Development of a new foundation unit in engineering

G. E. Town, and D. McGill
Department of Electronic Engineering, Macquarie University, NSW 2109, Australia.
gtown@elec.mq.edu.au, dmcgill@ics.mq.edu.au

Abstract: We present our experiences in the design and delivery of a foundation unit for first-year students in electronic engineering and related specialisations. The aim of the unit was to provide engineering students with foundation skills for their subsequent engineering studies, with an emphasis on communication skills, working in groups, and design. The unit development process commenced as part of a project to introduce engineering academics to problem-based learning, with the development of the foundation unit set as a workshop project. The project had limited success in the latter context, however the resulting foundation unit proved very popular with most students.

Introduction

For several years there has been increasing recognition by professional associations, industry, and universities of the need to incorporate "generic skills" development in professional engineering education programs. Communication skills, problem solving skills, and an ability to work in teams are prime examples of such skills, and are amenable to development through group projects and problem-based learning (PBL) activities (Hadgraft, 1998). The increased importance of such skills in graduates is a reflection of the changing nature of the workplace; modern industry tends to be customer focussed and consequently often organises its workforce into teams working on projects addressing specific customer problems or needs. In such an environment generic skills such as the ability to communicate clearly and work in teams are paramount, and detailed technical skills are less important than an ability to locate and assess information and learn new skills on an as-needs or project-specific basis.

The current Engineers Australia accreditation process (i.e. in operation since 2004) encourages universities to address the industry demand for generic skills development, and it was in this context that Macquarie University was motivated to introduce a new teaching unit to start developing engineering application and professional skills in the early years of its engineering degree program (i.e. also in operation since 2004, with six new specialisations added in 2008). Additionally the University saw a general need to encourage the development of generic skills in all its education programs. The latter confluence of needs resulted in a proposal to address both needs through a University-funded teaching development project. The fundamental aim of the project was to educate engineering academics about problem and project-based learning, and to encourage them to experiment with this teaching mode by incorporating some problem and project-based learning activities in their teaching units.

In this paper we describe the approach taken in the teaching development project, its main outcomes, and the responses of both academics and students to their problem-based learning experiences. The unexpected challenges faced and the lessons learned during the teaching development project and the introduction of a new project-based learning unit are highlighted.

Teaching Development Project

In this section we describe the approach taken in the teaching development project, the aim of which was to expose engineering academics to problem-based learning methods, and to encourage them to adopt these methods, where appropriate, in their teaching units. We then summarise the lessons learnt in the course of the project.

Project description

A particular challenge faced in the teaching development project was that most of the academics in the Department where the project was undertaken were over 40 years of age, and had little exposure to problem-based learning methods, except in the context of infrequent final year project supervision and their own research. For this reason it was decided to run the project in two stages; firstly, to introduce the rationale for PBL and examples of good practice through a series of workshops lead by professional educators, and then to encourage the academics develop PBL activities themselves whilst providing educator support and feedback on the process.

The three initial 2-hour workshops largely comprised presentations and discussions of the motivations for problem based learning ranging from the pragmatic (e.g. accreditation “push” and employer “pull”) to the pedagogical (e.g. the need to engage learning at all levels in Bloom’s taxonomy (Bloom, 1956)). Nevertheless there was considerable scepticism and resistance amongst the academics to the introduction of PBL, even in part of a teaching unit. A fourth follow-up full-day workshop one year later by a professional engineering educator met a largely similar response. The reservations expressed were not uncommon, and included concerns about the extra workload involved, especially in large classes, and the difficulty in teaching highly mathematical subjects such as circuit theory using problem based learning. On the latter subject one academic stated the following view: “The learning of analysis requires students to become familiar with all fundamental laws applied to electronic circuits. … This highly mathematical and theoretical nature of the unit does not allow straightforward adoption of PBL techniques. It is unlikely that this unit will gain benefit from PBL.” Issues such as the latter have subsequently been dealt with in the literature, where it was shown students who learn basic circuit theory by PBL perform better, on average, in a common assessment than students taught the same material by traditional methods (Costa et al, 2007).

