly boxes that do not actually fit their identities. They recommended extending the toolkit in the future to include class and other aspects of intersectionality—to help researchers consider additional issues related to equity, including ethnicity, nationality, class, physical ableness, etc.

2.2 How to detect gender stereotypes, inequities, and biases

Participants noted that we should be careful not to introduce stereotypes when considering gender dimensions, or at least carefully consider how conscious and unconscious biases might influence our own assumptions. This topic was the primary focus of the second breakout group, on detecting gender stereotypes, inequalities, and biases.

The toolkit recommends that while considering gender aspects in your research, individuals ask if they might be “projecting stereotypical roles onto how men and women behave, what they need and desire” and consider repeatedly if there are hidden aspects related to gender and stereotyping that might be inadvertently embedded in your research questions or objectives [1, p.32].

Related to teaching, what do you do to raise students’ awareness of gender stereotypes in engineering, and inequities they might face as professional engineers? As engineering remains a male-dominated profession, for attendants of the SEFI workshop particular question from the toolkit was quite relevant: “have you considered how your female students feel about [the] professional scene they are entering?” And vice versa, we should be reflective on how the male students feel about entering a profession that lacks diversity and equality. Discussing inequity and bias in STEM recruiting and selection may help students as they enter the professional world, for instance. A participant indicated that discussing a variety of experiences to prepare students for workplace experiences, settings, and challenges (cultural differences as well as gender ones) has proven helpful to students.

A different participant noted that their course includes discussion of how to address inappropriate questions (for example, “Are you planning to have kids soon?”). That course tries to discuss this in an inclusive way, recognizing that there are inappropriate questions for male and female interviewees.

Others noted that “we always try to take the different perceptions of male and female students into account but are sometimes hindered by the low number of females” and asked “I am hiring a PhD researcher to do social science on female students' experiences in STEM/engineering education. A=applicants are of various genders. How will I be able to tell if they are sensitive enough to gender issues?” Likewise, discussion prompts can help reveal important issues of embedded bias and make them visible for students. A teacher explained that a male student had used the reflection activity the previous week to think about contemporary issues and the new ban on abortion in Texas. “He took it as an opportunity to be aware of how laws that don't affect him may affect his female co-workers.” Creating a space where students feel safe and empowered to discuss uncomfortable topics can foster growth.

2.3 How to apply gender-sensitive methodology

Step two of the toolkit covers how to apply gender sensitive theoretical and methodological structure. The underlying rationale is that “Research that does not apply gender-sensitive approach may draw general conclusion based on partial data” [1, p.33]. To understand social processes, both genders must be included and perspectives specific to men or women must be considered. Likewise, research on medical conditions must include both genders. Indeed, focusing “on female and male gender only is too narrow an approach, e.g. trans people are having health issues too”, one participant noted.

Researchers must consider balance of participants, gender-wise, in their research sampling. This might have distinct repercussions in engineering education research, as a workshop participant noted: “By default, my research group always tries to include gender balanced samples – however, this also means that we have an overrepresentation of female students in our sample (not representative of our population in most cases).”

Researchers also need to make sure survey questions are relevant and properly worded for male, female, pan-, or transexual respondents. Forcing people to select a response before they can move forward on a survey can yield inaccurate data, when options are insufficient to capture diverse respondents’ life experience. The toolkit asks, “Are you using gender-sensitive language in your project outline?” [1, p.34]. The toolkit notes that many European languages use masculine form, for mixed-gender groups as well as “unknown individuals, officials’ titles, names of the profession, etc.” [1, p.34]. For instance, Portuguese is gendered, “so plurals (engineers) are masculine”, one participant noted. The toolkit suggests using the feminine form or alternating it with use of the male form to help make gender and potential gender discrimination more visible in research, but a participant noted that “I sometimes feel that my using feminine form (as a female) in my content is less effective than if they see this in a male's subject content”, reflecting traditional bias.

Regarding teaching, the toolkit asks: “Do you teach students gender-sensitive methodology? Do you use gender-sensitive language when teaching and writing course materials? Do you use visual material in gender-sensitive way?” [1, p.34]. Participants noted that whereas printed material may be written sensitively, bias is often still evident when they are “sourcing material to contextualise learning” and that they find “'real world' examples are less gender sensitive”. Unfortunately, “some students see visual representations as 'token' gestures” but regardless, it is still very important to consider visual representations and how gender bias might be embedded in photos and other graphic depictions.

Considering EER, participants noted that socialisation affects the ways in which those of various genders experience education. Teachers should consider a variety of viewpoints when making teaching intervention. Here again, of intersectionality and the importance of not treating groups homogeneously or prematurely assigning meaning or causation based on a specific demographic variable was emphasized.

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HOW DO WE BUILD EFFECTIVE ONLINE STUDENT COMMUNITIES?

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ABSTRACT

Delivering engineering programmes online presents several challenges, including issues around effective technologies, digital access, and delivery of traditional hands-on project and laboratory activities. Reflection on these issues after a full year of online teaching suggests that despite initial difficulties, both educators and students have adapted well to online delivery of content, and indeed certain aspects such as video content and online quizzes have been very well received by students. However, significant challenges remain in creating effective social structures and peer groups which are vital for student learning, mental health and wellbeing.

This workshop explored how can we encourage students to build online communities. In particular, what structures and opportunities should be in place? What activities can we build into our programmes that embed social interaction? How can technology be used to facilitate this?

The workshop started with a short poll to gather information on participant experiences of teaching in an online environment verse face-to-face. It was facilitated using virtual breakout rooms with participants split into two groups. Group one focused on how we create an appropriate online environment while the second discussed what methods and technologies could be utilised to achieve this. Responses and contributions from each breakout session were gathered using the electronic collaboration platform Padlet. A summary of each area was created and disseminated.

This workshop was an excellent starting point in discussing the complexities of building and maintaining online student communities. The majority of participants felt they gained new ideas on how to encourage students to interact and moving forward are keen to try something new in their teaching. Participants found sharing their experiences with colleagues useful.

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1 INTRODUCTION

The rapid switch to online modes of delivery in many institutions has brought with it a myriad of challenges for engineering programme delivery, including issues around effective technologies, digital access, and delivery of hands-on project and laboratory activities.

Reflection on these issues after an academic year of online teaching suggests that despite initial difficulties, both educators and students have adapted well to online delivery of content, and indeed certain aspects such as video content and online quizzes have been very well received by students. However, significant challenges remain in creating effective social structures and peer groups which are vital for student learning, mental health and wellbeing. Online delivery remains 'distant' (Ní She, *et al* 2019), not only is there a degree of separation between the educator and student but the student is also separated from their peers. Lui *et al* (2007) highlighted how online modes of delivery can lead to a sense of student isolation. To overcome this, it is important to embed opportunities and activities for engagement. Some activities within our school such as an ongoing reflective journal activity for Mathematics, involving online peer group feedback sessions, have been generally well received: *"I have thoroughly enjoyed being part of my group…it's been refreshing to be able to talk to people on my course and not just be watching lectures all day. They've been super helpful with any problems I've had."* However, managing these has been technically challenging and time intensive, and issues with engagement remain.

Drawing on the experiences from our own School, it is intended that this workshop is a starting point for collating best practices in building engaging online communities, with potential opportunity for further collaboration between workshop participants across various institutions. The workshop aimed to provide opportunities for participants to share experiences and both motivate and give confidence to those who want to try new forms of online engagement with their students. The intended learning outcomes were:

- Benefit from shared discussion of prior experiences both positive and negative.
- Gain ideas and methodologies for building online learning communities.
- Acquire understanding of how methods could be applied within own teaching context.
- Develop motivation and confidence to try new approaches.
- Gain access to a support network of peers building online communities within engineering education.

2 METHODOLOGY

This workshop targeted those who wished to share their experience of trying to develop an online student community. It was also an opportunity for those who are new to online delivery and looking for ideas to engage with more experienced colleagues. Online polls and breakout rooms were used to facilitate the workshop and gather information.

2.1 Workshop structure

A short introduction was given outlining the structure and to provide context to the activities used. The first activity involved asking participants to complete a short poll, using MS Forms. This was to determine the experiences within the group of online teaching and learning and to establish how participants felt about the delivery of content and engagement with students using online environments compared to face to face. Once the experiences poll was completed participants were asked to join one of two breakout rooms. Participants were allowed to select which topic they would like to focus on. The theme of each breakout room was,

1. **Creating**: How do we put structures in place that will encourage students to engage. How does it become a natural part of the learning environment? How can we encourage students to build online communities?
2. **Methods**: How can technology be used to facilitate this? What activities can we build into our programmes that embed social interaction? How does the group size, dynamic and environment affect the approaches taken - Blended vs Online vs In-person? What pedagogical methods are key? How do we switch traditional group project and hands-on activities to an online format?

Responses and contributions from each session was gathered using electronic collaboration platform Padlet. This enabled participants to easily engage not only with the workshop facilitator but with each other. Using the platform gave the participants a choice of several of methods of interaction; oral, post comments or attachment of documents they would like to share. A discussion was held to allow participants to explain and elaborate upon the points they contributed to the Padlet. A summary from each breakout room was collated and disseminated back to the wider group at the end of the session.

3 RESULTS

3.1 Online vs Face-to-Face Experiences Poll

Figure 1 outlines the results from the initial poll which asked participants how challenging different issues were in an online environment compared to face-to-face teaching. Responses were provided by 12 participants.

