PROBLEM BASED LEARNING FOR ON-CAMPUS AND DISTANCE EDUCATION STUDENTS IN ENGINEERING AND SURVEYING

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ABSTRACT

Our University has one of the most diverse student intakes of any Australian university. It offers a suit of integrated programs to both On-Campus and Distance Education students in Engineering and Surveying. The programs cover 2, 3 and 4 year courses in 9 majors. The student profile includes a large intake of mature age students, particularly studying via distance education, international students as well as traditional school leavers.

In 2000, the Faculty embarked on a major review and restructure of its programs leading up to its reaccreditation cycle. The review process established that some major changes were required to develop new graduate attributes relating to teamwork, problem solving and life-long learning patterns as required by Engineers Australia. Proposed changes to the programs included the removal of some traditionally taught, content based courses such as physics and statistics. Their place was to betaken by a newly developed strand of 4 integrated courses which used a Problem Based Learning (PBL) methodology.

The first offer of the new foundational course took place in Semester 1 2002. It has since been recognised through a number of national and international awards.

As far as is known, the offering of this type of course to engineering students at a distance from the campus, working in virtual teams, has never been done before in the world. This course is now delivered to about 400 students annually. Student feedback indicates that the course successfully inculcates new attributes in an engineering graduate such as the ability to work in a team, to communicate, to self-learn, and to solve technical problems. All these attributes have been identified as desirable by professional and industry bodies around the world.

This paper gives an overview of the implementation strategy as well as results from a longitudinal study of students progressing through the strand.

INTRODUCTION

The University of Southern Queensland (USQ) is a regional university located in south-eastern Queensland, Australia. The main campus is in the city of Toowoomba which lies approximately 130 km west of Brisbane, the capital of the state of Queensland. The university incorporates five faculties – Arts, Education, Business, Science and Engineering and Surveying - and has a total enrolment of over 26,000 students

The university has an international reputation for providing distance education with approximately 76% of the total number of students studying via distance education. The university also offers online education as well as the traditional face to face courses and programs.

USQ gives opportunities for tertiary education to a broad range of people by providing many alternate entry paths. This has lead to a very diverse student population. In Australia, student demographics have changed dramatically in the last 10 years. Now only 41 percent of university students are the traditional school leavers while 37 percent of students have attendance patterns other than internal full time modes (1,2). This contrasts with USQ where less than 30 percent of students enter university **directly** from school and only 24 percent are internal full time students (3).

The Faculty of Engineering and Surveying (FoES) is unusual in that it offers 9 majors (agricultural, civil, computing/software, environmental, electrical/electronic, mechanical, mechatronic, surveying (spatial science), GIS) with no departmental subdivisions. Staff have discipline specific knowledge and teach in their discipline areas at higher levels of the course, but the foundational years are taught by **all** staff, often in multidisciplinary teams.

The faculty has approximately 2,500 students with 76 percent studying via distance education. The diverse background of students in the faculty includes people with trade backgrounds or other tertiary qualifications and many mature age students. This means that a high proportion of students lack the traditionally expected background of maths and physics as prerequisite entry. At the same time some of the students with previous qualifications have gone well beyond the minimum entrance expectations. With all courses offered by distance education, many of our students are already working in the engineering and surveying disciplines. This student population brings a great range of prior knowledge, skills and experience as well as cultural and age differences. In the past, this student diversity has been seen as a disadvantage, but the faculty review suggested that the diversity represented an untapped potential advantage.

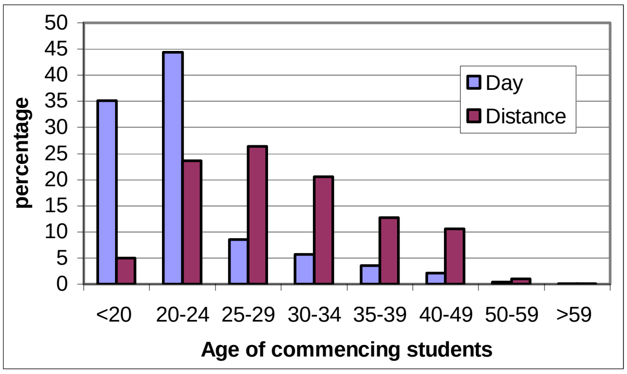

Figure 1 Commencing Student Age Profiles for USQ Engineering Programs.