The workshops concluded with an attempt to provide practical experience of PBL. It was decided (in retrospect, somewhat ambitiously) to do this by asking the group of academics to develop a new foundation engineering unit that emphasised development of professional skills and background knowledge relevant to engineering - it was hoped that the resulting unit would incorporate a significant amount of problem or project-based learning. It was also hoped that this experience would encourage the academics to introduce small PBL activities into their own teaching units with ongoing support of a professional educator, i.e. to encourage the academics, and to evaluate the process and outcomes from both the students’ and academic’s perspectives.

Unfortunately most of the available workshop time was spent discussing what learning goals were appropriate for the foundation unit, and how and whether PBL could achieve the desired learning outcomes. Again, the reservations expressed were not new. The main concern centred on the question of “content or context first?” – most academics felt nothing substantial could be taught (or learnt) without some prior input of technical fundamentals (Minutes of PBL Workshop, November 2006). There was a general desire for examples to illustrate good practice in PBL, and whilst there were some good examples available outside the domain of electronic engineering, the academics found it difficult to extrapolate from these to their own discipline. The “content or context first” question dominated the remaining workshop time and did not seem to lead to a better understanding of connectedness of content and context in PBL. Consequently the foundation unit was developed largely independently by the authors, as reported in a later section.

The last stage of the project involving academics in developing PBL activities themselves did not engage as many academics as hoped, partly due to staffing and timetabling changes. Nevertheless there are encouraging signs that some academics are now starting to experiment with PBL, even after completion of the teaching development project.

Discussion

The reluctance of many academics to adopt or even experiment with problem-based learning is not uncommon, and was likely due to a combination of the following factors;

i) A continuing lack of recognition of the importance of generic skills development as part of the education process, especially in technical and mathematical subjects,

ii) A perception that even if generic skills development is assisted by PBL, it is not suited to teaching technical content, and that in PBL technical skills development is necessarily compromised,

iii) Perceptions that PBL involves relinquishing control of the teaching and learning process, and/or that it reduces the value of academic input in the learning process,

iv) A general reluctance to experiment with new teaching practices, justified by scepticism about the need for change and/or concerns about doing it poorly, at the expense of students,

v) Concerns about the increased workload, initially to develop and subsequently to run PBL activities,

vi) Lack of skills and practice in PBL amongst academics, and associated difficulties when challenged to adopt and develop PBL activities in their own teaching.

In the course of the teaching development project it became apparent that each of the latter issues needs to be addressed specifically and carefully when encouraging the adoption of PBL, or any new approach to teaching and learning. The four workshops held in the course of this project proved insufficient to adequately address these concerns.

The last item above is something of a “chicken and egg” problem, and unfortunately the approach taken in the project reported here, i.e. of attempting to engage academics in a PBL activity to convince them of its value, was not immediately effective. The latter remains somewhat surprising given that PBL is effectively what academics practise in doing research. We conclude that revisiting the teaching-research nexus may be a useful way to promote the practice of problem-based learning in future, i.e. by highlighting aspects in common relating to the practise of learning (Brew & Boud, 1995) rather than the more commonly recognised links to maintaining the quality of unit content and curriculum.

A New Foundation Unit in Engineering

In this section we describe the structure of, and response to, a new foundation engineering unit developed by the authors in the context of the teaching development project described previously. The unit was designed to develop generic skills relevant to engineering practice, to provide an appreciation of the role of the professional engineer and the impacts of engineering on society, and to highlight the iterative nature of both engineering design and learning. The foundation unit was developed to integrate with engineering units in subsequent years of study, but had no direct relation to other units in the first year of engineering studies delivered by other Departments.

Foundation unit outline

The primary aims of the unit were to develop foundation engineering skills such as information gathering and assessment, group work, written and oral communication, and basic project management skills. To achieve the latter learning outcomes the unit was structured around a sequence of three projects completed over the duration of the unit, with each project involving problems of increasing complexity. The cycle for each project included reporting and feedback both from and to students to facilitate continuous improvement in their group work and communication skills, and to emphasise the cycle of design, implementation, and assessment. Lecture topics and workshop activities were timetabled to support the projects. Instead of a standard 3 hours per week of lecture and 3 hours per week of laboratory, the week was usually structured as 1 hour of lecture, 2 hours of workshop/tutorial, and 3 hours of laboratory, hence the emphasis was on learning through practice.

