

Ensuring quality outcomes from the first year of Bachelor of Engineering degrees



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***Abstract:** In 2001, the Faculty of Built Environment and Engineering at QUT began a review of the first year of all core Bachelor of Engineering Programs (Civil, Electrical and Computer, and Mechanical) in response to a number of identified problems with the current course structure, delivery and student experience. A project officer worked with a team of academic staff across the three Schools concerned to undertake the review process and to recommend strategies to implement and evaluate any changes to be proposed. This paper discusses the process that the multi-disciplinary review team undertook and the nature of the recommendations that resulted. A process for supporting course development is outlined for projects such as that discussed which fosters ownership amongst the diverse staff upon whom the success of the changes proposed depends. Despite the driving force for the review being initially about addressing drawbacks of the current course structure, the focus of the review process quickly moved to enhancing students' learning outcomes. The paper illustrates that educational theory on student learning is supported by experience in practice and is a necessary consideration in course review.*

***Keywords:** engineering education, first year, course development*

Introduction

Since the inception of the Course Experience Questionnaire, the results for engineering Faculties and Schools have been consistently poor in the areas of *Good Teaching* and *Workload* (Ramsden, 1992). In 1996 a review of engineering education in Australia recognised that the focus on the development of technical knowledge at the expense of broader social and environmental underpinnings was a weakness of engineering education generally (IEAust, 1996). Further, within the engineering education community there has been a recognition that for many engineering academics teaching is a minor concern well below research and in particular research in a technical field (Macdonald, 2000).

More engineering academics are, however, grappling with issues around the increased participation of students in universities and a decrease in the perceived preparedness for engineering studies. This has resulted in a community of researchers in Australia who

recognise the need to understand the nature of teaching and learning and to undertake engineering education research to ground their teaching practice. This understanding is what underpins the current course developments in the Queensland University of Technology's Faculty of Built Environment and Engineering.

The process of review described here was informed by Australian and international research in teaching and learning and in engineering education in particular. It aimed at enhancing the learning outcomes and experiences of students while fostering a “deep” approach to study that could be supported in later years. It was also focused on the development of professional identity as an engineer in first year students to provide a motivation and context for future studies.

The current first year in the Bachelor of Engineering course is made up of four “units” in each semester. There are a number of common units but in each discipline area there is at least one unique unit and students make their choice of discipline at the time that they enrol in first year. Each unit is the same size, nominally 12 credit points in the QUT system. A complete Bachelor of Engineering is four years with four units per semester – a total of 32 units and 384 credit points.

The Process of Review

The model of course review and development that was followed can be described loosely along the lines of the frameworks proposed in Al Holou, et al (1998) for considering the introduction of an integrated curriculum in first year engineering. The process is summarised in Figure 1. Each of the steps will be considered in turn.