The challenge of managing the student diversity is complicated by the different expectations of students in the 3 levels of faculty programs. We offer Associate Degree (2 year full time), Bachelor of Technology (3 year), Bachelor of Engineering and Bachelor of Spatial Science (4 year) programs across all majors previous listed and a number of 5 year double degree programs (e.g. engineering/business, engineering/ science). Economic constraints have led to the development of a large number of common courses for all programs and majors in foundational years, particularly in first year.

PROGRAM REQUIREMENTS

Engineering educators are becoming increasingly focused on graduate attributes, driven by the needs of employers for immediately productive professionals and of professional registration bodies for globally comparable graduates. In Australia the professional accreditation body (Engineers Australia) has focused heavily on the development of graduate attributes required in engineering professions. They now nominate a range of attributes and require universities to demonstrate how these attributes are incorporated into the curriculum. This focus on graduate attributes is also supported by other accreditation bodies around the world (4,5,6,7) In short, the main focus of higher education now is on outcomes and not the process.

University policy in Australia at the national level is also concentrating on generic attributes of graduates for quality control reasons. Universities now explicitly list their required graduate attributes including such things as teamwork, communication skills and problem solving (8). Students and employers both appear to support this change. A recent survey of Australian engineering graduates rated “contributing positively to team-based projects” as the most important work skill to be acquired, while ‘technical knowledge’ rated only 29th out of 38 nominated success factors. Thoben and Schwesig (9) expand these attributes, listing working globally in a multicultural environment; working in interdisciplinary, multi-skill teams; sharing of work tasks on a global and around the clock basis; working with digital communication tools; and working in a virtual environment as requirements of engineers and a responsibility of engineering educators. Meeting these requirements presents a large challenge indeed given the current economic climate in higher education and the resistance to educational cultural change in the conservative world of engineering academics.

In this paper we describe how the nature of the challenge was defined by review and then implemented in a revised curriculum as part of the re-accreditation process.

In 2000 the faculty prepared for their regular re-accreditation process by examining the curriculum to establish how well these graduate attributes and the traditional discipline-specific knowledge were delivered to students. A comprehensive review by the faculty of its courses, curriculum and quality control was able to establish the need for new courses to meet a range of teamwork, communication and life-long learning requirements.

In addition to the requirements of accreditation and our student diversity, the faculty also had other objectives for the accreditation process These included developing an ‘engineering mindset’ in our students; the effective integration and communication between our distance education students; interaction between programs and majors so students can have a better understanding of the breadth and depth of the engineering professions and staff professional development in educational strategies and theories.

We accepted the argument of Spender and Stewart (10) who proposed that if educational organisations are to survive, they must move from a didactic to a more student-centred approach to learning. This call has been reinforced by current Australian government policies with incentives for universities to improve teaching and leaning within their organisation. Staff promotion pathways are increasingly dualistic, with greater emphasis now being placed on the quantification of ‘teaching performance’ in ways that mirror the traditional measures of research performance. The concept of a “good teacher” is being more clearly articulated in university circles. Helping staff to move from the didactic teacher, the ‘sage on the stage’ to the facilitator, the ‘guide on the side’ is now an integral part of staff development in the faculty (11).

IMPLEMENTATION STRATEGY

The Faculty concluded in 2000 that the new requirements for engineering graduates could be met through the introduction of Problem Based Learning (PBL) courses. It found that the didactic teaching of a number of foundational courses was not meeting the needs of our students. The courses could not challenge the better students while helping those who lacked prior subject knowledge. Consultations with industry employers, past graduates and academic specialists indicated that these courses contained little if any knowledge that was essential for a professional engineer. As a result the Faculty substantially changed the content and teaching methodology of one eighth of the 4 year degree program.

Four content based courses were removed and replaced by a strand of 4 new courses to be delivered using PBL, with our existing final year research project as a capstone course for our 4 year programs. The new courses were designed to cumulatively develop attributes of teamwork and communication as well as the ability to identify and acquire required content knowledge within contextual engineering problems. They had secondary objectives of introducing students to engineering at an early stage of the program and inspiring them to continue with their studies. The habit and skills of life-long learning were also an objective of the strand.