The first project was to assemble and test a simple electronic kit. For this project students worked either individually, or in pairs. Whilst a minority of students had assembled kits at home or school, most had not. The purpose of this project was largely to provide a context for learning occupational health and safety practices, and to learn practical skills such as identification of circuit components, board assembly and soldering skills, and basic testing skills – skills that were expected to be useful for completing subsequent projects.

The second project was to design, build and test a small electrical lift. For this project students worked in randomly selected groups of 5. To simplify the design process, the solution was constrained in that the students had a selection of only three or four types of power supply, and three or four different motors to choose from. To avoid many similar solutions each group was assigned a criterion against which to optimise their design, i.e. cost, speed, or efficiency. The groups were expected to devise tests to quantify system performance against the latter three criteria.

The final project was a choice of two projects from the Engineers Without Borders design challenge. For this project students again worked in randomly selected groups of 5. Whilst this project did not have an implementation component, it was chosen to provide a taste of problem solving in the real world, and to provide a context for learning about other societies and their specific needs. Groups were motivated by the possibility of being chosen to represent the University in the EWB Challenge.

Lectures and workshops were timed to provide the small amount of technical content (e.g. basic circuit theory, group dynamics, etc.) as needed, but were otherwise interspersed with contextual material. The overall structure of the unit is shown schematically in Figure 1.

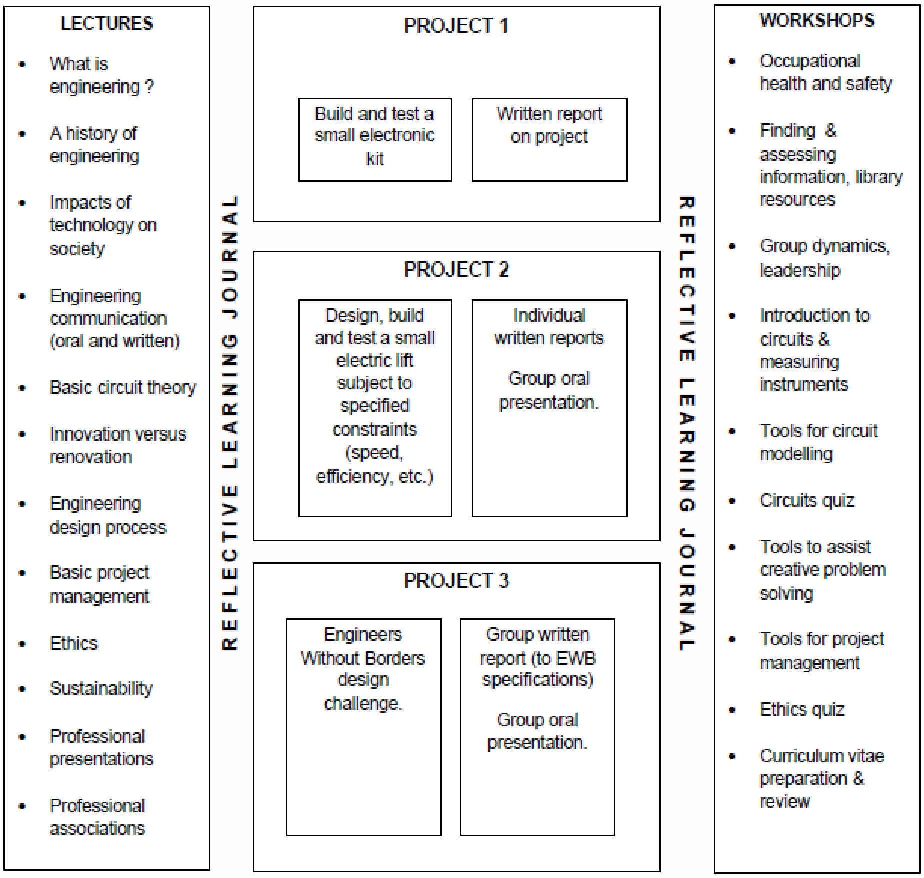

Figure 1: Schematic representation of the foundation unit content.