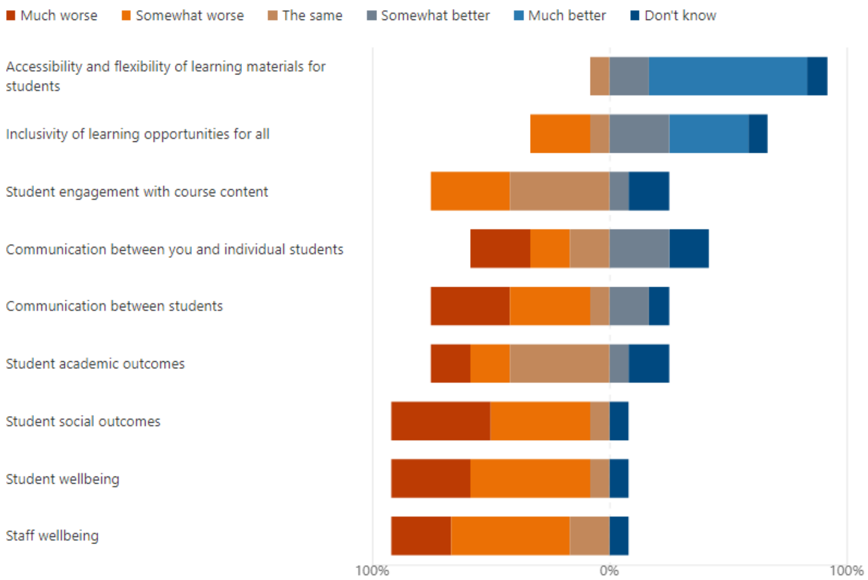

Figure 1. Results from teaching experience poll looking at online vs face-to-face. Question posed: "In your experience, how challenging have the following issues been in an online environment compared to face-to-face teaching?"

As expected, experiences for the participants varied. 91% of participants found accessibility and flexibility of learning materials for students to either be the same or improved. In terms of inclusivity of learning opportunities for all, 58% of participants found this to be improved while 25% felt it was somewhat worse. Communication between participants and individual students was varied and communication between students tended to be worse (66%). The majority felt that student engagement was either the same (42%) or worse (33%). Interestingly, 33% indicated that students' academic outcomes were worse compared to 25% who stated they had improved, whereas 42% confirmed student academic outcomes remained the same. Overall, the majority felt that student social outcomes, student wellbeing and staff wellbeing were worse using an online environment.

3.2 Breakout Rooms – Padlet Discussion Board

Table 1 and Table 2 provides a summary of the Padlet discussion boards that were used in the breakout rooms. Each breakout room focused on one area, with a series of questions within the topic posed and discussed. The link to the Padlet discussion boards is provided in row one of each table.

Table 1 Summary points from Padlet Board discussion 'Creating structures and opportunities for student community building online'.

Link to Padlet Board: "Creating structures and opportunities for student community building online" https://qubeps.padlet.org/louisepick/mix0r1xjvglzxsi3
Give a good example of a strategy you have used (or seen used) to encourage student community building online
Setting up groups and maintaining them throughout the year. Designing group activities to encourage students to get to know one another, including collating the experiences of a group through a group CV, getting groups to share work with the class, present to class, and to provide peer feedback on other groups. Using appropriate techniques in tutorial sessions to encourage group interaction. Encouraging individual engagement, for example using of peer instruction questions, informal drop-in sessions, letting students set the agenda, encouraging use of cameras. Explaining the importance of engagement to students.
Have you experience of a strategy that did not work well?
Making the assumption that students will know how to use the technologies. Not making questions challenging enough- the threshold for answering seems to be higher in virtual environments than physical. Difficulties in successful groupwork online in large classes. Not using the chat functions appropriately. Online "dating" to find a collaborator, video pitches to find appropriate group members, and online course cafes did not prove successful.
How do we make student community building a natural part of the online learning environment?
Letting students create their own social spaces, many students did not "sign up" for online learning, so they might only want to communicate with their learning group via chats. Try to introduce students virtually in a social context before the course start. Dedicate time to social interaction in class, small talk, checking in.
What are the barriers to students to effective community building?
Lack of motivation, lack of time, lack of self-confidence. Digital poverty - poor accessibility to internet/ computers e.g. Lack of social skills.
How do we as educators encourage students to interact online?
Give them tasks they can only complete if they cooperate and interact.
How do we assess the effectiveness of our structures?
Student feedback, grading.

Any other points you wish to add?
One suggestion was to develop a digital communication/participation crash course.

Table 2. Summary points from Padlet Board discussion on "Methods to facilitate student community building online"

Link to Padlet Board: "Methods to facilitate student community building online" https://qubeps.padlet.org/louisepick/tu81n6slmzzgv45d
What is the most useful technology that you have used (or seen used) that has helped students engage with each other online?
Gathertown - a virtual walk through environment **GoReact** - video submission and feedback approach to make feedback feel more personal **Github** -programming lecturers used it a lot with their classes **Piazza** - Posting questions and allowing other students, teachers and Tas to interact/edit answers to solve them. **Breakout rooms** **Team quizzes** e.g. using Kahoot, TurningPoint **Slack -** Text based chat with potential audio/video conferencing. **Virtual meeting spaces** – e.g. Mozilla Hubs https://hubs.mozilla.com/ **Discussion boards** **Collaborative and interactive software** – useful for groupwork, e.g. Miro
What are the downsides to using technology to facilitate student engagement with each other?
Sometimes the focus becomes the technology not the pedagogy. Major issues with connectivity and poor broadband or bandwidth. Access to technology and digital poverty are real issues. Lack of integration of various learning platforms and apps. Too much variation and new technology can cause confusion and can be overwhelming for students. "Zoom fatigue".
Are there any activities that we can use, for example in online lectures, to embed social interaction? How do they support good pedagogy?
Display student working and showcase multiple ways of solving a problem. Share power - the lecturer is not necessarily the one with the best method. Portfolio using WordPress, Mozilla Hubs etc. where students can share their work and other students can comment and get used to give constructive feedback and build their confidence to share their own work. Jigsaw activities. Cooperative learning - grouped by experts. Think-pair-share and peer discussion.
How does the environment (fully online, F2F, blended), and group size and dynamic affect the strategies and technologies used?
Found it much easier to get online engagement in first lockdown when we already knew students rather than starting a relationship online. The blend of face-to-face vs online time can make a big difference. Difficult to get large groups who don't know each other to turn on cameras etc. Premade groups don't always work. Positive peer pressure in smaller classes and F2F it is harder to stay hidden.
How do we handle traditional hands-on group projects?
Design build projects adapted by providing kits for students to use at home.
How do we assess if our methods are effective?
Talking with individual students, but it's much more difficult than face-to-face, focus groups, polling students.

When trying to develop structures and environment, the key themes that came out of the discussion were,

1. It is important to try and encourage the use of cameras as much as possible to create a sense of belonging and community.
2. Actively trying to encourage participation in other ways including creating group activities that force students to work together, creating peer feedback activities is one option.
3. Letting activities remain formative remains an issue. Creating activities that carry some summative credit tend to be more successful.

In terms of methods and technology participants felt that,

1. It is too easy to focus on the technology and not the experience, students can be overwhelmed with too many platforms.
2. Poor technology, internet access etc is an ongoing issue for many students, which impacts their ability to fully participate.
3. Creating social activities and social hubs through platforms such as Gather/Mozilla hubs has potential to be useful.

4 SUMMARY

This workshop was an excellent starting point in discussing the complexities of building and maintaining online student communities. The majority of participants felt they gained new ideas on how to encourage students to interact and were keen to try something new in their teaching. Participants found sharing their experiences with colleagues useful. Moving forward an area for investigation is how do we fully understand the student experience and gauge student understanding while using an online environment. Evaluation tools such as forms are useful however they are quite restrictive.

With blended learning at the forefront of engineering education now more than ever, and students engaging predominantly via online both academically and socially, it is vital that we continue to evolve our methods of engagement via online platforms. Not only will this benefit students from a learning perspective it will help facilitate healthy relationships with peers in both a social and professional capacity. This in turn will help students to develop essential skills that will be beneficial in the workplace. Given the likely longer-term impact of changes in professional working environments, which were driven by Covid-19 pandemic, it is important that students gain experiences of effectively interacting remotely and building relationships with colleagues at all levels as this is likely to be a core element of the workplace of the future.

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WORKSHOP: HOW DO TEACHERS RESPOND TO SUSTAINED CHANGE?

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OVERVIEW

Higher Education is facing profound shifts, because employers seek graduates who can work effectively with others in rapidly changing, transdisciplinary contexts, defined by globalisation, digitalisation, sustainability, complexity and, most recently, a global pandemic. COVID caused an instantaneous acceleration to online learning (we often call emergency, remote learning), where academics were forced to conduct their normally face to face classes through video conferencing tools. The calls for sustained change are challenging academics to rethink their traditional teaching role.

This workshop seeks to understand how academics have responded to these challenges, both short term (emergency remote teaching) and the longer-term shift to transdisciplinary teaching, where problems in the world have become more complex and where graduates need to be prepared for transdisciplinary learning, working with diverse communities on their solutions.

BACKGROUND

In Australia, the Australian Council of Engineering Deans is currently undertaking a review of engineering education, the 2035 project. Its preliminary findings have identified the following changes in teaching practice will be required to: integrate real world situations in classroom teaching, integrate human/social dimensions of engineering problems, increase industry collaboration, use digital technologies and e-learning more effectively, and ensure professional development for engineering educators. We are keen to see how the European experience matches the current review in Australia and to explore the nature of professional development that will be required through this transition, towards more real-world, active learning.

PURPOSE

The purpose of this workshop is to collaboratively explore teaching experiences during the COVID pandemic and future engineering practice challenges, to gain insights into the of future directions of higher education and engineering education in particular. All teachers will benefit from this interactive workshop. This session is an invitation to share ideas and think with others about the changing nature of their teaching and their other academic roles. This is particularly important as we reconsider how curriculum and teaching methods need to evolve in response to constant change.

With changing teaching methods, a more systematic academic development strategy will be required to provide academics with the teaching and facilitation capabilities for these new styles of learning. These capabilities include project-, team- and practice-based, integrative learning approaches. They require facilitation skills beyond what most academics experienced in their own university education.

ACTIVITIES

Participants will work in small groups to discuss three big domains:

1. Teaching changes due to COVID:

   What have been the **positive and negative changes in your teaching practices** in the last 18 months due to COVID? How have these changes **affected you and your colleagues** as teachers? What have you observed about **student reactions** to this new form of completely online teaching and learning? **What are we learning** for the future of learning and teaching?

2. Preparing graduates for their professional future:

   What do you see as some of the **big challenges** facing your graduates, in their lifetime? How do you see the **academic role changing** to prepare graduates for this increasingly complex world?

3. Supporting teachers for their changing role:

   What formats, topics, and methods of **continuing education** would prepare you to become a more future-focussed academic teacher to prepare graduates for their professional engineering future in this constantly changing, increasingly more complex and uncertain world?

