Revising the Civil Engineering Curriculum at The University of Sydney

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NSW 2006
Australia

Abstract

A major revision of the civil engineering curriculum took place in 2004/2005. The reasons for the revision included: rationalisation of course offerings, changes in expectations from industry and the institutions, simpler integration with combined degrees offered by the faculty, moves toward a common engineering first year, reductions in staff numbers, changing student expectations and abilities, and greater integration of teamwork and generic skills development within the course.

The review process involved a SWOT analysis of the undergraduate programme/department, surveys of alumni who have graduated since the last major course change in 1995, surveys of employers of engineering graduates, focus groups with current students, and input from the Department's industry advisory group. The paper will discuss some of the results of these surveys.

It was found that the combination of a desire to take a gradual approach to change and the constraints provided by faculty and various combined degrees meant that there was little flexibility for innovation in curricula. However, the broad thrust of the changes were consistent with the objectives set out by the ASCE in their body of knowledge for the 21st century, and with statements by EUCEET in Europe. The paper will discuss the constraints and compare the adopted course outline with curricula in other parts of the world.

Although one of the primary intentions of the course changes was to better integrate the various branches of civil engineering (structures, geotechnical, fluids, and project management) this was found to be difficult to achieve while allowing students the flexibility to take courses outside the core. There was considerable debate on the core curriculum and the value of professional engineering subjects within this core. The paper will discuss these issues and the compromises that were agreed. A further important consideration was the role of The University of Sydney as a research intensive organisation, and the desire to produce students with the skills and motivation to follow more academically focused careers.

"Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium on Engineering Education

Introduction

The Department of Civil Engineering is one of the four schools in the Faculty of Engineering at The University of Sydney. Student enrolments have been increasing over recent years with commencing students increasing from 80 to about 150 over the last decade. At the same time academic staff numbers have been falling from 20 to about 12. Staff have expertise in four main areas; structures; geomechanics; environmental fluid mechanics; and project management.

The Faculty of Engineering has as its goal the provision of innovative, world class research and teaching to develop engineers who contribute to wealth creation and enrich the quality of life. The Faculty aims to provide a quality learning experience, a quality research environment, and appropriate recognition and reward for its staff and students. One of the Department's major strategic goals has been to maintain and enhance its position as a provider of high quality undergraduate and postgraduate teaching.

In 2002 The University of Sydney started moves towards adopting a standard 6 credit point model for all subjects, with students taking 48 credit points per year. One of the motivations for this change was to encourage curriculum review throughout the University. This coincided in the Faculty of Engineering with moves to introduce a common first year curriculum. Within Civil Engineering the need for a major review of the curriculum had been apparent for some time, and these external changes provided the opportunity. The course change process was precipitated by attempts to create a substantial thesis component in final year for all students as required by our accrediting body, and as required to meet changes in University and Faculty rules regarding course progression and enrolment. A departmental sub-committee was set up to examine thesis arrangements and recommended a 12 credit point unit of study for all students. It was found that this recommendation could not be implemented without a major revision of the entire course structure.

The need for a review and revitalization of the Department's undergraduate programmes was discussed at staff meetings in 2001 and 2002. There was general agreement for a review, as the last major revision of the Civil Engineering programme had taken place in 1993/94. Since then some minor revisions have occurred mainly in response to reductions in academic staff numbers. A number of staff meetings were held to consider how to proceed, and how the course should be changed. Several issues were raised at these meetings and it was agreed to proceed with a major review of the course structure. Actions included a SWOT analysis of the undergraduate programme/department, surveys of alumni who had graduated since the last major course change in 1995, surveys of employers of civil engineering graduates, the organisation of two focus groups with current students, and a review of the curricula at other universities both in Australia and internationally.

At the same time changes to teaching practices within The University of Sydney were being promoted through a series of faculty reviews conducted by the Academic Board. The Academic Board Review (2002) made recommendations for the development in the engineering faculty of a professional practice programme to address core and generic concepts. The course revision

presented an opportunity to include professional practice units throughout the course, not just in final year as they were previously.

