Creating a supportive PBL Environment in two engineering courses at Central Queensland University

Dr Ahmed Elgezawy (corresponding author)
Faculty of Sciences, Engineering and Health
Central Queensland University
PO Box 5606 Mackay MC Qld 4741
Email a.elgezawy@cqu.edu.au

Dr Fae Martin Faculty of Sciences, Engineering and Health
Central Queensland University
PO Box 5606 Mackay MC Qld 4741
Email f.martin@cqu.edu.au

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F. Martin[1], A. Elgezawy[2]

[1]Faculty of Sciences Engineering and Health, Central Queensland University, Australia (f.martin@cqu.edu.au)
[2]Faculty of Sciences Engineering and Health, Central Queensland University, Australia

Abstract
Project Based Learning (PBL) is challenging existing conceptions of good teaching in engineering education. When developing and reviewing the first year Engineering Skills course and the second year Fluid Mechanics course at Central Queensland University strategies were implemented to improve student engagement in the learning process.

The learning outcomes for both the courses include many of the professional skills that are now recognized as being essential in the engineering workplace. These skills are introduced in the context of engineering projects rather than in separate 'add-on' modules. Self-directed learning and reflection which are fundamental aspects of PBL assist the development of important lifelong learning skills. The learning outcomes are aimed at building upon the various experiences which students bring with them.

By promoting social and academic engagement within the project teams and between students and staff, the PBL paradigm facilitates the development of a learning community and therefore further improves the quality of the learning. The development of a learning community has been shown to be an important predictor of the development of student learning outcomes both in generic attributes such as communication, problem solving and ethical awareness as well as discipline-specific skills.

PBL encourages student initiative, independence, collaboration and responsibility for learning through project work resulting in a productive pedagogy in the Engineering Skills and Fluid Mechanics courses. This paper will discuss the strategies employed in these two courses and how student learning is enhanced when the student participates responsibly in the learning process.

Keywords: PBL, contextual learning, learning community, productive pedagogy

1. INTRODUCTION

It has long been recognized that learning is about more than the formal activities that happen in the classroom. The interactions that occur between students and their peers, and between students and staff influences student outcomes both in terms of the quality of the learning that takes place and the persistence of the student in completing the program of study. In many cases although the formal classroom interactions are very structured, the informal interactions are incidental and unplanned.

At Central Queensland University (CQU) the professional engineering program has been designed around the project based learning (PBL) educational philosophy. The first year of the program is a common year that all disciplines study. Since all students study the same set of courses there is the potential to create a learning community and indeed many of the first year activities are designed to encourage that outcome. The supportive environment created during first year is then further reinforced in the second year courses.

This paper will consider the first year course Engineering Skills and the second year course Fluid Mechanics, showing how each creates a supportive learning environment that promotes the development of student initiative, independence, collaboration and responsibility for learning.

2. USING PBL TO IMPROVE STUDENT ENGAGEMENT AND ENCOURAGE DEEP LEARNING

Deep learning implies an understanding of the fundamental principals involved in the subject material whereas shallow learning may be characterized by students simply reproducing delivered material in an examination. Many innovative techniques in the past aimed to develop the self-learning and time management skills of students in order to promote deep learning characteristics. However many of these techniques were unsuccessful in fully engaging students in the entire learning process.

Hargreaves [1] concluded that lecturers need to change their teaching paradigm from one where the lecturer stands outside the students' learning context, to one where lecturers are intimately involved in the learning context. He emphasised that lecturers should become interested in pedagogical strategies to improve students' learning.