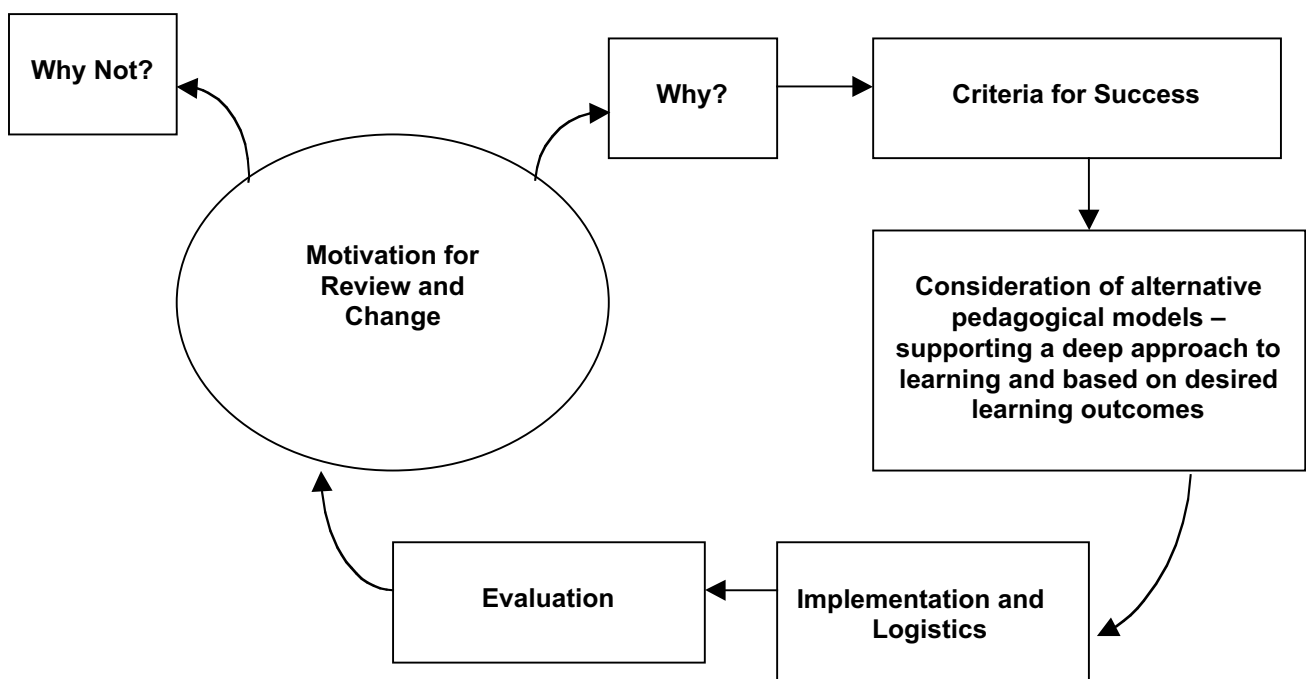


Figure 1: Model of Course Development Process

Motivation for Review and Change – Why or Why Not?

In the Faculty of Built Environment and Engineering, much discussion has occurred about whether students and the Faculty would be served well by developing a common first year across engineering courses. The reasons for doing so generally relate to two core advantages:

1. Pedagogically, staff felt that student learning would be enhanced if students experienced a foundation year in which the multi-disciplinary nature of engineering projects was emphasised. It was surmised that this would allow them to see the interconnections between the different disciplines and support their ability to make an appropriate choice of discipline for further study. This could be achieved by increasing their understanding of the engineering profession;
2. Organisationally, economies of scale may result from having first year classes that are common. This will also result in advantages in marketing courses to students who are uncertain about which discipline to choose.

However the disadvantages raised by a number of staff have meant that the idea of introducing a common first year has not gained widespread support. The objections raised relate primarily to the need to ensure that at the end of first year students have sufficient technical depth to support their movement into second year in their chosen discipline. There is also an element of competitiveness between the Schools, which means that each would like the chance in first year to cement student's commitment to their particular discipline area.

A proposal was developed that focused not on a particular course structure (a common first year) but instead on reviewing the first year generally, with a view to improving student experiences and learning outcomes and on addressing a number of identified problems including:

- Poor retention rates;
- The perception by staff that the incoming cohort had changed and was continuing to change. This applied particularly in their schooling experiences in mathematics and the physical sciences that provide the basis for some of the engineering fundamentals traditionally the core of a first year course;
- The need to support both part time and full time study which had slipped from focus;
- The perception amongst staff and industry partners that students were graduating without a holistic sense of the profession of engineering;
- The feedback from higher year units that students were not linking the outcomes that they were supposed to have achieved in first year with learning in second and later years. This resulted in the need to “re-teach” areas and thus crowd an already overcrowded curriculum.

Further impetus was given to the need to review first year by an impending visit by the Institution of Engineers, Australia (IEAust), the national engineering professional association that accredits undergraduate programs. Following a review commissioned by the IEAust and others, which was published in 1996, accreditation processes have undergone a fundamental shift in focus. Instead of requiring universities to maintain a balance in the areas of *content* of degree programs, accreditation now requires a focus on student *outcomes* expressed in a list of graduate attributes (see Table 1). Traditionally accreditation by IEAust depended on ensuring the right number of maths, science, engineering and “management” units, whereas the current process responds to the changing nature of engineering work and in particular the recognition of the need for students to enter the professional arena prepared for organisational and societal expectations.