The Department's industry liaison body, the Civil Engineering Foundation, was briefed on the need for changes and asked to provide input into the course review, both through the surveys sent to industry representatives and individually. The Foundation also nominated two members to work with the group to provide more specific input. Some significant changes were made following this feedback and incorporated into the revised programme structure.

Survey Results

Staff

The staff considered that the course had a good mix of theory and practice, but acknowledged that there were issues with the increasing number of low credit point subjects fragmenting the programme and creating difficulties with workload and in developing continuity across and between years. The previous course had large numbers of units of study with 2, 3, and 4 credit points, often introduced to deal with shortcomings in programme coverage in subjects such as Risk and Reliability, Communications, and Transportation. This resulted in the students taking large numbers of subjects each with an exam at the end of semester so that students would be typically taking 7 exams per semester. The programme fragmentation was also creating difficulties in integration with the remainder of the Engineering Faculty, and for students taking combined degrees across faculties. Staff were also concerned with the declining funding which had halved the number of academic staff since the last review and had led to reductions in laboratory based teaching. Declining government funding to students was also considered to be causing stress as increasing numbers of students were reporting a need to work more than 20 hours a week to support themselves.

Students

Two focus groups were run in October 2002, one comprising students from Years 1 and 2; and the other comprising Years 3 and 4. Most of the issues raised in these groups were related to the interaction between students and staff and related to how the material should be delivered. The students, particularly in the early years, did not see much connection between what they were learning and engineering practice and thought that this should be a priority for any change. They also commented on the large mathematics content which they perceived to have little relevance, and the difficulties facing students doing combined degrees. There was a general consensus that workload was heavy for engineering students, and that students doing combined degrees found other faculties asked less of their students. However, they were not over-concerned with workload, except for wanting assignment deadlines better coordinated across the faculty and with other faculties. The students were in favour of increased integration of generic skill development with technical content. The students saw benefits in increasing the amount of project work. There was a recognition that this should provide the opportunity for developing communication and leadership skills, but the management and assessment of groups was seen to be problematic. There were also concerns regarding the lack of practical computer skills.

Graduates and Employers

Surveys were sent to 250 students who had graduated between 1998 and 2002 and to 76 (major) companies that employ civil engineering graduates. The response rate from the students was 13% and from the employers was 50%. It should be noted that employer responses were for all civil engineering graduates and not specifically for those from The University of Sydney. Where employers were able to identify graduates from The University of Sydney there was no general difference between our graduates and those from other institutions.

There were interesting differences between the responses of the graduates and the employers on their skill development, with the graduates being more positive about the course outcomes than the employers. For example graduates felt that development of communication skills had met their needs whereas 40% of employers responded that communication skills were inadequate. Graduates thought that the development of problem identification and solution skills exceeded their needs whereas 20% of employers felt these skills were inadequate.

The main shortcoming of the course identified by the graduates was a lack of appropriate computer and IT skills. This was reflected to some extent by employers several of whom made comments that engineering is not simply about high level computer analysis. The graduates felt that the mathematical and analytical skills they had developed far exceeded their requirements, and many graduates and employers expressed a desire for a more practical focus to the course, with greater involvement with the practice of engineering.

A small but significant number of graduates believed that the course content was not meeting their needs, and that similarly it was not providing a solid foundation for their professional development. This comment was also echoed by the employers who saw a problem with providing appropriate career advice and subject selection.

Employers tended to emphasise the need for more business skill development, but this was not mentioned by any of the graduates.

Discussion

These surveys did not identify any major shortcomings of the existing programme content, although there were similar concerns expressed by staff and students regarding the integration of the programme, and a clear desire for the students for a more practical focus. Although students did not report major concerns with content or delivery, independent surveys of student perception of civil engineering have found them to be overall negative about the quality of teaching. As the University and government are moving to allocate increasing funds based on student perception of teaching there is a priority for staff to address student concerns.

The comments of employers are similar to those in the USA reported by Siller et al. (2004), that employers want graduates "who can communicate better, who understand the business world, and who know something about finance". At the same time employers want traditional "technical skills, and graduates who can think clearly and exercise good decision making skills".