Mills and Treagust [2] noted that in recent years, the engineering profession and the bodies responsible for accrediting engineering programs have called for a change from chalk and talk strategies in learning. The Institution of Engineers Australia carried out a review of professional engineering education and produced the *Changing the Culture: Engineering Education into the Future* report in 1996 [3]. This report called for major changes in professional engineering education program curricula, particularly an increased emphasis on generic professional skills. The report, *Employability Skills for the Future* [4], was prepared for the Australian Government by the Australian Chamber of Commerce and Industry and the Business Council of Australia. Most recently the Department of Science, Education and Training produced *Graduate Employability Skills* [5], a report that investigated how universities currently develop and integrate employability skills into programs of study, and how they teach, assess and report those skills.

It is widely accepted that PBL provides a good environment for the development of generic skills such as communication, teamwork and the capacity for life-long learning but the effect of PBL on technical skills is more controversial. However Fink [6] has reported that the learning environment created by the PBL approach enables students to develop excellent analytical skills and the ability to deal with complex engineering problems. Mills [7] showed that students in a structural engineering course incorporating a design project perceived that the project was the most useful component of the course for developing both generic and technical skills.

Smith and Bath [8] carried out a study of students at an Australian university that showed that the strongest predictor of the development of communication and problem solving skills was the presence of a learning community, with teaching quality next. Learning community was also one of the strongest predictors for discipline knowledge and skills (teaching quality in terms of, for example, lecturer expertise and intellectual challenge was equal strongest predictor), ahead of program quality. What is a learning community? Learning communities can be formed by ensuring that a group of students are enrolled in the same cluster of courses to promote peer learning [9]. They can also be formed from disparate student groups as in the case of Rutar and Mason [10] who formed a learning community of first-year university students from two different courses and a group of high school students. However all learning communities share some characteristics: in all cases students work collaboratively on the learning activities. These activities encourage peer and staff interaction where the learning takes place in an environment that encourages social and interpersonal exchange as well as formal learning. PBL creates an environment conducive to the formation of a learning community as students are working together in small peer teams towards a shared goal. PBL also encourages personal interaction between staff and students with staff facilitating the student teams in their project work.

3. PBL IN THE CQU ENGINEERING PROGRAM

In 1994 the BEng(Co-op) was introduced at CQU. The cooperative education model used in the BEng(Co-op) required students to carry out a six month work placement at the beginning of their third year and another at the end of their fourth year of study. The first cohort of co-op students did their third year placement in 1996. Employer feedback at the time indicated that students were ill-prepared for the workplace. Perhaps this is not surprising considering many employers considered even graduating students of that time ill-prepared for work. In response to this feedback and the *Changing the Culture* report [3] a review of the engineering programs was carried out. Extensive research worldwide indicated that PBL was an appropriate educational paradigm to address the lack of professional skills and it was implemented in 50% of the courses in the program in 1998 [11] with the remaining 50% of the courses continuing to be delivered in ‘traditional’ mode.

In 2005/6 the CQU engineering program suite again underwent a major review. At this time it was determined that the philosophy of the programs would be further developed to reflect a 100% commitment to PBL where PBL could refer to either project-based learning or problem-based learning. The intention of articulating this philosophy as the driving force behind the program as a whole was to highlight the fact that traditional chalk-and-talk approaches were no longer to be the default delivery model and all lecturing staff should be looking for ways to contextualize their course content. As had previously been the case, 50% of the courses were based on the project-based learning philosophy where students worked on team projects and the assessment was portfolio based. For the other 50% of the program content, each course developer could choose the way in which they contextualized their course delivery, but it was expected that these courses would engage the students in active learning in some way. The remainder of this paper will discuss how the PBL philosophy was implemented in one of the team-based portfolio courses and one of the courses that had previously been delivered in a more traditional lecture/tutorial manner.

3.1 Engineering Skills: Introducing the PBL philosophy to first year engineering students

Engineering Skills is a first year course that all students in the engineering program study regardless of discipline. The learning outcomes of Engineering Skills are focussed on professional skills such as communication, teamwork and information literacy. These skills are introduced in the context of engineering projects rather than as separate ‘add-on’ modules. A series of team projects are designed to give each student an opportunity to develop the required skills. Throughout the term each student accumulates evidence from their project work showing how they have demonstrated the achievement of the learning outcomes. The product of a particular project may include a technical report or an oral presentation. The facilitators give feedback on the project work and may even require resubmission of items they deem to be unsatisfactory. However the project work is formative assessment only: it does not contribute to the final grade for an individual student. This approach is intended to give students the opportunity to make mistakes without the fear of ‘losing marks’.

