

## **Using a problem based project to develop graduate attributes in first year engineering students.**

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### **INTRODUCTION**

This paper investigates the use of a Problem Based Learning (PBL) project within a first year engineering Design Project module to assess how effective it can be in improving graduate attributes. As a teaching pedagogy, the benefits of PBL include a deeper understanding of lecture material by students and enhancement in problem solving and collaboration skills. However, the benefit of PBL in developing graduate attributes is unclear.

The Dublin Institute of Technology (DIT) offers a range of Level 8 honours degree engineering programmes, although all students transition through a common first year programme. Modules within the first year are typically broad and wide ranging. Students are also given the opportunity to experience a Design Project module to expose them to the different disciplines of engineering available to them. The module is split into three projects based around; Mechanical Engineering, Electrical and Electronic Engineering and Civil & Structural Engineering. This paper describes activities around the Civil & Structural Engineering project.

This project aims to encourage engineering students to design sustainable infrastructural projects for developing countries and the brief was to design a pedestrian bridge to span 6m across a river for use in emergency situations within Nairobi. The research work and design solutions needed to take cognisance of the local conditions, materials and labour available in that area.

The initial aim of the tutors involved in the module design was to teach the students key technical concepts within civil and structural engineering whilst having fun and working in teams. As the design of the project and the marking scheme developed, the tutors decided to prioritise learning outcomes related to graduate attributes such

as; teamwork, communication skills, self directed learning and project management. This change in focus initiated the research question 'Can PBL, as a teaching pedagogy, enhance graduate attributes?'

Students responded to a survey to identify how successfully the PBL approach to the project attributed to the development of specific graduate skills upon completion of the project. The findings from the study are presented in a radar diagram which highlights areas where graduate attributes were significantly increased, underlining the benefit and limitations of PBL in this context. The information gained will be used in future cycles of the project to develop weak areas. The aim is to encourage focussed PBL teaching as a way of enhancing graduate attributes, thus improving student employability upon graduation.

## **1 CONTEXT AND RATIONALE**

Problem Based Learning (PBL) is a well-known pedagogy that involves planned thought or action. Several studies have been carried out using PBL in a civil engineering context and results have indicated success in increasing the technical knowledge of the particular subject in the students psyche. Results from two case studies of PBL implementation in transportation courses for civil engineering students [1] showed increased engagement from students and evidence of critical thinking and deep learning. Similarly, the Civil Engineering Programme at University of Limerick (UL) which is delivered with PBL at it's core, reports that students show increased understanding of material [2]. The National University of Malaysia (UKM) undertook a PBL project within a concrete laboratory module which concentrated on how effectively the students learned the technical aspects of concrete mix design [3]. It concluded that PBL was effective in encouraging deep learning of the subject and provided insights into potential problems arising for the students in terms of adjusting to this new way of learning.

However, technical knowledge alone is not enough in today's marketplace. Engineering graduates need to be technically proficient, all round good communicators, excellent team workers and project managers with financial and economic awareness. How can we as educators enhance these skills within our teaching pedagogy? Should they be taught within independent modules such as 'Professional Development' or can we prove that a particular pedagogy will achieve the same outcomes?

The literature review takes a thematic approach initially looking at the emphasis on graduate attributes in recent research and the links between PBL and the development of soft skills. This paper looks at a small scale example of an intervention, but there are applications for large scale studies, should the data support the theory.

## **2 LITERATURE REVIEW**

Graduates of today face an international global industry where communication and social skills may be as important as the intellectual prowess gained by obtaining a degree itself. The acknowledgement of the importance of these skills is abundant in literature. Graduate attributes can also be defined as; soft skills, key skills, employability skills, generic skills, non-technical and transferable skills. [4-20]. These terms are used interchangeably in the literature.

The definition of the required attributes differs depending on the industry and the employer characteristics (design consultancy, manufacturer) and research has been

carried out to attempt to define employability skills and graduate attributes [6-8, 11, 14]. Employability has been defined as *'having a set of skills, knowledge, understanding and personal attributes that make a person more likely to choose and secure occupations in which they can be satisfied and successful'* [6, p.7]. A UK literature review on employability skills in engineering [7] highlighted the range of different attributes considered important to employers. Rather than clarifying the required skills, the extent of literature published by variant organisations merely confused the definition and the outcome of the work concluded that further research is required to define *'graduate skills for employability'* [7].

Employability skills are influenced by employers and accrediting authorities. In a report on the ABET (Accreditation Board for Engineering and Technology) accreditation of Civil Engineering Programs in King Saud University [9, p.6], a key student outcome is identified by the *'ability to articulate professional ideas clearly and prepare written materials, graphical communications and make oral presentations'*. ABET also requires that students from engineering programmes must be able to communicate effectively and function on multidisciplinary teams [10, p.3].