Institution of Engineers, Australia - Generic Attributes of a Graduate

Graduates from an accredited program should have the following attributes:

- Ability to apply knowledge of basic science and engineering fundamentals;
 - Ability to communicate effectively, not only with engineers but also with the community at large;
 - In-depth technical competence in at least one engineering discipline;
 - Ability to undertake problem identification, formulation and solution;
 - Ability to utilise a systems approach to design and operational performance;
 - Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member;
 - Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;
 - Understanding of the principles of sustainable design and development;
 - Understanding of professional and ethical responsibilities and commitment to them; and
 - Expectation of the need to undertake lifelong learning, and capacity to do so.
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Table 1: Generic attributes of an engineering graduate (IEAust, 1999)

While there seemed to be many good reasons to review the first year, it was recognised that there was also likely to be some opposition to change. Unfortunately there are still some perceptions amongst engineering educators that “students should know how to be *independent learners* and it is not their [educators’] responsibility to teach them how to learn” (Macdonald, 2000). Furthermore any changes proposed would have implications for the balance of funding amongst Schools within the Faculty and within other Faculties that provided service teaching into first year. The need to keep in mind the implications of change in this sense was emphasised from the beginning of the review process.

Criteria for Success

From the motivating factors for undertaking a review, a picture of the desired outcome emerged. Any course development would be successful if:

- It would foster deep approaches to learning by the diverse incoming cohort of students;
- It would support incoming students in learning what engineering is about and thus begin the process of professional formation of the next generation of engineers;
- It supported a successful accreditation of the QUT engineering programs in the 2002 accreditation round with IEAust. Thus it would need to be a foundation for students to further develop the graduate attributes identified by IEAust as well as recognise the need for quality processes to support implementation and delivery that are part of the accreditation;
- It improved student retention.

Which Pedagogical Model? – Supporting a Deep Approach to Learning and Focusing on Learning Outcomes

The review process was informed by the current structure of first year and the requirements of the second and higher years of the Bachelor of Engineering courses in Civil, Electrical and Computer and Mechanical Engineering. However, the team of academics charged with working on the review were more importantly committed to ensuring that students completing first year achieved appropriate learning outcomes and for whom the context of learning provided an orientation to studying that would more likely foster the adoption of deep approaches to learning in later years.

At this stage in the review, the team felt that a deep approach to learning would be more actively encouraged by increasing the focus on projects modeled on “real” engineering

problems. This contrasts with the traditional engineering curriculum that was heavily assessed through examinations and left project work to the final years of a course.

The team developed a list of desired learning outcomes. These were roughly grouped according to whether they might be considered as *generic capabilities outcomes* or *technical capabilities outcomes*. The review team, however, agreed that professional engineering life was not divided between the generic and the technical, so that the outcomes were in fact related. However given the relatively recent shift in engineering education from a purely technical focus, it was decided that listing them separately would serve to emphasise the “missing” generic capabilities.

From the desired learning outcomes, options were considered for:

- **Curriculum models** – a commitment to some form of integration across traditional discipline boundaries emerged early. How this integration could be achieved, what a program might look like (number and size of units) and whether or not a project based learning model might be adopted was open to debate;
- **Learning environment** – recognising the transition experience and the range of models including active learning, experiential learning, project based learning (PBL), cooperative learning, teams, that might require space and technology was considered. Further the link between theory (as espoused in universities) and professional practice (as experienced in work) and the need to avoid a dichotomous introduction influenced discussions;
- **Principles of delivery** – the role of teaching staff, modes of delivery (lectures, tutorial, laboratories, site visits), assessment (the balance between team and individual, ensuring that assessment was appropriately devised to encourage a deep approach to learning), the balance between on-line and face-to-face delivery modes, the use of technology and the use of time (standard hours per week for each unit or a more flexible sharing of time between units depending on the weekly focus – referred to as “real-time allocation” by Al Holou, et al, 1998).

For each of the models considered in parallel with the pedagogical drive, the logistical implementation requirements were also important.

Implementation and Logistics

As pedagogical models emerged, details of the implementation and logistics requirements of each were considered. These included:

- **Staff Development** –the review team recognized that effective student learning and implementation of course developments could only take place if staff involved in the first year had a shared vision and commitment to the principles and outcomes. Thus ownership of the development by all staff was important. Furthermore implementation would need staff to be supported to develop a focus on teaching.;
- **Scheduling** – how to timetable units that might not be delivered in standard hours or over standard semesters;
- **Space and technology requirements** – many of the proposed models required new ways for students to work cooperatively. Also the possibility of using new technologies was explored;
- **“Accounting” across Schools and Faculties** – as in any university, competition for EFTSU (equivalent full time student units) is a major driver for many Schools and Faculties. Any Schools adversely affected by proposed changes would need advance notice and careful negotiation for successful outcomes;

- **Entry points** – consideration of students who might enter with credit from other higher education or TAFE courses was a necessary consideration;
- **Failure rates and repeating students** – any proposal that involved cross-unit integration must take into account the needs of students who do not progress in minimum time;
- **Staged versus step introduction** – whether changes should be introduced with a pilot cohort (as has been the case with a number of course developments reported by US institutions in engineering, see for example Al-Holou, et al 1998) or for the entire cohort;
- **The nature of incoming cohorts** – the need to recognise the diverse range of student backgrounds.