METHODS

The workshop will commence with a short overview of current developments in rethinking engineering education in Australia. We then intend to use the breakout room feature of the conference's videoconferencing tool, e.g., Webex. Participants will be divided into groups of 4 or 5 to give everyone more chance to speak. We are expecting 15-20 participants, so about 3-4 groups.

We will use a whiteboard tool that enables each member of the breakout room to post their ideas, thus accelerating the collection of ideas from a serial process of speaking and note taking to a parallel process of everyone being able to write at the same time. We expect that participants will use one whiteboard per question (three in total).

In a workshop of 60 minutes, time is of the essence. We have broken this down to 10 minutes introduction and overview, 20 minutes of discussion in small groups, 20 minutes of reporting back to all participants highlighting key ideas, and 10 minutes for wrap-up. This method will give all participants opportunities to hear, share, and problematise the ideas generated in the other groups.

OUTCOMES

At the conclusion of this workshop, participants will have explored future trends in teaching engineering, with the intent of defining continuing education needs for those future skills. They will personally benefit from exchanging points of view and collectively developing didactic strategies for future transdisciplinary teaching.

The anonymous data gathered at the workshop will also help the workshop facilitators to shape an on-going research project: *Developing the Deliberate Teacher's Voice in the Age of Complexity, Sustainability, Globalisation, Digitalisation and Transdisciplinarity – how do Continuing Education Programs for Academics need to Change to Enhance Teaching Competence at University?*

ETHICS

We are currently applying for Ethics approval through our university's Human Research Ethics Committee, which will be finalised by the time that the workshop runs. We will ensure that the final version of this workshop description includes a clear statement of the intent of the workshop, which will specify that only anonymous data will be collected. Participation will be assumed as consent for the anonymous and ethically responsible use of the ideas generated.

RESULTS

In your opinion which are the most crucial positive and negative changes in your teaching due to Covid?

- Sense of urgency to adapt
- Social wellbeing came to the forefront
- Forced change made it possible to change but it is a double-edged sword because we might fall back to previous routines
- Realised that we ask so much of teachers: number 1 remains research and then making big changes in teaching without any support
- There was a clear difference between those who are good at adapting and experiment with different approaches and those who are reluctant to change
- Teachers are overworked and tired, longing to go back to more interaction
- Some people noticed that the teaching barriers were only in their head

What do you see as the big challenges facing your graduates?

- Responses related more to student learning than future world of work
- Lifelong learning
- Need for more hands on experiences
- Emphasis on personal development
- Lack of transferable skills

What formats, topics and methods of continuing education would prepare you to become a future-focused academic teacher?

- The discussion ranged widely from course team approaches to management and structural barriers
- Peer to peer learning
- Discussing change
- Creating space to tell stories and interact and share experiences
- Learning in hybrid systems, working in teams and experimenting together
- We only learn when we are present
- Rethink the conditions within which we have to work as teachers; setting up the right incentives
- In my university I've got the feeling that teachers are passionate about their courses and subjects but do not really feel part of a team. My feeling is that that is related that a lot of programs are not really a well designed curriculum but more a bunch of really interesting subjects joined together without cement
- I think our PBL helped to get teachers working more together
- I think our intentions to have peer supported development is sometimes undermined by the desire to be a 'leader' and seen as successful. Peer development requires openness around failure and not having individuals competing to be in charge of the group.
- The program perspective is lacking for many subject teachers. They see their discipline, but not the students' education.
- We need to encourage reflection in keeping good bits and integrating with previous models. Space to do that is important.
- I am struggling to get development time to be included in the workload model.

BREAKING THE TYRANNY OF CONTENT IN CURRICULUM DESIGN: A WORKSHOP SYNTHESISING AFFECTIVE, COGNITIVE AND FUNCTIONALIST CONSTRUCTS

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INTRODUCTION

Participation in this workshop will introduce colleagues to a new way of looking at curriculum design based upon a distinctive approach that has been developed by colleagues at WMG, University of Warwick. Initially created for use in the design of the new Advanced Professional Engineering Programme (APEP), the approach, which is grounded in the three concepts associated with the Engineering Habits of Mind Study ('Heart', 'Hand' and 'Head'), introduces the Three Pillars of Curriculum Design (Affective, Cognitive, Functional).

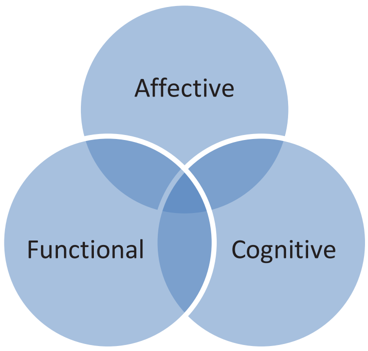
The workshop will provide colleagues with an opportunity to actively participate in the new design process; working in small groups we will explore the need to align programme specific learning outcomes with professional body standards and employer expectations to develop a curriculum design which is authentic across the three pillars.

THE LITERATURE

Comprising an essential part of Engineering Education, Curriculum Design is usually underpinned by a complex mixture of wider educational theory including Constructive Alignment [1] and Concept Mapping [2], and discipline-specific theoretical approaches which have emerged out of Engineering Education Research (See for example [3], [4]).

In Engineering Education the approach to curriculum design is further complicated by the requirements of accrediting bodies and, in the case of Degree Apprenticeships in the UK, by the requirements of apprenticeship standards – developed by 'Trailblazer' groups of employers. A frequent criticism of the design of engineering courses is that they are too content focused. As Rompelman and De Graaf [4] note, often 'a curriculum is described on the basis of the contents by summing up the modules'. This approach creates an input rather than output-focused approach, causing issues including cohesiveness of the curriculum and authenticity of the learning experience. In looking at the relevant literature, the concept of Signature Pedagogies [5] represents an important epistemological standpoint as it encapsulates an applied pedagogy in which the *habits of head, hand and heart* are central drivers in how the curriculum is designed and delivered [6]. Taking this notion one step further and grounded in the Engineering Habits of Mind concept proposed by Lucas and Hanson [7], the tripartite approach developed in WMG represents a holistic model of student development in which three distinctive yet interlinked pillars of curriculum design, representing the affective, cognitive and functional aspects of education are given equal consideration in developing a more connected and 'holistic' design approach [8].

Figure 1: The Three Pillars of Curriculum Design: The EIG Approach



WORKSHOP AIM

Grounded in the emergent findings of our study, the workshop activity is designed to help colleagues get to grips with the practical design of Engineering Education programmes using signature pedagogies. Using the case of a new open Degree Apprenticeship programme in engineering, the workshop will illustrate how approaches such as Signature Pedagogies and Threshold Concepts can be combined to energise staff around developing a programme which is driven by the vision of the Engineer developed through the programme, and not by the technical content of the programme.

WORKSHOP PARTICIPANTS

The workshop has been purposefully developed so as to whet the appetite of those colleagues who are interested in evolutionally and revolutionary curriculum design. It is equally suitable for colleagues who have previously participated in design activities and those with little or no experience. Useful preparation for the session would be to look at the Miro platform (An Online Whiteboard & Visual Collaboration Platform for Teamwork | Miro) which is free for educational applications at time of writing, but this is not a requirement.

WORKSHOP FORMAT

a. ***Introduction to Design Principles: 5 Minutes***
   A quick summary of the principles to be applied over the workshop
b. ***Group Activity (1): Fast-Forward to Basics: A course in a tweet: 10 minutes***
   Start from the 'Why'; focusing on the central purpose of the programme you have 140 characters to create a compelling vision for potential students and industrial partners.
c. ***Group Discussion: Feedback to identify themes and issues: 5 minutes***
   What can we learn from the exercise? Focused reflection in action.
d. ***Group Activity (2): Using Miro to collaboratively design a curriculum guided by the 3 pillars: 25 minutes***
   Two-for-one: a quick engagement with the collaborative design software Miro, which has been transformational in our ability to work together online in WMG and to build a curriculum from a principle-led, outcome-focused perspective.
e. ***Facilitated Discussion: Applying the Three Pillars Approach to bespoke institutional settings: 15 minutes***
   Reflection on action to consider how the lessons from this session might be applied in your context.

WORKSHOP OUTPUTS AND OUTCOMES

1. A better understanding of the complex link between pedagogy and design
2. The opportunity to engage with colleagues in an active, focused discussion around the challenges of curriculum design in engineering
3. Application of Miro boards in course and module design.
4. Knowledge of a distinctive and innovative approach to curriculum design which may be adopted and adapted to a range of engineering education settings.

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A TOOL TO ENSURE CONSTRUCTIVE ALIGNMENT IN COURSE DESIGN

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Conference Key Areas: *Digital tools, Methods, formats and essential elements for online/blended learning*

Keywords*: constructive alignment, course design, visual tool*

WORKSHOP

According to the principles of constructive alignment first described in the literature by Tyler (1949) and later on by Biggs (1999), an outcome-based curriculum should be designed as a coherent system containing three central elements: learning outcomes, teaching strategies and assessment strategies.

Through our experience of teaching support, we have noticed that integrating content and contextual elements (e.g., the resources available, the audience, etc.) allows the teacher to focus on his/her immediate concern (i.e., designing a course) without disconnecting it from the realities of higher education. Overall course alignment helps both students and teachers to reach learning outcomes.

We have developed the course design canvas (CDC) to support teachers throughout their course design process. The canvas builds on the constructive alignment theory and extends it by adding the content and contextual elements. It can be used both for creating or revisiting a course as well as for reflecting on its overall alignment.

The canvas was developed to address course design for both engineering and non-engineering education. To make the session as relevant as possible, the tool will be presented with an example in the field of engineering.

The workshop proposes to introduce participants to the course design canvas. Participants will familiarize themselves with the tool and process by applying it to a course of their choice. To do so, they will work with an electronic version of the canvas using Mural. As part of the workshop, participants will be invited to share

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their canvas with a peer. The workshop will end with a group debrief and a short Q&A session.

In terms of learning outcomes, participants will be able to:

- Describe the elements of the course design canvas
- Apply the canvas to a course of their choice
- Reflect on their canvas through peer-work

The organizers will share with the participants comments pertaining to the alignment of the different canvas produced and, more generally, a set of best practices. Participants will be also able to export their canvas for further use.