From an Irish perspective, the Institute of Engineers of Ireland (IEI) which is the accreditation body for degree courses in engineering, note the requirements for graduates to achieve 'Chartered Status' as including; *'extract, through literature search or experiment, information pertinent to an unfamiliar problem that is within the current boundaries of the field; design and conduct experiments and, under guidance in a peer or team relationship, to analyse and interpret data; write technical papers and reports, and synthesise their own and their team's work in abstracts and executive summaries'* [12, p.16]. These attributes have been developed in consultation with employers and should therefore also form the backbone of engineering education. This concurs with a study commissioned by the Institutes of Technology in Ireland in 2011 to look at the strengths and weaknesses of engineering programmes in Ireland [13]. It recommends that *"The teaching of key non-technical skills such as oral and written communication should be enhanced and further integrated into the earlier years of the engineering programmes"* [13, p.8].

It is clear therefore that soft skills have become an important aspect of our graduates' education. The next step is to investigate if educators have refined teaching strategies to develop these skills. Several studies have been carried out to determine if there is a link between independent learning and development of soft skills or student centred learning approaches and development of generic skills [4-5, 14]. It has been stated that PBL can be an effective vehicle for improving soft skills in graduates [15] but evidence is lacking in this study to support this statement. Significant work in recent years showed improvements in transferable skills in chemical engineering graduates with a project centred curriculum and the use of integrated projects. [4, 17-19]. In particular, the outcome of a laboratory project based on a PBL approach [4] over a three year period found that transferable skills achieved by students increased significantly.

The RMIT University, Melbourne interviewed recent engineering graduates to compare responses from those who had come through a PBL programme and those who had not [20]. Whilst some of the results and personal reflections from graduates were interesting, there were several confounding factors identified in the study. As all graduates had completed one year of vacation work, this experience alone appeared to contribute significantly to the development of soft skills and so it was difficult to determine the impact of PBL alone.

This literature review has revealed that whilst some research has been carried out into the link between PBL and graduate attributes, there are limited publications in relation to civil and structural engineering students and the link between PBL projects and graduate attributes which is the aim of this paper.

### 3 DESIGN OF THE PROJECT

The idea for this project was inspired by previous work carried out in UL [21]. They undertake a similar bridge design and building project and report success in student engagement, active learning and enthusiasm of students.

In keeping with PBL methodologies, the students were given very little guidance or specifications to complete the design of the bridge. The problem was defined as 'Design a pedestrian bridge to span 6m across a river for use in emergency situations in Nairobi'. The only limiting criterion was that the bridge design and construction methods needed to take cognisance of the local conditions, materials and skilled labour available in Nairobi.

The project ran over a 6-week cycle with approximately forty students in each cycle and groups were formed consisting of four to five members. The students were given four weeks to research, design, analyse and verbally present a bridge design solution to the remainder of the class.

The tutors then determined a winning group who were given the opportunity to build and test the full scale bridge over a pond on campus as shown in *Fig. 1* below. The remaining groups constructed balsawood models, which were also tested in the lab (*Fig. 2*). The construction activity took place in week 5 with testing in week 6.



*Fig. 1.* Testing of the full scale bridge



*Fig. 2.* Testing of balsawood models

The aim of this project was to address the particular learning outcomes noted below:

- Operate effectively within a design team
- Undertake independent research
- Apply engineering concepts and design tools to solve engineering problems.
- Communicate results, both verbally and graphically
- Recognise the social role engineers play and see relationships between technology and society
- Produce solutions to basic engineering problems using graphical methods

The project timescale involved a weekly tutorial class of 4 hours and in this project, the 4 hour slot was purposefully ill-defined for the teams. The only requirement was that each team started the session with a 'Design Team Meeting' to mirror what happens in industry and each group presented their progress at the end of the session. Tutors circulated amongst the teams providing guidance and advice and

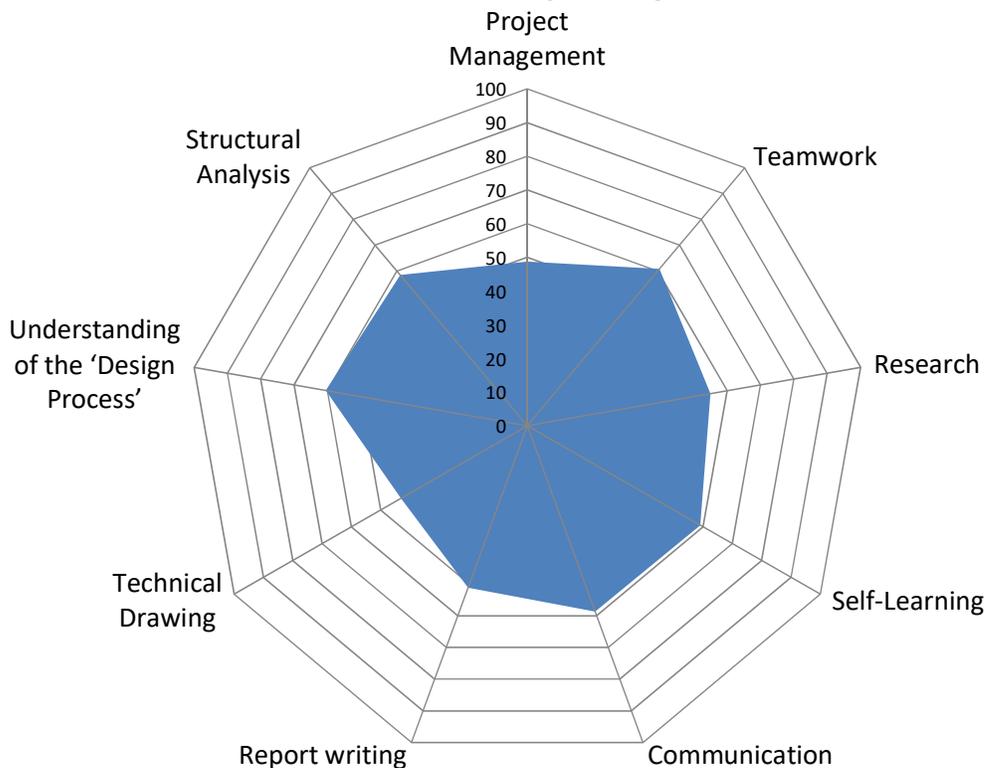
particularly feedback on structural analysis and records of minutes of meetings. However, no formal teaching was carried out and teams were encouraged to try novel ideas of bridge designs and construction techniques.