The four courses in the strand were named Engineering Problem Solving 1, 2, 3 and 4 and were integrated into our suite of programs as shown in **Table 1**.

Table 1: PBL Strand of Courses

Course	Student cohort – all majors	Team Size
Research Project	Bachelor of Engineering, Bachelor of Spatial Sciences	1 (individual)
Engineering Problem Solving 4	Bachelor of Engineering	3 to 4 students
Engineering Problem Solving 3	Bachelor of Engineering	3 to 5 students
Engineering Problem Solving 2	Bachelor of Engineering, Bachelor of Spatial Sciences, Bachelor of Technology, Associate Degree	5 to 7 students
Engineering Problem Solving 1	Bachelor of Engineering, Bachelor of Spatial Sciences, Bachelor of Technology, Associate Degree	6 to 8 students

The curriculum and course objectives for these four courses were completed and formal specifications written so that the strand functioned as an integrated unit (12,13).

As students progress through their program the problem complexity and technical difficulty of each problem solving course increases as does the need for student independence and application of research. Teamwork skills are developed in the early courses where the teams themselves provide peer support to the students. Many students find it a revelation that they have significant knowledge and skills from their life experience which help their teams overall task. The appreciation of their peers' skills and the friendships formed through working together are common outcomes of these courses. As student confidence in their ability to learn and research skills grow, the team support is reduced until the student is ready to demonstrate professional level engineering work in his or her final year research project.

The first problem solving course focuses on 'setting the scene'. It introduces students to PBL and has a greater emphasis on teamwork, conflict resolution, problem solving skills, application and sharing of prior knowledge, self learning and reflection, communication skills (both individually and as a team), task allocation and finding and applying appropriate resources.

Students are allocated to a team of the appropriate size, as indicated by table 1 and assigned a staff member who acts as team facilitator. Resources provided for the teams in these courses include:

- A course web page where problems are released and specific resources are provided or indicated to help address the problem or improve the team operation. They include a Frequently Asked Question (FAQ) section, regular tips and hints from the Examiner and extra resources particular to each problem.
- Communication facilities through a commercial courseware environment (WebCt). This provides email, discussion boards and chat facilities for each team and facilities for electronic submission of final project reports, weekly team reports and individual portfolios. It is also used to gain student feedback through electronic surveys.
- A course resource book that contains general information on all aspects of the course from setting up email accounts and maintaining a computer file structure through to technical information for each of the problems. However the technical information is taken not from traditional engineering or technical texts, but other sources so that students are forced to understand it in the context of their own problem before they can apply it.
- Other people: students are encouraged to seek resources from outside the course e.g. work colleagues, team members etc.

Assessment of the courses varies according to the learning objectives and course specifications. In the first course, there is no examination. Individual marks are determined from the team result of the project report and individual peer and self assessment forms. The four reports account for 75% of the total marks available with the other 25% coming from an individual reflective portfolio. In addition the weighting on 'technical' aspects and a team reflection of the processes changes throughout the course as shown in Table 2. The team's project report must cover aspects of project planning and management and research methodology. Communication skills are enhanced by a requirement to use different presentation formats including a formal technical report, a technical memo, an informal report and a PowerPoint presentation (with appropriate speakers notes). This is designed to increase the students' communication skills by identifying the audience and writing appropriately.

Table 2 Sliding scale of marks for team reflection

	Project 1	Project 2	Project 3	Project 4
% marks for project report *	50%	60%	70%	80%
% marks for team reflection**	50%	40%	30%	20%

* reports also require sections on project planning and research methodology
** reflection includes plan and strategies for improvement in team performance

ACHIEVEMENTS AND CHALLENGES

The strand of PBL based engineering courses have been progressively introduced since 2001. When the foundational course was first offered it was to our knowledge the first offering of an engineering PBL course to truly distance students working in virtual teams and communicating solely by electronic means, such as discussion boards, email and chat sessions.