TAKEAWAYS FROM WORKSHOP

- The canvas makes the “alignment” part clear but less the “constructive” part
- One could benefit from a way to integrate students who do not have the same level into the canevas and how to include this in the “teaching strategy”
- The meaning of curriculum (as part of the context) could be made clearer
- How can one ensure coherence at the course level or at the program level

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THE PURSUIT OF GREAT ENGINEERING COURSES. DIVE INTO A STAFF DEVELOPMENT PROGRAM AND REACH THE TOP?

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In the recently started special interest group (SIG) on Capacity Building, we noticed that teacher qualification requirements differ between countries and, sometimes, even between universities in the same country. Based on this observation, we arranged a workshop during the annual SEFI meeting in September 2021, asking participants for up-to-date information about requirements in their diverse national and institutional contexts and could learn about best practises from each other. Most of participants were from Europe (11), but Australia (1) and the United States (1) were also represented.

HOW IS PEDAGOGICAL TRAINING ARRANGED?

The discussion was lively: several interesting points were raised regarding how pedagogical training is arranged in different contexts. For example, in Twente (the Netherlands), university lecturers are required to have university teaching qualification (~100h) focusing on pedagogy, assessment, and pedagogical technology. In Finland, there is a difference between universities of applied sciences, where all lecturers are required to have pedagogical competence (60cr), and traditional universities, where pedagogical training is not obligatory. In Sweden, a pedagogical portfolio and the attendance at pedagogical courses are required to become a "qualified teacher" and finally an "excellent teacher". One participant from London (United Kingdom) wrote: “We've worked to create an environment in our institution where education is valued and rewarded, which persuades staff to take part”). However, in many places, pedagogical training possibilities and/or requirements are missing or just start to emerge.

Interestingly, in many technical universities, pedagogical training is organized at the institutional level. Such a format makes it possible to concentrate on discipline-specific pedagogical training, but it misses the opportunity to talk across totally different disciplines, like humanistic fields or social and health care. At Umeå University (Sweden), pedagogical training is provided by a pedagogical development centre, but lecturers from all departments are invited to co-teach pedagogical development courses. The aim of this approach is to build capacity for decentralized capacity-building, that is, lecturers learn how to train other lecturers and can thus help their home departments in local pedagogical development. In Finnish universities of applied sciences, capacity building is provided at vocational teacher training colleges. Those colleges bring together teachers from all parts of Finland and from different disciplines (technology, business, social and health care etc.). Pedagogical training is part of these studies. Most of the workshop participants reported that participating in pedagogical training does not give any reduction in teaching load, meaning that all pedagogical studies must be done at one’s own time. Sweden is an exception, where pedagogical training can be done as part of a given allotment of “competence development time” that all lecturers are entitled to. However, most lecturers prefer using that time for research rather than pedagogical training.

IDEAS FOR IMPROVEMENT

Pedagogical studies and training are a key in developing engineering education. The combination of theory and practical training is a main element in learning, also in pedagogical training. A participant from Twente (the Netherlands) mentioned that they experience that teaching quality (at least among newer teachers) has increased since requirements for pedagogical training were implemented. Unfortunately, there is no research yet to support this experience. No matter whether there are requirements for teaching qualification or not, none of the participants reported on continuous pedagogical development requirements during lecturers’ careers. Notifying the rapid change in possible or necessary teaching practises (COVID-19!), progression with pedagogical training would open eyes for e.g., new technological possibilities.

We also note that, if participating in pedagogical studies does not lead to a reduction in teaching load, it is very understandable that lecturers may be reluctant to participant in these activities, especially if they are optional. There are so many things one must learn at the early stages of a career, that optional studies are not the first thing in the mind. However early teaching experiences may influence how one approaches teaching later in one’s career and early pedagogical training could therefore be particularly beneficial . Participants also raised the idea of developing a standard qualification or even a European certificate for capacity building for higher education lecturers, but this question needs to be discussed further.

CONCLUSION

During the conference we heard several keynotes and panels focusing on future skills of engineers. All of these presentations emphasised continuous learning, technical knowledge, and working online. We argue that future engineers will not be able to reach these skills if the teaching staff is not encouraged (or required?) to develop these skills themselves.

Figure 1. Map of participants in the workshop

WORKSHOP: WHEN EMOTIONS ARE *NOT* OUTLAWED: USING EMOTIONAL SCAFFOLDING TO ENHANCE STUDENT LEARNING

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Conference Key Areas: *Sustainability and ethics, Resilient curricula and teaching methodology*
Keywords: *emotions, scaffolding, sustainability, instructional strategies*

1 WORKSHOP AIMS

The aim of this workshop was three-fold: (1) to introduce participants to educational emotion research and the notion of "emotional scaffolding", (2) to provide examples of emotional scaffolding, with a special focus on engineering education for sustainable development, and (3) to let participants collaboratively develop strategies for emotional scaffolding they can use in their own teaching.

2 BACKGROUND

According to socio-cultural theories of learning, scaffolding is a form of support that teachers (or peers) provide to students, allowing students to perform tasks they would not otherwise be able to do [1]. Scaffolding can, for example, consist of hints, explanations, modelling behavior, or guiding questions. Three forms of scaffolding are described in the educational literature: cognitive, meta-cognitive, and affective/emotional. While cognitive and meta-cognitive scaffolding have been studied extensively, affective/emotional scaffolding has received scant attention [2], [3]. Yet, a sizable body of research shows that emotions profoundly affect teaching and learning [4]—and there is some research to suggest that emotional scaffolding

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can be used to influence students' emotional reactions in ways that can enhance learning [5], [6]. Also, emotional scaffolding seems to be particularly important in the context of dealing with sustainability issues, due to their seriousness, high levels of complexity, and the need to navigate conflicting values and interests [7], [8]. Emotional scaffolding can, for example, aim to help students regulate emotional experiences when they encounter difficult tasks, cognitive conflict, or confrontation with others. It can also aim to build positive social relationships or to create opportunities for students to express emotions in constructive ways, for example in group work or in giving/receiving feedback [2], [3], [5], [7], [9]–[11].

3 WORKSHOP DESCRIPTION

We started the workshop providing a short overview over educational emotion research, including the widely used *typology of academic emotions*. This typology distinguishes between *topic emotions* (emotional responses to subject matter), *achievement emotions* (emotions related to students' perception of their academic performance), *epistemic emotions* (emotions related to the process of learning, such as grappling with uncertainty and ambiguity), *social emotions* (emotions related to interaction and social relationships in the classroom), and *incidental emotions* (emotions related to events and relationships outside the classroom) [4].

We also introduced the notion of emotional scaffolding, tentatively defined as "teachers' pedagogical use of emotive tools and strategies to influence students' emotional experiences and expressions related to subject matter, learning processes, performance, and social relationships in a way that promotes transgressive learning for all students." We provided the following examples of *emotive tools and strategies* from the literature on emotional scaffolding and sustainability education: instructors can acknowledge and validate expression of emotions [8]; create safe spaces for emotional expression and failure [12]; model constructive emotional responses [8], [12]; provide encouragement and reassurance in the face of unconstructive emotional experiences [5], [7]; adjust subject content and/or pedagogical presentation to match students' interests, cultural backgrounds, and competencies [6]; or build positive relationships in the classroom [5].

Next, we asked participants to join virtual break-out groups. In these groups, participants shared and discussed their own experiences of situations in which students' emotional reactions may have impacted learning, taking notes on a shared electronic platform. In total, participants created around 30 posts on the platform, covering a wide range of situations and themes. In a short midway plenary session, we asked participants to vote which of the themes they would like to discuss further. The following four themes were chosen: (1) Fear of making mistakes and being humiliated, (2) Fear of feeling stupid, (3) Emotions in learning about inequalities, and (4) Joy of feeling competence increase – empowerment.

We then created four new virtual break-out rooms, one for each of the above themes. Participants self-selected to one of the rooms, where they then worked together to develop strategies for emotional scaffolding that could enhance student learning in similar situations. Participants again took notes on the shared electronic platform.

Finally, in a concluding plenary session, participants shared their experiences and results from the discussions. We also discussed more general questions related to emotional scaffolding and how it could be implemented in engineering education.

4 WORKSHOP RESULTS

The participants developed a rich set of emotional scaffolding strategies for different situations that can arise in engineering education. Below, we have organized the main results using the above-mentioned typology of academic emotions.

4.1 Emotional scaffolding strategies directed at social and achievement emotions

Theme (4) relates primarily to achievement emotions, and themes (1) and (2) each relates to achievement emotions *and* social emotions. Therefore, participants' descriptions of emotional scaffolding directed at these emotions overlapped to some degree. For example, participants suggested that instructors could reduce students' fear of feeling stupid by providing a safe learning environment, characterized by mutual trust and an acceptance of vulnerability and failure as important aspects of learning. Participants also suggested that instructors could add more formative assessment to help students build confidence and thus reduce anxiety related to exams and oral presentations. Finally, participants suggested that instructors could focus more on re-explaining challenging content, providing access to resources for self-directed learning, or experiment with different pedagogical approaches that could be more aligned with students' needs and thus help them build trust in their own learning and competence.

4.2 Emotional scaffolding strategies directed at epistemic emotions

With regard to epistemic emotions, participants particularly focused on how to provide emotional scaffolding to help students realize that failing is part of learning. Participants suggested that instructors should explicitly encourage processes in which students can test, fail, and learn from failure. Instructors should put more emphasis on validating students' learning *processes* and less on whether or not the students arrive at correct *results*. In fact, participants suggested that instructors should tell students to be "proud of [making] mistakes and learning from them".

Participants also discussed the need for emotional scaffolding when students are confronted with contrasting values and worldviews. These situations can challenge students' views of knowledge—which in turn can challenge their ideas of engineering as a profession and their own identities as future engineers.

4.3 Emotional scaffolding strategies directed at topic emotions

Theme (3) focused primarily on topic emotions and how instructors can help students deal with negative emotions triggered by learning about inequality, suffering, or environmental degradation. Participants suggested that instructors should not only acknowledge and validate students' emotions, but also create opportunities for students to (anonymously) share their emotions. Instructors can also act as role models, demonstrating how one can deal with challenging topic emotions. For example, they can demonstrate how one can express emotions in constructive and respectful ways, and how one can use them as resources in ethical decision making.

Further, participants suggested that institutions and instructors should create curricula that allow students to use their learning for a good cause. Such curricula could empower students to use their topic emotions (such as anger about inequality) as *productive resources for learning and societal transformation*.