#### 4 DATA COLLECTION

A total of 98 students were involved in the data collection, over three cycles. Students were surveyed to determine their perception of improvement in particular skills and abilities as a result of their involvement in this project. The students were asked to score on a scale of 0-100% their increase in ability under particular headings. The mean score for the 98 students was calculated. The students also produced reflections at the end of the project and although these provided useful feedback, they have not been analysed as part of this study.

#### 5 RESULTS AND DISCUSSION

The aim of the project was to consider whether the use of PBL in a Design Project module had an impact on graduate attributes. The radar diagram in *Fig. 3* presents the survey results for mean percentage increase in perceived ability. The results are graded from 0% (no increase in ability) to 100% (significant increase in ability).



*Fig. 3.* Results of students perceptions on increased skills and abilities as a result of the project.

The diagram indicates that overall the project had a positive effect on all skills identified, with the top two being Teamwork (62%) and Understanding of the Design Process (61%). The percentage increase was calculated from mean score; however, the data is backed up by commentary provided within the reflections by students.

The feedback indicates that this was the first time many students had worked in a team, which was a little surprising to the tutors. This would indicate that the secondary level education provided to students focussed on individual achievement rather than team projects. As teamwork is such an important attribute to be developed, this shows clearly that more opportunities for teamwork should be provided within the curriculum.

It is unsurprising that Understanding of the Design Process also scored highly (61%) as this was the first year of an engineering programme and the first opportunity students were given to design a product.

Communication (59%), Self directed learning (59%), Structural Analysis (58%) and Research (55%) also show significant increases. This is expected, as previous work shows that PBL is an effective teaching pedagogy in enhancing communication skills [5] and independent research [1]. Furthermore, it is worthy to note that Structural Analysis shows an increase of 58%. This was most likely the first time students had encountered any subject on structural analysis and no doubt experienced a surge in technical knowledge from a low baseline. This concurs with previous work on the effect of PBL on technical knowledge [3].

The aim of the project was to identify areas where this approach did not enhance development of graduate attributes. The results show no particular areas where this is true. However, the two lowest scores are Technical Drawing (41%) and Project Management (47%).

At the beginning of the project, each team member chose from roles provided such as; Project Manager, Bridge Designer, Health and Safety Consultant, Technician and so on. It is likely that the lower score in these two areas is due to the fact that only one team member had the opportunity to develop skills in this area. For example, each team had one Project Manager so other team members may not have considered that they had learned any project management skills. The student reflections also provided some opinions as to why the Project Management attribute scored poorly; namely that the project was badly managed! Students provided honest opinions on what went wrong within the team and gave examples of both poor and exemplary project management. Whilst they may not realise it, the students will have learned by example what qualities make a good project manager.

## **6 CONCLUSIONS**

Overall, this project was well received by the students. They enjoyed the research and teamwork aspects as well as the practical testing of the bridges.

It is clear that PBL is an effective teaching pedagogy to enhance deep learning of a subject, but unless the PBL project is designed with specific graduate attributes in mind, it can be lack opportunities to develop particular soft skills. Changes will be made to further cycles with a view to creating a PBL project which is focussed on providing opportunities for students to develop graduate attributes. The main change recommended for the next cycle is that students should be required to choose at least two roles within the team which allows them the opportunity to develop a broader range of skills.

## **7 RECOMMENDATIONS FOR FURTHER WORK**

This was the first year that the project had been implemented in this fashion and it would be useful to investigate on a longitudinal study how effective this project was in preparing students for further years of study and the skills required of them.

Furthermore, information from three cycles of the study have been collected. The first cycle occurred when students had only just registered and were new to first year and college life in general. As the final cycle completes, students are finishing first year and it will be interesting to investigate how their perception of their ability within certain aspects changes over the first year timescale.

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