Evaluation

At the outset the team was charged with ensuring that a process of evaluation was built into any recommended implementation strategy. Quality outcomes can only be achieved within a climate of reflective review and continuous improvement. The team recognised that they were laying the foundations rather than completing a course development process. To support continued evaluation and review, the review team ensured that processes for evaluation should be embedded in the outcomes suggested. The process of evaluation was proposed around a number of dimensions in consultation with the Higher Education Program Evaluator at QUT. These dimensions included (Nulty, 2001):

- Student and staff experience;
- The quality of teaching and learning;
- The approaches to learning and orientation to study adopted by students;
- The establishment of professional identity as a novice engineer in students.

Quantitative evaluation was proposed in the form of:

- Measure of retention:
 - Within an engineering discipline;
 - Within engineering;
 - Within QUT;
 - Within higher education;
- Time to complete first year;
- Grade Point Average (GPA) and Student Progress Rates (SPR);
- Quantitative surveys of student experience and feedback;
- Survey measurement of student learning approaches;
- Predicted resource implications compared to actual (in particular staff time).

Qualitative measures were also proposed including:

- Student feedback in surveys and focus group interviews;
- Staff reflections and discussion.

Recommendations and Outcomes

The review team developed an extensive list of learning outcomes for first year and grouped them into possible units in a number of ways. The core team agreed that more complete unit development would need to be carried out by a wider group of staff who would become the core teaching team for first year but also work with teaching teams for second and higher years to ensure vertical as well as horizontal integration. The review team also committed to a set of principles for the delivery of first year. They are listed in Table 2.

Principles of Delivery of First Year Engineering, QUT

- All units are made interesting to students and provide appropriate explanations of topic areas in relation to the practice of engineering and Professional Engineers;
- Each unit should include aspects of engineering design and systems thinking to ensure that students experience an integrated first year. These may be said to be themes which are emphasised in all units.
- Teaching staff are aware of the nature of the cohort of students that they are teaching. They show concern and respect for student learning outcomes and recognise the need to take into account diverse backgrounds and understandings in an equitable way;
- Each unit has a range of appropriate assessment tasks and a planned way of giving students feedback on their learning particularly in the first five weeks of semester. Students are given many and varied opportunities to test their understandings and skills in a supportive, non-threatening environment and to learn from their failures;
- Students feel that they have clear goals in terms of learning and assessment in every unit and in every encounter with staff. This goes from having clear objectives for whole units through to providing an appropriate introduction and conclusion to each lecture that links the material covered to the “big picture” of students’ learning;
- Students experience independence, control and active engagement in their learning. In every unit there is some aspect of peer learning and support which allows them to take control of their learning outcomes and share with fellow students. There is a balance between lectures, tutorials, practical classes and other learning experiences;
- All units are taught by multi-disciplinary teams of academic and visiting staff. A team culture amongst staff is supported, so that students experience an integrated outlook in each unit and to some extent across units. Thus staff in teaching teams must be committed to working together and supporting the achievement of unit learning objectives in a holistic manner;
- Units in first year provide a foundation for the development of skills and understandings that allow students to become lifelong learners and give them a sense of joining a professional community that values learning;
- Staff in first year teaching teams are committed to evaluating and improving units over time. Evaluation may be quantitative but should definitely be qualitative and should recognise the value of staff reflection along with student comments.

Table 2: Principles for first year engineering delivery

Conclusion

The process of course review and development that has been undertaken by the Faculty of Built Environment and Engineering has been driven by a theoretical framework related to student learning outcomes. It has resulted in a course proposal that involves not just specifying units and content but a range of supporting principles that are aimed at providing a student experience that will be enjoyable, motivating and a foundation to further learning in the professional field of engineering.

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