5 WHERE DO WE GO FROM HERE?

The large interest in this workshop and participants' vivid discussions suggest that *emotional scaffolding is a topic that should be further explored in engineering education research*. During the workshop, participants developed and shared many concrete ideas on how engineering instructors could provide emotional scaffolding to support student learning. However, participants also raised more fundamental questions and concerns regarding the (often neglected) role of emotions in engineering education. They suggested that students' emotions and their impact on learning should be explored further, as should *instructors'* emotions and how students' and instructors' emotions are closely interrelated [13]. For example, participants suggested that instructors may need to engage in *for themselves*, that is, they need to take care of themselves and their own emotions in order to avoid transferring insecurities and emotional challenges to their students. Especially in teaching about controversial or uncomfortable topics, instructors need to be prepared both with regard to content and potential lines of conflict (for example, understand the historical backgrounds of racism from different perspectives) and emotions (for example, practice speaking about the topic and monitor one's own emotional reactions). In light of the high incidence of teacher burn-out in higher education [14] and education focused on emotionally challenging topics [15], participants' call to exploring how instructors can take care of themselves (and their colleages) is very timely and important.

Another important point raised during the workshop is that instructors need time and resources to develop and provide meaningful emotional scaffolding that to all students, especially since emotional reactions differ between individuals, which means that instructors may need to provide several forms of emotional scaffolding simultaneously. One possible approach to addressing these challenges could be to provide students with resources and encouragement to develop and provide emotional scaffolding strategies themselves—with and for each other. Just like we can train students to provide high-quality *cognitive peer-feedback* on problem sets and essays, we should also be able to train them to provide supportive, respectful, and stimulating *emotional peer-scaffolding*. This is another important area for future engineering education research to explore.

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WORKSHOP: ROLE-PLAYING HYPOTHETICAL STAKEHOLDER SCENARIOS

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Keywords: *role-playing, case studies; stakeholders, ethics, ethical dilemmas*

ABSTRACT

Recently, the use of simulations, often in the form of role-plays, has found favor for developing an ethical mindset among students. Role-plays have been used with the goal of developing environmental awareness, gaining a better understanding of the principles of sustainable development and the need to develop environmentally friendly artefacts, making students aware of the constricting factors affecting their professional activity, as well as allowing them to reflect on the measures needed to change constricting structures and develop institutional frameworks more conducive to responsible action.

INTRODUCTION

Case studies and scenarios are common in engineering ethics education. Case studies have been criticized for focusing disproportionately on individual-level micro-ethical issues, such as a problem faced by a middle manager or new engineer in a company. The reality is often more complex and there is a need for pedagogical methods that can capture the complexity of the profession and realistic features of the professional environment.

BACKGROUND

Recently, the use of simulations, often in the form of role-plays, has found favor for developing an ethical mindset among students. Role-plays have been used with the goal of developing environmental awareness, gaining a better understanding of the principles of sustainable development and the need to develop environmentally friendly artefacts (i.e. [1]. [2]) making students aware of the constricting factors affecting their professional activity, as well as allowing them to reflect on the measures needed to change constricting structures and develop institutional frameworks more conducive to responsible action [3].

Role-plays are an effective method for contributing to the development of the students' professional identity ([4]; [5]) and can familiarise students with the different subjectivities involved in the design and creation of an engineering artefact or decision process, each bringing different backgrounds, problem conceptualisation and desired outcomes ([6], [7]). They are able to achieve this as they provide context and situation, bringing the micro and macro together.

The workshop aims to respond to the need for developing teaching instruments for engineering ethics instruction, in particular, role-play scenarios and cases. Given that the workshop aims to initiate the development of new roleplays, the workshop organisers will encourage collaboration and co-creation by creating a cloud folder at https://bit.ly/3am1zTn that includes the notes and roleplay drafts initiating during the workshop discussion. We will work with templates and model documents to scaffold development of scenarios for role-play and also work on how to implement them in different settings. Participants will thus have the opportunity to follow up and finalize the case studies drafted. The role plays developed can then be incorporated by the participants in their own teaching. The opportunity to share role-play scenarios will create a community and participants will be able to apply and test their role-plays with other participants.

WORKSHOP SETUP

To allow participants to develop their own role-plays that can be used in their domain course we proceeded as follows: 1) participants were introduced to a designed template for role-plays, as described in the section above 2) participants were given examples of top-down or bottom-up roleplays developed by the authors 3) in breakout-rooms, participants proposed role-playing themes and followed the steps provided in the intro 4) participants reconvened in the plenary to discuss key insights or challenges that can be encountered during the application of role-plays 5) participants were given access to a database of roleplays and literature resources, available at https://bit.ly/3am1zTn

TEMPLATE FOR DESIGNING ROLE-PLAYS

Participants were introduced to a step-by-step guide to develop their own role-plays. It consists of the following steps:

1) Identifying a problem-situation

The problem-situation can affect one's local community or be relevant for one's national context. It can be meaningful for the local community through the lenses of safety, well-being, environmental impact, policy implications or the discrimination of specific groups. Such problem-situations involve polarizing actors and groups (i.e. Nuclear energy), and may be rooted in an incident or disaster (see role-plays by Johri on Boeing Max Crash on https://bit.ly/3am1zTn , in [8], [9], [10], [11] and Wilson on Chernobyl [12]).

2) **Identifying actors**

The identification process starts from mapping the stakeholders directly or indirectly affected by this issue or involved in the design and decision-making process for addressing this issue. This includes identifying the main typologies of individuals (i.e. manager, graduate engineer) or of main groups (i.e. consumer groups, environmental groups, lobbying groups, citizen associations). It also highlights the relevant characteristics of these actors, such as demographic characteristics, stance on the problem-situation, values, desired outcomes, potential losses, power status. The characteristics provided to students would enable positionality in regard to the problem-situation.

3) Providing rich contextual descriptions

This step focuses on the description of the physical, organizational or sociocultural context in which the problem is set. Contextual details could include aspects such as

"the nature of the business, agency, or institution in which the problem occurs, what is produced, annual reports, mission statements, balance sheets, and profit-and-loss statements, the values, beliefs, sociocultural expectations, and customs of the people involved, who sets policy, what sense of social or political efficacy do the members of the setting or organization feel, what are the skills and backgrounds performers and the hobbies and resumes of key players" [13: p 20].

Providing a rich contextual description might imply making the scenario as immersive as possible when implementing it, which can be achieved through the use of props and locations outside the classroom.

4) Preparing reflective questions

Role-playing by itself is not sufficient in raising student awareness about stakeholders or wider structural issues [3]. Role-playing a scenario is an opportunity to prompt students to reflect on the meaning of the solutions they opted for their own role and for the final solution. This can be facilitated by the insertion of opportunities and mechanisms for reflection on the role-playing activity (i.e. through intermediary and/or final questions). The answers collected have the potential to serve as research data for publication [6].

Overall, these steps will lead to the development of a roleplay scenario and of the roles that students can enact.

CONCLUSION

Role-plays can be a powerful instrument to raise students' awareness of local and national problems and how they affect different stakeholders. They facilitate teaching ethics in a macro manner, that looks beyond the individualistic responsibilities, decision-making and actions specific of microethical approaches.

To facilitate the development of role-plays, workshops focused on designing role-plays that bring together communities of educators and researchers can be useful. An additional step would be for educators or researchers themselves to initiate co-creation workshops involving a community or group affected by a specific problem, to render more accurately in the design of the role-play and of the actor roles the group's characteristics, perspective, values, needs or exposure to risks.

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TEACHING TRACK FOR ETHICS OF TECHNOLOGY IN ENGINEERING EDUCATION

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ABSTRACT

The Dutch research project "Wijs met techniek" (Tech-Wise) explores ethics education for engineering students from a tool-based, practical perspective. In the project we have made an inventory of tools that are currently used on different levels of higher education. From the experiences so far, we have proposed to build a tool-based teaching track for ethics education in engineering curricula. In the workhop we present in this paper we built on this experiences with a short tool-based exercise, called 'Wisdom on a Delft Blue tile'. Furthermore we present the backgrounds of the project, the set up of the workshop, and the results of the exercise with the participants. From the experiences with the workshop we reflect on the next steps of the research project.

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1 INTRODUCTION

In a Dutch research project "Wijs met techniek" (Tech- Wise) we explore if and how practical tools for ethical deliberation on the impact of technology can be helpful in ethics education for engineering students. The approach is tool based, intended as a variation on theories in ethics and technology. It focusses on the impact of technology as a way toward ethical deliberation. Both characteristics are intended to better appeal to engineering students. In the project we cover three levels of higher education; a University, a University of Applied Sciences and a School for Vocational training.

1.1 Background

Systematic and critical thinking about societal and ethical aspects of technology is not yet regularly included in higher education programs. Not in the least because teachers find it rather difficult to discuss ethical questions about the impact of technology with students. However, nowadays ethical deliberation on the impact and meaning of technological choices, makes up a necessary component of the research, design and development process. As future professionals (researchers included) our present students are expected to be fully aware of societal and ethical effects of technological innovations. Therefore, educational programs should include a teaching track for ethics of technology to turn students into responsible professionals. Knowledge of ethical theories does not seem the most important aspect here. Much more, students should become sensitive for the meaning and effects of technology. Our hypothesis is that active tools will be most appropriate to learn students deliberating about the impact of technology.

1.2 Tech-Wise

The research project is called "Wijs met Techniek", which can be translated as Tech-Wise, but in the Dutch regional culture can also be understood as "happy with technology". In a first phase of the research project, experiences of students and teachers indicated that practical tools for ethical deliberation are most valuable, provided that they are to linked to explicit learning goals. The tools should be designed to cover different topics of ethical deliberation. In addition, it appeared to be important to determine direction and ambitions for ethical deliberation about the impact of technology. More than a one-time exercise, ethical deliberation should be an integrated part of the education program. Different tools should be applied toward different goals in a teaching track for ethics of technology. *In the workshop questions about aim and content of a valid teaching track for ethics on the impact of technology in engineering education, were addressed.*

1.3 Theory

In our research project we identified several topics for ethical deliberations based on literature (Van Beveren et al., 2018; Marin, 2020; Van der Poel, 2018) and our own experience in engineering education (Dorrestijn, 2017; Tijink & Verbeek, 2019). These topics represent ethical issues accompanying technology, the *whats or* *whereabouts* students should learn to think about in a systematic and critical way. Taking the impact of technology (Dorrestijn & Eggink, 2014) as a starting point, we ran across topics such as the ambivalence of technology, intentional and unintentional effects of technology and changing behavior and values.