A further major driver of the change was the need to meet accreditation requirements, and in particular to satisfy the generic skills expected by the Institution of Engineers, Australia (IEAust). Accreditation by IEAust requires certain general requirements of an approved engineering programme. In recent years there has been increasing emphasis on generic skills, which in the current accreditation manual (IEAust, 2004) require:

- ability to apply knowledge of basic science and engineering fundamentals;
- 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 communicate effectively, not only with engineers but also with the community at large;
- 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

The IEAust expectations regarding the generic attributes that all students should attain had been mentioned in the previous accreditation process as needing attention. The course review presented an opportunity to integrate these more coherently with the programme structure, and enable us to more directly address issues of social, cultural, global, and environmental responsibilities and sustainable development. In addition to the requirements of the accrediting body The University of Sydney has its own set of attributes that it expects all graduates to attain. Attempts have been made recently at University and Faculty levels to align these attributes, and within the Faculty to map the attribute development across all units of study. The revision to the programme, in association with the flexible first year, was also intended to improve the students' communication skills and their ability to take on team and leadership roles.

The civil engineering profession worldwide has been re-considering the skills expected from university graduates. The American Society of Civil Engineers (2004) has recently published a Body of Knowledge (BOK) that all professional civil engineers should have in the 21st century. During the review process a draft version of this was available and was found to be helpful in informing decisions about course content. A particularly helpful aspect of the BOK was the set of commentaries supporting the 15 outcomes. A review of civil engineering education in Europe has also been undertaken by EUCEET (Manoliu, 2001, 2003). This review has revealed great similarities in curricula. One notable observation was that the contact hours in Australia were at the low end of the European spectrum, and local pressures are to reduce these further. It is interesting to note that EUCEET (Majewski, 2004) appear to have accepted the ASCE BOK as the basis for what should be included in civil engineering curricula.

A number of goals were set for the course revision that included:

- Simplify the course structure, particularly for students taking combined degrees

- Reduce staff and student workload especially in light of increasing student numbers
- Increase integration between units of study
- Increase integration of generic attributes across units of study

The rationalisation was planned to assist the Department's efforts to improve the quality of learning and teaching by reducing assessment load, providing clearer information about assessment, and making clearer goals and standards. It was hoped that this would significantly and positively influence student perceptions of the teaching.

The programme for the standard civil engineering degree developed after this review is shown in Table 1. Only the core subjects which are required for all students taking both single and combined degrees are shown. There was no perceived need to change the emphasis of the degree programme based on employer, graduate surveys, or on comparison of our existing programme with Civil Engineering programmes in other countries. The changes have primarily involved reorganisation of the course material to meet the objectives listed above.

Table 1: Programme layout

	Semester 1				Semester 2			
Year	1	2	3	4	5	6	7	8
1	Differential Calculus + Linear Algebra	Chemistry 1A	Engineering Computing	Introduction to Engineering Disciplines	Integral Calculus and Modelling + Statistics	Engineering Mechanics	Professional Engineering 1	Elective 1/ Engineering Geology
2	Linear Algebra and Vector Calculus	Structural Mechanics	Materials	Engineering Construction and Surveying	Intro to Structural Concepts and Design	Fluids Mechanics	Soil Mechanics	Elective 1/ Engineering Geology
3	Engineering & Society	Concrete Structures 1	Environmental & Fluids Engineering	Project Appraisal	Steel Structures 1	Elective 2	Elective 3	Elective 4
Practical experience between years 3 & 4								
4	Elective 5	Elective 6	Engineering Design & Construction	Thesis	Civil Engineering Design	Thesis	Elective 7	Elective 8

Combined degree programmes with Science, Commerce, Arts and Law are popular in Australia attracting many high achieving students. In these programmes students typically combine 3 years of engineering with 2 years of the second degree in a 5 year programme. Because of the large range of options associated with the second degree students need some flexibility in the order in which subjects are taken, and how many subjects from each degree programme are taken in any year. Providing this flexibility limits the degree of innovation possible in the core engineering programme. For instance, we decided it was not possible to include design courses that integrated subject matter from the various technical disciplines until the final year, as we could not guarantee that students would have covered the necessary knowledge. To simplify the requirements for the students, it was decided to identify a core programme that all students would take irrespective of the combined degree, or of any specialisation in civil subjects. The core subjects shown in Table 1 are therefore taken over 5 years with required subjects of the combined degree.