The first week of term is designated ‘Induction Week’. During this week, students take part in several special activities that are designed to help them in the transition to tertiary education [12]. The week begins with a welcome address to the entire cohort where the teaching team introduce themselves and the PBL philosophy of the course is explained to the students. Being the first PBL course for the students, Engineering Skills is seen as an important introduction to this form of learning. It is essential that the students recognise from the start of their program of study that the responsibility for their learning lies in their own hands: the facilitators are there to assist them in their learning journey but they cannot do the learning for them. After the welcome, students take part in teambuilding/icebreaker activities meant to begin the process of forming a close-knit cohort of students. This session includes physical activities as well as problem solving activities. At the end of the session, students are asked to articulate what they learnt from the activities. During this debrief students will generally talk about the importance of communication and teamwork, but they will also say that they noticed that some students were more likely to take leadership roles than others, some seemed to be good problem-solvers etc, showing that they have already started the process of getting to know the strengths and weaknesses of their future team mates. Throughout the first week students undertake a simple design and build project. Students are told that this project is intended to be a 'fun project' so that they can begin the process of building peer relationships without the pressure of assessment. The students also participate in another physical teambuilding activity later in the week. This activity occurs outside the university precinct and during the session debrief, one of the points that is drawn out is that all learning does not occur within the confines of the classroom: learning occurs in many settings and students come to the university with a variety of valuable experiences.

From the beginning of the course, students are required to keep a reflective journal. The journal is a record of the student's learning throughout the term. In the journal, students are instructed to chronicle their thoughts and feelings about the delivered content and their teamwork. The delivered content includes topics discussed in lectures and workshops. These lectures and workshops are deliberately constructed to encourage discussion with facilitators asking students to break into small groups and come up with ideas then report the group's finding back to the larger assembly. Since this is often the first course that students study in the program, it is important to recognise that they are coming into the course with a wide range of life experience. Although many of the students are school leavers, there is also an increasingly large cohort of mature students coming into the course. These mature students are often studying the course externally and therefore do not have face-to-face contact with the facilitator. After an initial residential school, these distance students maintain their team interactions electronically.

Assessment for Engineering Skills is 100% portfolio based. There are several compulsory items in the portfolio. The reflective journal is one compulsory component. The other compulsory items are the individual drawing folder, self and peer assessments and an individual reflective paper that each student writes on a book they have read that relates in some way to the learning outcomes for the course [13].

By promoting social and academic engagement within the project teams and between students and staff, Engineering Skills facilitates the formation of a learning community in the first term of the engineering program. As Smith and Bath [8] found, a learning community enhances the development of the professional skills as well as technical skills. Thus Engineering Skills provides a strong base for further intellectual and personal growth throughout the program of study.

3.2 New approach to teaching the analytical course Fluid Mechanics

Elgezawy et al [14] found it is popular to use strategies implementing project based learning when the course allows or problem based learning when the course is context based. Such strategies enhance the intellectual quality and connectedness among the learners and prepare them for lifelong learning style when they work with the real life problems. It is the intellectual demands embedded in classroom tasks, not the mere occurrence of a particular teaching strategy or technique, that influences the degree of student engagement. A new wave of engineering programs using PBL (Project based learning and/or problem based learning) has been emerging around the globe. The Fluid Mechanics course taught in the second year at CQU has implemented PBL as part of that course

It could be argued that the Fluid Mechanics education strategy is conventional lecture based learning except for the practical part. However various strategies have been implemented to ensure that students are actively engaged in the course. Firstly, weekly tutorials use problem based learning where students work together in teams. The tutors ensure that students actively research and attempt the solutions.