For defining direction and ambitions for ethical deliberation we used elements and levels which we came across in several definitions about reflective skills (Mittendorff, 2014; Kember et al., 2008). So, an essential element for ethical deliberation is that it should start with the use of a practical example of an innovation or new technological application concerning the professional context of the future professionals (Eggink & Dorrestijn, 2018). As to the extent and depth of ethical deliberation in engineering education we initially distinguished three different levels to deliberate on the impact of technology: evaluation, reflection and critical reflection.

2 WORKSHOP: TOOLS FOR ETHICAL REFLECTION ON THE IMPACT OF TECHNOLOGY

For the workhop we decided to discuss the tool- based teaching track with the participants alongside an exercise with one of the proposed tools resulting from our initial research phase. Following the principle ‘practice what you preach’. In the workshop we first explained the background of the research project and then did the short exercise. Finally we discussed with the participants the contents of a possible teaching track for ethics of technology in engineering education, inspired by their experiences.

2.1 Set up of the Workshop

The complete one-hour workshop was divided into four parts, with the following schedule;

- Introduction Research Project (10 minutes)
- Ethical Deliberation Tool “Online Conference” (30 min)
- Discussion about a Tool Based Teaching Track for Ethical Reflection (15 min)
- Questions, thoughts, remarks (5 min)

For the exercise we chose the tool ‘Wisdom on a Delft Blue tile’. From our previous experience we know that this is a tool that is simple to explain and execute in a short amount of time (van der Heijden et al. 2021). Although simple, it showed to foster the ethical deliberation on different levels, connected to the proficiency of the participants. The goal of the exercise is to write a short aforism, expressing an ethical concern or value observation from the discussion with the participants. The connection to a Delft Blue tile makes the goal explicit and recognisable (figure 1).

Figure 1. Example of a Presentation Slide, used in the workshop: 'Wisdom on a Delft Blue Tile'

The exercise 'Wisdom on a Delft Blue tile' consists of four steps; orientation, research, select, and design. For the workshop we decided to reflect with the exercise on the technology of online conferencing, as we would be all experiencing at that moment. For the orientation phase we make use of a three-minute humorous video about online meetings called "A Conference Call in Real Life". The full instructions for the participants are then as follows:

- Part 1: Oriëntation
  Watch the video 'A conference call in real life': https://www.youtube.com/watch?app=desktop&v=DYu_bGbZiiQ
- Part 2: Research
  The video shows what all of you have been experienced for over a year now. What do you notice watching this video? What did you observe yourselves during online meetings, presentations, teaching activities?
- Part 3: Select
  Presume that Online Conferences will be a new standard, should we be alert? What should be preserved? What do we not want to loose? - Think about certain behaviour and values.
- Part 4: Design
  Write down on a Delft blue tile an "Online Conference Aphorism" - A behaviour manifest in one phrase.

After the discussion, the resulting aphorisms will be 'written' on a tile in the workshop presentation.

For the discussion on the “Ethics Teaching Track with Tools for Ethical Reflection about the Impact of Technology” we prepared the following questions:

- Do activating tools and interventions make it more easy?
- How to address different levels?
- How to embed this in the curriculum?
- How to connect to different study topics (disciplines)?
- How to support teaching teams?

2.2 Execution of the Workshop

A total of 13 participants logged in to the session, from which 12 people attended the complete workshop. We decided that it was not necessary to use the breakout rooms with this amount of participants. After the session we downloaded the meeting chat for reference.

3 RESULTS

The results of the workshop can be divided in two parts; first the results of the exercise with the tool and secondly the results of the discussion about a teaching track for ethics of technology.

3.1 Exercise ‘Wisdom on a Delft Blue Tile’

After watching the video the participants were asked to share their comments and observations. They were invited to take the floor or put them in the chat. These comments were mostly focussing on three themes: about being present, about communication, and about participation. About being present, some comments were: “people coming and leaving”, “the sense of ‘being there’ and ‘being on time’”, and “people doing other things at the same time”. About communication: “You lose some communication without some body language cues”, “Communication is always much harder, difficult to ensure people are looking at the same thing, distractions or diversions, missing subtle clues”, and “no structure”. The most interesting comments from an ethical point of view were about participation. The accessibility of online conferences makes it more easy to attend. Less time-consuming but also less expensive. Having more and more diverse people at the table then also makes it important that everybody is heard and feels invited to contribute, as one participant put it: “It's (at least for some people) even more difficult to get turn to speak during online conferences, living their viewpoints or questions out. And maybe more difficult to make sure that everybody gets change to speak from meeting leading point of view.”

From the observations and comments we went to the next step; thinking about characteristics, behaviour and values that we would want to keep from online conferences. Most important aspects mentioned were: “efficiency” and “accessibility”. However, it was also mentioned that these come with a cost: “efficiency comes with the cost of personal relationships and maybe the good relations between coworkers”, and “You miss things like the chats to and from meetings.....some of this may be help clarifying issues or positions in the meeting but also helps support things like empathy with colleagues...”. It was emphasized that we should keep human values of openness, inclusivity, politeness and empathy in mind.

After the discussion, four aphorisms were concluded upon together (figure 2).

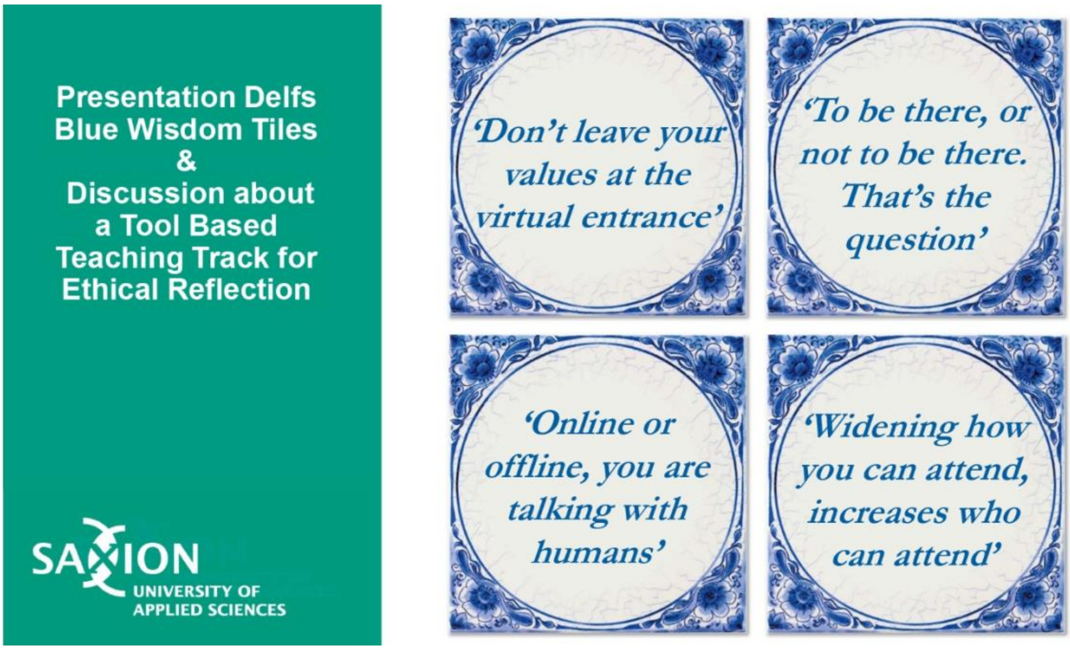

Figure 2. Text results from the Tool exercise “Wisdom on a Delft Blue Tile”.

The two aphorisms at the right concern the two topics presence and attendance. The two aphorisms at the left are about the possible changes in -social- behaviour.

3.2 Impacts for a teaching track for ethics of technology in engineering education

Due to some technical hick-ups in the online format, the exercise took longer than expected. Therefore there was no time left for the discussion about the teaching track.

4 CONCLUSION & FURTHER WORK

The results of the workshop confirm that the impact of a technology is always ambivalent. For this example, winning on efficiency and accessibility comes with a cost on the side of human values and empathy.

The exploratory study during the first research phase of the Tech-Wise project is input for a larger follow-up study. The aim of this follow-up study is twofold. On the one hand, it focuses on developing a conceptual framework for ethical reflection on the impact of technology. This framework should cover the different levels of ethical deliberation and the different levels of (higher) education, and it should be applicable or adaptable for several engineering domains. On the basis of such a framework, the various programs can formulate a vision on ethical reflection on the impact of technology with matching learning objectives for continuous learning lines. In addition, efforts are being made to (further) develop a suite of activating working methods and tools. The aim is to develop a package of teaching materials, together with the various engineering programs, consisting of concrete ethical exercises and assignments that can be used as a continuous learning line during their entire curriculum.

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Reports

CHALLENGE-BASED LEARNING TO IMPROVE THE QUALITY OF ENGINEERING ETHICS EDUCATION

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Conference Key Areas: *Ethics, Maffioli Award*
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ABSTRACT

The SEFI 2021 annual conference committee provided me the opportunity to publish this text based on the SEFI Francesco Maffioli Award. I am happy to use this opportunity to sketch the Engineering Ethics Education (EEE) and Challenge-Based Learning (CBL) research I have been doing the last seven years. I will focus here on the redesign of a large first-year's course for ethics and history of technology as an example. I will conclude with expressing my confidence that the dynamic communities working on for CBL and EEE can tackle the future challenges I list here.

1 INTRODUCTION

The SEFI 2021 annual conference committee provided me the opportunity to publish this text based on the SEFI Francesco Maffioli Award "in recognition of open-minded development of curriculum, learning environments or tools, novel didactics, methods or systems in engineering studies." I am happy to use this opportunity to sketch the Engineering Ethics Education (EEE) and Challenge-Based Learning (CBL) research I have been doing the last seven years, together with so many enthusiastic and dedicated teachers and researchers, in which the core of my work has been to contribute to the quality of EEE at my university (Eindhoven University of Technology).