There are only a limited number of references on team work organized for distance education students and all these still rely at least in part on face-to face meetings at specified times during the course (14,15,16,17). The cohort of students at USQ studies truly at a distance and there is little or no possibility of face-to-face meetings during the semester. USQ has the fourth largest international education program in the Australian higher education sector, and is the largest off-shore distance education international education program - recruiting from around 50 countries. Its success and support of distance education students has attracted large numbers of students not only from remote locations both nationally and internationally, but allows students who for work, family or personal reasons cannot be present on campus during normal hours. The implementation of team based work was organised with these students in mind. Course delivery for the on-campus cohort is then a comparatively simple exercise as a variation on the external offering.

The work of the staff of the problem solving strand has been recognised with several national and international awards. The strand has won the USQ award for the Design and Delivery of Teaching Materials for two successive courses and the Australasian Association of Engineering Education award for excellence for Curriculum Team Project. The delivery team for the foundational course were finalists in the prestigious Australian Awards for University Teaching (AAUT) in 2005. These awards have recognised the innovative nature of the courses, particularly for distance students, the development of resources for staff and students and the corresponding staff professional development.

Faculty staff are routinely rotated through the problem solving courses and must attend annual staff training sessions on delivering courses in this new engineering educational paradigm. This has resulted in nearly 50% of the faculty academic staff being exposed to cooperative learning techniques (11). It has significantly contributed to changing the culture of teaching within the faculty and even within the university. Staff responsible for training and implementation of the problem solving course have given university wide seminars and workshops on the techniques and strategies employed in the courses.

A perhaps smaller but still significant achievement is that of 'reflective practice' now being undertaken by students and in future by staff in the delivery teams. Part of the individual assessment for students requires a reflective portfolio. Students must learn to reflect on the learning that has (or has not) occurred during the course and present reasons, outcomes and implications of their reflections in the portfolio. Reflection is a novel experience for engineering students, and it is necessary to provide guidance on the process and requirements in the initial course. They are guided by a number of activities and a reflective writing guide that are available on the course web page. Where students undertake the reflective exercise properly during the semester the results have been very positive (18,19).

The development of the PBL strand within an engineering course offered to students at a distance from the campus was a novel, even world-first process. A longitudinal study was developed to document the students reception of these courses and their progress in acquiring the required attributes. The survey is ongoing, but results to date indicate that a large portion of the student cohort agrees that their learning, retention of knowledge and appreciation of problem solving and prior knowledge has increased through these courses. Key findings to 2004 include:

- 54% of students thought that the PBL courses had increased their ability to learn, with only 14% unsure of this effect.
- 52% of respondents either agreed or strongly agreed that their confidence in their ability to independently learn new concepts was increased, 22% were undecided.
- 70% of respondents either agreed or strongly agreed with the proposition that the course had enhanced problem solving skills and made effective use of prior knowledge. Only 15% were unsure of the effect.
- 83% of respondents thought that the courses had enhanced their appreciation of the prior knowledge and skills of their fellow team members. Only 8% had no opinion on this issue and 10% disagreed.

The student portfolios have qualitatively affirmed the results of this survey. Students tend to dislike the extra work required for the course and the need to depend on others in a team situation. Many do however realise how teamwork is now an essential part of the engineering profession and comment on how their skills in this area have been improved. Those with more experience in the university system are also likely to state that their learning experience has been significantly deeper through this course then it has in other traditionally taught courses.

CONCLUSIONS

The move to PBL was a huge undertaking by the Faculty of Engineering and Surveying at the University of Southern Queensland. It represented a significant cultural change for both students and staff, which has not been made without difficulty. Initially both parties found the change difficult but as problems were overcome, many of the inherent benefits of PBL became more apparent.

Now a large portion of the student cohort agrees that their learning, retention of knowledge and appreciation of problem solving and prior knowledge has increased as in the data below. A longitudinal study of the students is continuing with each offer of the course to document changing student attitudes, their perceptions of their learning progress and confidence in their ability to learn.

It would seem that the strand of Problem based learning engineering courses is achieving its objectives of inculcating teamwork, communication, and life long learning attributes while enabling our students to acquire specific technical knowledge as required for specific projects.

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