Laboratory videos are shown in tutorial sessions with questions related to the video so that students can see the practical application of the theory they are learning. Answers are collected and marked at the end of the tutorial. This contributes to the student's individual assessment. There is also some group assessment tasks for laboratory problems (virtual laboratory) which is combined with the last part of each chapter's questions in the text. Teams are made up of four or five students. The assessment consists of two parts: one part marked by the tutor and the other for peer assessment. By promoting substantive conversation between students and between students and staff, this strategy enhances intellectual quality. Knowledge integration and the problem based curriculum assists students to make the connection to the ‘real world’.

The PBL philosophy is also applied in the laboratory work by asking students to design their own laboratory experiment. Therefore rather than students simply following a ‘recipe’ approach they must develop strategies to demonstrate their knowledge of a particular learning outcome. Requiring students to design their own experiment promotes problem solving and deep learning.

There is also one major team project for the term that is broken into two sections. Sustainability forms an important element of the project. The ability to apply the principles of sustainability is one of the Graduate Attributes required by the accrediting body, Engineers Australia [15]. The concept of sustainability is introduced in Engineering Skills in first year and further developed throughout the program in many courses including Fluid Mechanics. This major project will vary from year to year but will always be an open-ended problem such as the design of water supply and waste water management for an industrial complex. As this course runs across three campuses and also has external students, the project is divided into sections so that each campus group carries out the complete design of one section. Students are expected to complete a project definition and scope, formulate a sustainable concept and report on their concept for the first part of the project. The second part of the project consists of the preliminary design, detailed design then finally the full design which has been contributed to by all campus teams. The final design includes a physical model, poster, detailed design report and peer assessment. The assessment criteria for the project requires students to demonstrate evidence of application and integration of knowledge as well as communication and justification of procedures.

Students must also keep a Workbook which contains tutorial work, reflection on the delivered content and the learning activities such as the self-designed experiment and project work. Students will also keep notes throughout the term, logging them as K (Knowledge gained), W (questions they Wonder about) or L (solution to a question). This log is witnessed by the tutor at regular intervals throughout the term and is a learning tool to assist both students and staff in rectifying any problems as well as providing incentive for students to work consistently.

There is a formal invigilated examination for the course. The examination is worth 40% of the total marks for the course but must be passed for the student to be eligible to pass the course overall. The idea of the exam is not to test the higher order skills but to ensure that the student has grasped the basic concepts.

Therefore by utilizing a variety of teaching and learning strategies, the Fluid Mechanics course ensures that students are engaged in the learning process. These strategies help establish the connection between the theoretical material that is being delivered and ‘real world’ applications.

4. CONCLUSION

These two courses use different approaches but the goal of both is to engage the students more fully by requiring them to be active and responsible participants in their own learning. The Engineering Skills course is a foundation course that introduces the students to the PBL paradigm and the idea that they should reflect on the teaching and learning activities that take place during the course. By having the assessment directly linked to the Learning Outcomes for the course, students become aware of the importance of the Learning Outcomes both to their success in the program and also to their ability to work as professionals on their work placements and after graduation.

The second year Fluid Mechanics course is a discipline-specific analytical course, but the principles of PBL have also been implemented in its delivery though in a different way. Students in this course are required to think for themselves, not just passively sit in lectures where the lecturer provides all ‘wisdom’ with regard to the subject material. In the tutorial sessions, students are required to work in teams, encouraging discourse that leads to a deeper understanding of the delivered content. Team project work encourages peer learning as well as clarifying the link to ‘real’ engineering.

It is clear therefore that although the two courses use different strategies and assessment, the purpose of both is to produce students with initiative who are independent learners and can collaborate well with their peers. In short, the productive pedagogies employed result in students and graduates who take responsibility for their own learning.

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