I allow myself a more narrative writing style in this text, telling the story of the previous seven years of course- and curriculum redesign and attempts to better understand what was happening and which improvements could be useful using evidence informed approaches.

2 CONTEXT: AMBITIOUS USER-SOCIETY-ENTERPRISE PROGRAM

I started at TU/e in 2014 as coordinator of the Eindhoven "USE" program. This program aims to increase students' awareness, knowledge and attitudes of the links between User-Society-Enterprise aspects of technological innovation [1]. It is a Bachelor College program that shows the ambition of TU Eindhoven on ethics and societal aspects in engineering education. First year's students have a 5 ECTS mandatory course on ethics and history of technology (the "USE basic course"). In their second or third year, students have a "USE course sequence". This is a 15 ECTS course in which students focus on a specialisation of a technology, linked to a human science discipline, like "robotics and ethics" or "standards and patents in mobility" or "psychology and smart lightning applications" (see [2] for more information). The course offers content and methodology of the human science discipline, together with a concrete application of the technical and social science knowledge in an actual case.

This interdisciplinary approach is ambitious. The student evaluations, based on the questions "Are you satisfied with this course?" and "How would you rate this course?", have been mixed. Some USE course sequences score high, comparable with high scores of the own major courses, other USE course sequences score lower (see for example [3]).

As an ethics researcher, I really like to link insights in my own research, as community energy [4], participation and risk perception in innovation [5]–[8], nuclear waste governance [6], [9], [10] or intercultural ethics [11]–[13], to the future societal role the role of experts in society [14], [15]. It is probably particular to social scientist in Engineering Education that they can relate their disciplinary work to the reflection of the future societal role of the engineering.

As coordinator of these USE courses, I had the pleasure to find out with many motivated colleagues how we could improve these courses. First, this question is challenging as the quality of ethics and social sciences courses in engineering curricula is far from evident. Together with colleagues, we used the Goodlad curriculum model to apply it to social sciences and ethics courses [16]. We started with the attained curriculum, looking at motivation and deep learning, and slowly also moved to the implemented and the intended curriculum. For brevity reasons, I mainly focus on the redesign of the USE basic course.

3 OUR JOURNEY

3.1 Redesign

We redesigned the course in an evidence-informed way doing action research [17]. As the course evaluations in 2014 showed that students' motivation for the course was low, we analysed motivational issues using self-determination theory in 2016. As reported in EJEE [18], we found that students in the 2016 USE basic course did not dislike ethics per se, but found the assignment not challenging enough, leading to lower intrinsic motivation and this in turn to a lower overall evaluation and feeling of relevance.

The USE-basic team (among others Antony Meijers, Andreas Spahn, Frank Veraert and Karolina Doulougeri) invited Jan van den Akker to do a rigorous redesign using the spider web in 2017-2018. We came up with an overall redesign of the course, but also decided to go for a challenge-based learning experiment for a group of 180 students in 2019-2020 (with Shelly Tsui and Mandi Astola). “In CBL, learning starts from an open ended, real life challenge and students are given the freedom to think out of the box and design a project directed entirely by them […] involving real-life opened challenges in collaboration with external industry partner.” [19] Students in the CBL ethics course developed technical solutions for real-life ethical challenges. The student groups produced a diverse range of end-products. For example, CASA, one of the external stakeholders, presented the challenge “How can CASA use sensors in smart houses such that it respects privacy and ensures security?” Concluding that the CASA house did not pose any ethical issues if its occupants were well-informed, one group developed Fourier transformations to change the sensor data into data that is not meaningful for future inhabitants but could still be used for acoustics analysis, thus avoiding privacy issues. A two-minutes video can be found here, Figure 1 shows some pictures.

Figure 1: Pictures of the Challenge-Based Learning Ethics course 2019

Students raised that the ethics CBL course nudges them to do technical developments, but they do not receive formative and summative feedback on these technical aspects. As such, the "E3 Challenge2" course (E3 stands for Eindhoven Engineering Education) was designed as a 10 ECTS course, still dealing with 5 ECTS of ethics of technology, but broadened with 5 ECTS of data analytics (involving many TU/e colleagues and teachers as Adam Watkins, Jeff White, Rick de Lange, Regina Luttge and nine dedicated teaching assistants)

The experiment aimed at: (1) maximising self- and shared-regulated learning; (2) maximising ethics learning in a complex context; (3) upscaling CBL with teaching assistants; and (4) learning about teacher and teaching-assistant support in CBL projects. The course comprised different learning activities in a weekly cycle. (1) Students participated in ethics-centred learning activities. (2) A trio of teaching assistants (background in ethics, data, and the case) organized student peer-feedback. (3) Expert meetings in which experts are present (teachers, sometimes also external stakeholders) scaffold the overall project work. (4) Each team weekly met with their coach for 30 minutes and students individually wrote a weekly reflection answering three questions: (i) "Describe a learning experience from this week."; (ii) "Why was this learning experience important for you?"; and (iii) "How will your learning be different next week based on this experience?". There was a weekly peer-to-peer meeting with the TAs to support their work and a weekly meeting with the teachers to evaluate the previous week and plan the next week.

3.2 Results and impact

We used an evidence-informed approach analysing many aspects of the course, like feedback, structure versus open-ended challenges, motivation and context (see for example[16], [20]–[25]). In a recently published article, we compared the 2019 challenge-based learning version with a non-challenge-based learning version. The results on students' motivation and basic needs showed positive results. Teachers in the course were satisfied about students' learning, but the quantitative analysis using the ACQA-competencies framework could not confirm that [26].

4 IMPORTANT CHALLENGES FOR A DYNAMIC COMMUNITY

I hope I made clear that the SEFI Francesco Maffioli Award for me is in the first place a recognition of the work of two vibrant communities, one on Engineering Ethics Education and one on challenge-based learning. I could say: "I was just lucky to be, enthusiastic and dedicated, in the middle". I would therefore like to use this last section to acknowledge some people and sketching the work that I think is in front of us.

A first important motor for EEE is certainly the SEFI Ethics Special Interest Group with Roland Tormey, Diana Martin and many other committed members organising monthly online sessions, openly exchanging results, ideas, and feedback, and being very active in organising workshops and writing research output. For those interested, here you can find updated info (and subscribe to the newsletter 😉). The Ethics SIG can only be this active because many people across Europe are engaged. I had the pleasure to work in the SCALINGS consortium studying co-creation in general and the link with CBL in particular in numerous captivating peer-to-peer session with TUM Germany, DTU Denmark, UEW Poland, ESADE Spain, University of Troyes France, Imperial College London UK. Several of these partners are now continuing the work in an Erasmus+ project EuroTeQBoost supporting CBL in Tallin University Estonia, TU Prague Czech Republic, TUM, DTU, EPFL, I'X Paris France, and Technion Israel. I also am pleased with the collaboration with Christian Herzog in a fellowship Hochschullehre 2020.

Of course, there is also my institute, Eindhoven University of Technology, that strongly supported my colleagues and me. Getting support from the management (the deans of the Bachelor College Ines Lopez and Graduate School Paul Koenraad and my Philosophy and Ethics group chair Wybo Houkes) who allowed me to spend time and money to all these experiments. A special thanks to Andreas Spahn with whom I have been redesigning a lot of the USE basic course and all the other teachers and students I worked with and with whom we together optimized the CBL courses.

Getting the prize is an acknowledgement, but this does not mean that the journey is over. Many challenges (yes, researchers also have challenges) of CBL are ahead of us. With Karolina Doulougeri, Michael Bots and Jan Vermunt we will look into the intriguing question "how students learn in CBL" [19]. With Diana Martin, Tijn Borghuis and other colleagues we will analyse the interplay of EEE and CBL, like "How can moral competencies be measures (with ACQA)?", "How can interdisciplinarity in cases of CBL be optimised?" [24], [25] and "What is the influence of engineering students' views on knowledge (epistemic cognition) on how they learn in CBL?". With Lukas Fuchs and Isabelle Reymen, we will approach CBL from a university-ecosystem angle, studying the interaction between CBL in a university's curriculum on the one hand and the responsible attitudes of organisations in the ecosystem (university, companies, communities, NGO's) on the other hand.

This is for sure a fantastic trip. I want to make one critical and realistic note here. My university too is an organisation with different opinions and dynamics that go different ways. Whereas the last years, the compass was really on educational innovation, currently this is more in debate. A new Bachelor reform is being discussed in which ethics and social sciences get far less attention. I certainly see the idea of colleagues being enthusiastic about *their* courses and wanting to increase them (I of course want the same level, or more, ethics). However, my personal worry currently is that this transition might go hand in hand with a lean and non-innovative education that allows teacher-researchers to do as much research as possible. I sincerely hope, and am confident, that my university keeps holding its educational innovation high in esteem.

I hope to meet you all, *in flesh and bone*, at SEFI 2022 to exchange more educational innovation stories.

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Monika Rummler

Laudatio for Günter Heitmann – SEFI's Leonardo da Vinci Medal

Dear SEFI community and especially dear Gunter Heitmann,

I am pleased to meet your request, Professor Berbers, President of SEFI, and Professor Heiß, Vicepresident of TU Berlin, to hold a laudatory speech about Gunter Heitmann. Today online, we are able to honour him as this year's recipient of the renowned SEFI Leonardo da Vinci medal.

I was asked to speak today and I am honoured to do so in recognition of our long shared history as colleagues and friends. Gunter, I have had many occasions to observe your thorough and brilliant mind at work. You combine subtlety in teaching and profound knowledge as well as the art of asking good and thought-activating questions and a clear position and statement in your attitude to improve the future of engineering education! The activities of your busy path of life and career are numerous and too many to list here. So I will highlight some selected merits! For further reading you will find an extended version of this laudatio in the proceedings!

Already during his Study of Industrial Engineering and Economics at TU Berlin he was student representative in the German Commission for Engineering Education. After graduation in 1969 he was a co-founder of the "Institut für Hochschuldidaktik" at TU Berlin, one of the first "Centers for Teaching and Learning in Higher Education" at a German University. Here he started his professional work in a project about "Integrated Curricula in Engineering Education and possibilities of creating a Comprehensive University for Berlin".

From 1972 until 2003 he worked as a tenured scientist at the Center with focus on curriculum development, new teaching and learning concepts, qualifications research and international approaches to engineering education.