The unit assessment was designed to reward students who developed the targeted skills and competencies. There was no end of semester examination, but instead regular assessable tasks as detailed in Table 1, which resulted in regular and timely feedback to students on their performance.

Table 1: Assessment breakdown for the foundation unit.

Assessable task	Value %	Due date
OH&S hazardous substance risk assessment - solder OH&S experimental procedure risk assessment - soldering	5	3/3/08
OH&S on-line work induction	5	3/3/08
Electric circuit theory quick quiz	5	17/3/08
Library search report	5	31/3/08
Circuit modelling assignment	5	31/3/08
Project 1 laboratory report	10	31/3/08
Project 2 management plan	5	14/4/08
Project 2 oral presentation	5	7/5/08
Project 2 written report/proposal	10	12/5/08
Ethics quick quiz	5	14/5/08
Curriculum vitae	5	26/5/08
Project 3 oral presentation	10	2/6/08
Project 3 written report/proposal	15	9/6/08
Reflective learning journal	10	9/6/08
TOTAL	100	

Student response to the foundation unit

Students were surveyed after completion of each project in the unit. Of the 32 students enrolled in the unit, 29 were in their first year of study at university, and five had previously studied at TAFE. The number of surveys returned for each of the three projects was 20, 13, and 30, respectively. The survey contained eight questions to obtain the students' perceptions of i) interest in the task set, ii) working in groups, iii) the knowledge gained, and iv) the learning versus effort balance. Comments were also sought.

The questions were as follows:

1. Did you find the project interesting?
2. Did you find that focussing on a practical engineering problem made learning seem more relevant to your interests?
3. Do you feel that you learnt more about the task by undertaking the exercise in this team-based format?
4. How much did you learn from one another by working in groups?
5. Do you learn more or less technical knowledge by doing this project than you might have in a set of tutorials alone?
6. Do you feel that you have understood the technical content associated with this project?
7. Do you prefer learning in this format comparative to other teaching methods?
8. Relative to assessment value, did this exercise take more or less time than other conventional lecture-based courses?

The responses were scored 5 = "very much" to 1 = "not at all", except question 8, which was rated "more" or "less". The results for each survey are summarised in the following three figures. Average scores are shown, except for question 8 which is the ratio of "more" to "less".

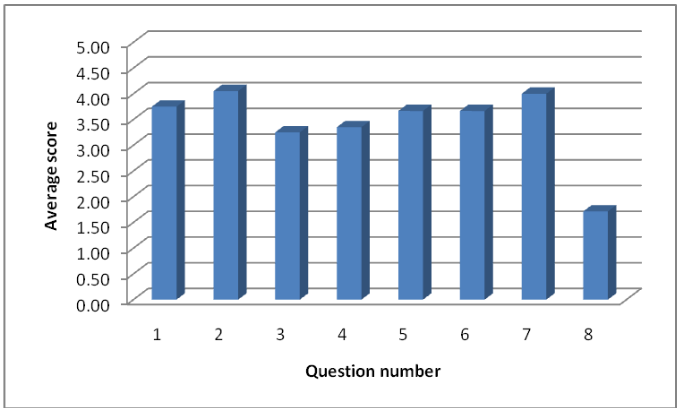

Figure 2 : Responses to Project 1 (overall mean = 3.7)

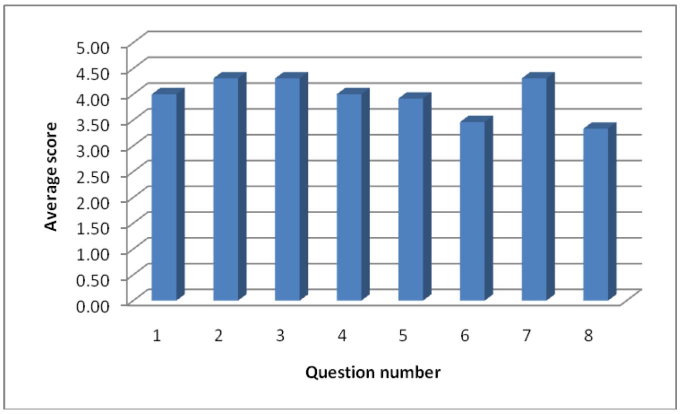

Figure 3 : Responses to Project 2 (overall mean = 4)