At the same time as the civil engineering changes were being discussed a "common" first year

programme was being introduced in the Faculty of Engineering. This is referred to as a flexible first year as it is not truly common as electrical engineering could not be accommodated in a single common programme, but it gives students the option of transferring between chemical, civil, aeronautical, or mechanical programmes after one year. It was decided that all civil students would take the flexible programme. This provided a further constraint on the programme design.

It was initially intended to have a professional practice stream spanning all 4 years with one 6 credit point subject in each year. However, because this would have led to a significant reduction in technical content for students taking combined degrees the external advisory group considered this plan too radical, and an additional structural subject was introduced. The resulting stream has Professional Engineering in 1st year, Engineering & Society in 3rd year and Engineering Design & Construction in 4th year. The first year course is designed to raise awareness of the importance of communication skills, teamwork and leadership, and ethics. The third year course has similar goals but provides more on sustainability and decision making, and the fourth year course covers constructability, contract administration, QA documentation, insurance, and, occupational health and safety issues.

Another of the goals had been to even up the course content between the Department's four main groups, so that after initial courses in mathematics, chemistry, and engineering mechanics the remaining courses would be split evenly between structures, geomechanics, fluid mechanics, and construction and project management. Design is covered in the core through integrated exercises in many subjects and a final year civil engineering design subject.

One of the goals in producing the new curriculum was to satisfy as much of the ASCE BOK as possible. This is clearly not possible in a three year core programme. However, when all the elective subjects are considered, outlined in Table 2, our undergraduate programme provides some coverage of all the BOK outcomes. This has been possible largely because of the Project Management focus of construction staff.

Table 2: Elective matrix

	Structural Stream	**Geotechnical Stream**	**Environmental Stream**	**Construction/ Project Management Stream**
3rd year	Structural Analysis	Foundation Engineering	Coastal Engineering	Project Scope Time & Cost Management
4th year	Concrete Structures 2	Environmental Geotechnics	Environmental Geotechnics	Contracts formulation & Management
	Steel Structures 2	Geotechnical Engineering	Hydrology and Wind Engineering	Project quality risk & procurement mgt
	Bridge Engineering	Finite Element Analysis	Water Resources Engineering	Project planning & tendering
				Project Formulation

Another issue that was considered during the course review was the positioning of the University as a major research organisation, and its goal to be the leading research University in Australia. Increasing numbers of our most able students are taking combined degrees and thus only the core curriculum. This group are potential research students, but they are not taking the advanced

academically challenging elective subjects that in the past have opened doors to research opportunities. The increasing numbers of "soft" subjects in the core were of concern as this could further reduce these students interest in technical research focused careers. To address this concern attempts have been made to integrate research activities across the curriculum.

Some of the challenges remaining include:

- Curriculum focus: Although there is greater awareness of the need for skill development across subjects and across years, individual staff still have a focus on content delivery. Thus, although increased generic skills development (such as communication and team work) is expected within technical units of study this is not occurring. The challenge is to ensure academics are suitably trained and resourced to ensure they can provide assessment tasks which adequately help development of these skills.
- Timetabling: This remains complicated for students doing combined degrees, or who have failed subjects and are doing subjects across a variety of years.
- Computing skill development: This requires integration across subjects and years. There is also a continual conflict of ideas when trying to teach the basics of engineering analysis and avoiding the computing "black box" mentality, versus the student and industry desire for training in specific proprietary software. This is being combated by a number of initiatives which are beyond the scope of this paper.
- Changing skills base of students: Today's students have vastly different experiences and expectations from the previous generations. Seeking to instill an appreciation of "life long learning" and challenging problems is difficult in this age of instant information by the WWW or SMS.
- Improvement to student perception of relevance: Challenges have always existed in early year service courses such as maths and chemistry. These courses have been reduced in the course changes with more engineering subjects in second year. Further efforts are needed to link engineering science to the practice of engineering.
- Integration with Masters programme: The change of syllabus to include a greater proportion of generic skills and a consequent reduction in detailed technical information provides an opportunity for higher degree learning.

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