As a member of the German Association for Educational and Academic Staff Development in Higher Education he contributed in particular to a reference framework for the pedagogical qualification of teaching staff in higher education in 1994, which formed the basis for a modularized continuing education programme for teaching staff at TU Berlin, which until today is successfully provided and continuously up-dated and expanded.

Gunter Heitmann‘s outstanding performance as active SEFI member started shortly after SEFI’s foundation with TU Berlin as one of the founding parties, when he became official representative for almost 30 years. He engaged himself successfully in different activities and consequently has been appointed SEFI Fellow and granted honorary membership!

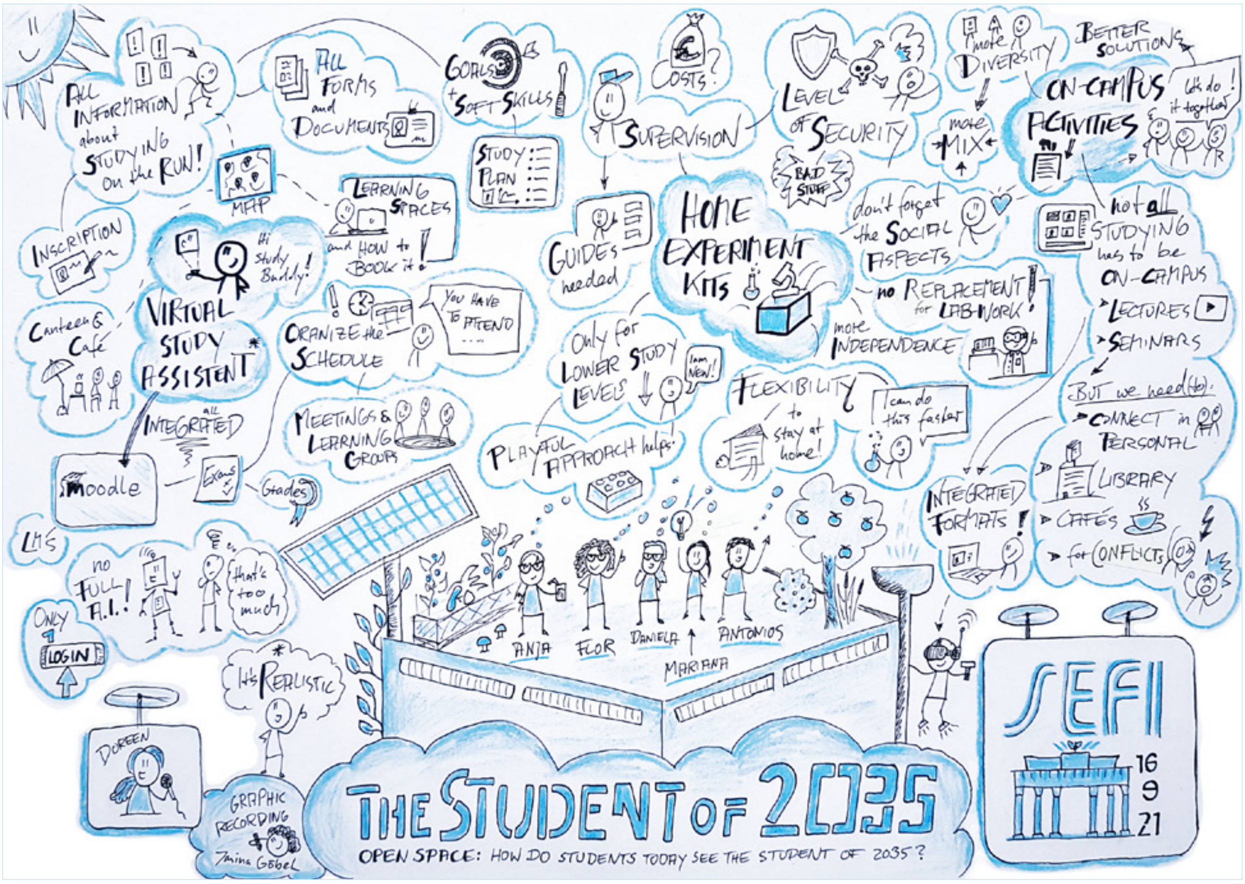
Some important steps were taken as co-founder of the first SEFI Curriculum Development Working Group, thus building the advancing wheel of today‘s SEFI organisational structure! Here he contributed to more than 20 annual workshops and conferences resulting in proceedings and publications. He was involved as board member and chair of working groups in EU Socrates Thematic Networks for Higher Engineering Education in Europe. As chair of a Special Interest Group he was in charge to develop a Glossary of Terms in Engineering Education which was applied in publications of different thematic networks and the European Network for Accreditation of Engineering Education ENAEE. For SEFI he also expanded the cooperation with the American Society for Engineering Education!

Since his retirement in 2003 he was still requested as engineering education senior expert consultant with activities mainly in three areas: Curriculum development, quality assurance and accreditation of programmes and teaching staff development. Until today, he is engaged in the field of European Standards for Accreditation of Engineering Education of Bachelor and Master Programmes, implemented during the Bologna process, for engineering education contributing to the design of the so-called EUR-ACE standards and disseminating the EUR-ACE label, also counselling to projects and programmes in Russia, South Africa, Namibia and the UK. On national level as member of the Advisory Board of the Association of German Engineers VDI, he was in 2007 initiator of the first Quality Dialogue on Engineering Education offered on a bi-annual basis. Just tomorrow it will be continued in the 2021 Quality Dialogue.

In summary, in all these years he yielded and achieved high national and international reputation in the field of engineering education and teaching in higher education as well as quality assurance and accreditation processes for universities. For you, all this has not been just a profession, but a calling and all colleagues and friends you have met during your activities could share this calling. There are few who have done so much for engineering education, good teaching and learning and curriculum development also, over so long a period as you!

So we can be grateful that today, in the face of changing reality at universities and global challenges, you remind us to stay always engaged with our life passions and goals!I am very much looking forward to celebrate this award in person with you!

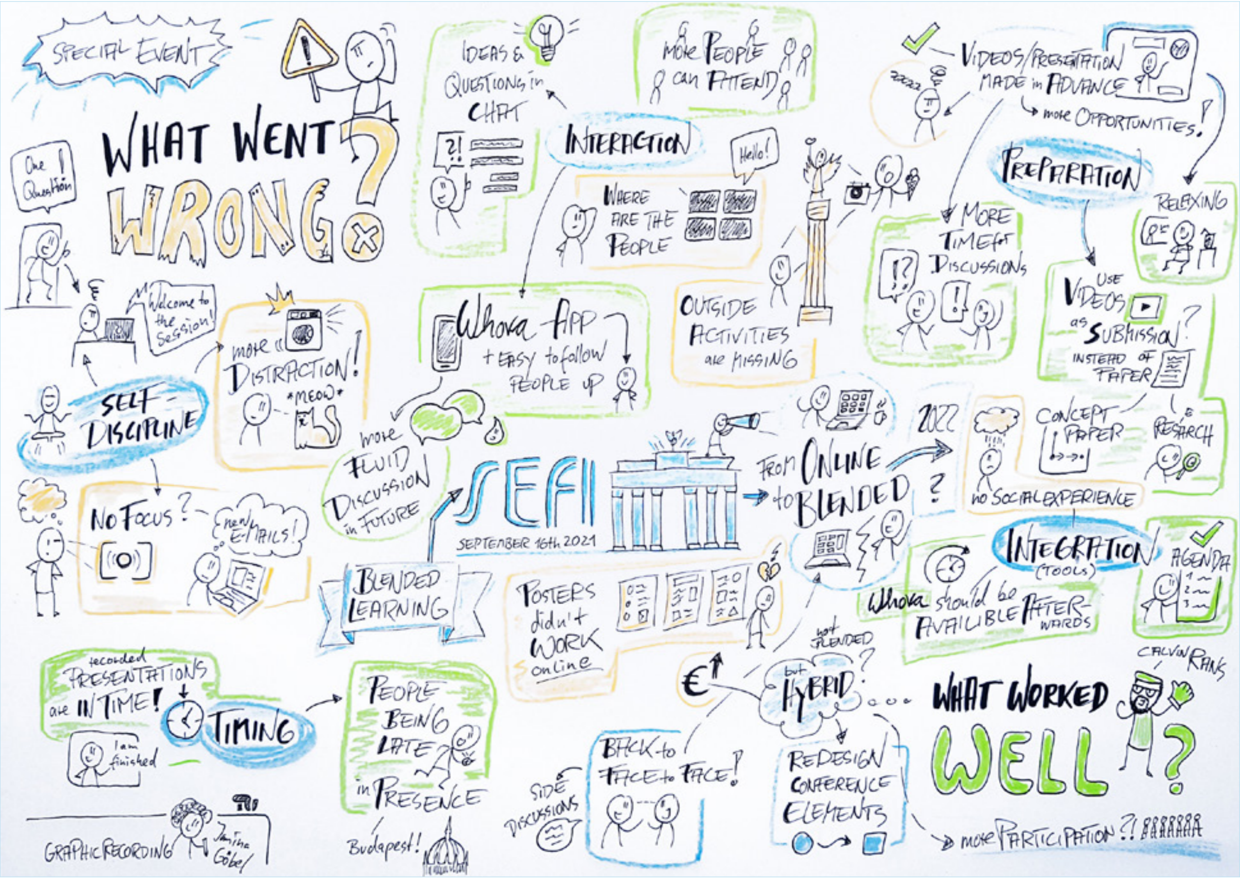
Thank you!



Open Space: How do students see the student of 2035? (Graphic recording)

With the experiences of the last semesters: How do students see their fellow students in 2035? Will the students of the future look at their study app every morning, which tailors the learning material for the day/week/month? Will they still have to meet at a face-to-face university at all, or will experiments also be online and practical exercises offered on-site in companies?

Or is exactly the opposite the case: does university remain a place where learning together is cultivated, especially in times of digitalization? Where it's all about being in personal contact and building knowledge together?



Special Event: What went wrong? (Graphic recording)

In keeping with the theme of the conference on “Blended Learning”, we felt a reflective session on the online nature of this conference would be useful to see what would be welcomed – or adamantly resisted – in future blended conferences leveraging the best of online and face-to-face.

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