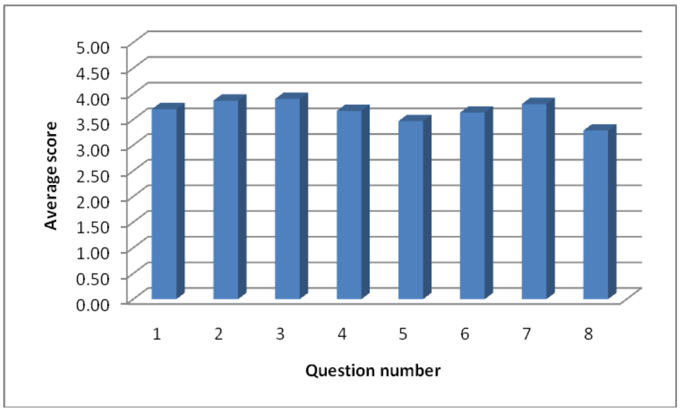

Figure 4 : Responses to Project 3 (overall mean = 3.7)

Discussion

The students' responses and comments clearly showed that the component of the unit that they enjoyed most was the group and practical work. A clear majority of students (by approximately 3:1) said the mode of learning was more time consuming, however the same students said they learnt more. The latter response must be taken in the context that the emphasis in this unit was on developing generic skills; the worst component of assessment was a multiple choice quiz on basic circuit theory.

Overall, most students found the unit very different from their other learning experiences to date, and some responded better than others to the level of responsibility they were expected to take for their own learning. Nevertheless, the above average scores and positive comments indicated that most found the unit very enjoyable and beneficial. Ex-TAFE students performed significantly better than average in this unit due to their previous practical experience and familiarity with group work.

A problem which emerged in some groups was unequal sharing of the workload amongst students. This led to concerns about some of the group assessments not reflecting the unequal participation. The latter problem arose despite early lectures and workshops on group work, where students were provided with guidelines for working effectively in groups, and tools for managing non-performing group members. The assessment methods and breakdown will therefore be re-evaluated next delivery.

Academic response to the foundation unit

Following the proposed project methodology, the academic staff (i.e. the first author) was surveyed after each project to determine their perceptions of problem-based learning in terms of student learning outcomes. In summary, whilst the projects were enjoyable and provided good motivation for students to participate in learning activities, there was relatively little teaching or learning of technical content accompanying the projects in this unit, and hence it was not problem-based learning in the truest sense. It was also observed that most groups preferred to work their way through problems, e.g. by trial and error, rather than sit down and think through a solution. Consequently techniques for improving the students' study skills and work practices will be trialled at the next offering of the unit. Despite the above shortcomings it was felt that the unit was very successful in achieving its aims to develop some necessary generic skills.

Conclusions

The teaching development project was a good experience for those academics and students who engaged with the project and the resulting foundation unit. Several useful lessons were learnt which will be taken into account in developing future workshops and teaching units. Additionally, there have been a number of positive outcomes, including a slow but steady increase in the number of academics considering adopting problem-based learning methods, and an enjoyable introduction to engineering for many new first year students.

References

Hadgraft, R. (1998). Problem-based learning: a vital step towards a new work environment, *International Journal of Engineering Education*, 14(1), 14.

Bloom, B. S. (1956). *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain.* New York: David McKay Co Inc.

Costa, L. R. J., et al (2007). Applying the Problem-Based Learning Approach toTeach Elementary Circuit Analysis, *IEEE Trans. on Education,* 50(1).

Brew, A. & Boud, D. (1995). Teaching and research: Establishing the Vital Link with Learning, *Higher Education*, 29, 261–273.

Acknowledgements

We acknowledge the support of a Macquarie University Strategic Curriculum Development Grant for support of the activities described in this report.

Copyright statement