

Transitions to First Year Engineering – Diversity as an Asset

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Abstract

Both the tertiary education sector and engineering profession are facing numerous challenges to adequately prepare professionals to meet the future needs of society.

Higher education institutions rely heavily on the secondary school system to direct students into programs with appropriate prerequisite studies for their chosen career. However, schools are now offering a greater breadth in education at the expense of depth in specific areas. They are now catering for alternative student destinations by offering work-based and trade-oriented programs. Traditional subjects required for engineering such as physics and high level mathematics are suffering from falling numbers. Universities are struggling with the challenge of graduating students with a diverse educational background. The wide range of entry paths to formal higher education compounds this difficulty.

Diversity in the university classroom, particularly in the entry level courses, has always been viewed as a ‘difficulty’ by academics. This paper will argue that the careful integration of Problem Based Learning (PBL) into the curriculum can turn the disadvantage of diversity into an advantage. PBL can assist in meeting many of the desired graduate attributes such as teamwork, effective communication and problem solving. PBL can also help ensure that students with diverse educational backgrounds have a reasonable chance of success and that those students with a more ‘traditional’ education background are not ‘bored’ by covering basic concepts again.

Problem Based Learning, cooperative-based learning, and collaborative-based learning all offer the possibility of using student diversity to advantage.

Keywords: Problem Based Learning, engineering education, diversity

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Background

The University of Southern Queensland (USQ) is a new, regional university in Australia. Founded as a College of Advanced Education in 1967, it gained full university status in 1992. USQ was an early adopter and pioneer of distance

education and over time it has acquired international recognition as a leader in providing flexible study options for students. It offers on-campus, distance (off-campus), and online modes of delivery.

Between 2003 and 2008 the total student numbers remained constant with between 25 700 to 25 900 students enrolled across five main Faculties: Arts, Business, Education, Science and Engineering & Surveying. USQ offers both undergraduate and postgraduate qualifications. The majority of students study in the distance mode with only 24% enrolled as on-campus students. International students make up 29% of the total student population; studying either offshore (22.5%) or on-campus (6.5%) (USQ, 2007)

The Faculty of Engineering & Surveying has approximately 2700 students in three undergraduate programs across nine majors. Programs offered by the faculty include the Associate Degree (two years), Bachelor of Technology (three years) and Bachelor of Engineering or Surveying (four years). All programs are fully articulated and fully accredited by the appropriate professional body.

In 2002, the Faculty became the first in the world to have its distance mode of offer fully accredited by the professional engineering body (Engineers Australia). The faculty programs were then evaluated by a panel and deemed to be 'world's best practice' by the Washington Accord.

Introduction

Political, social and economic forces have produced major changes in higher education in Australia. In the last decade, overall undergraduate commencements increased by 31% (Department of Education Science and Training [DEST], 2004) while the Government has focused on meeting skills shortages during a prolonged economic boom. The probability of a person participating in higher education in Australia at some point in their lives has increased to 47% (DEST, 2004). These increasing student enrolments are a direct result of increased access to education and increased flexibility in study opportunities.

Universities now routinely offer multiple entry pathways to undergraduate programs. One consequence is that students entering university after completing secondary school now account for only 41% of commencing student admissions. (Refer to Figure 1.) While the size of this cohort has grown by 6% in the last 10 years, their share of the commencing student enrolments has decreased by almost ten percentage points since 1991. By comparison, students admitted on institutional examination and employment experience have increased by over 200% and entry on the basis of prior non-secondary vocational (TAFE) studies have increased by 177% (DEST, 2004).

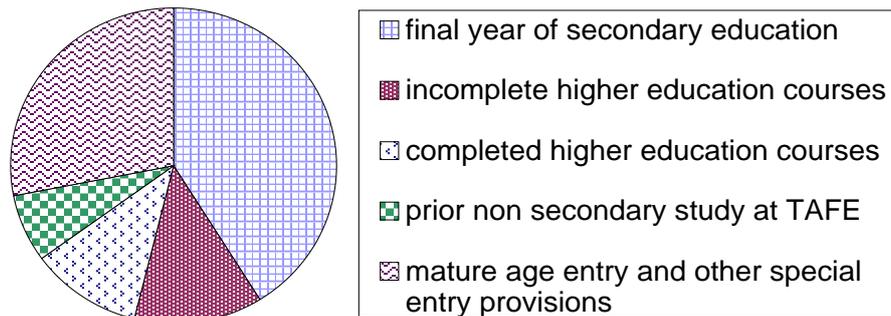


Figure 1 Mechanisms for entry to undergraduate programs

To cater for changing demographics (from school leavers who studied full time and lived at home to students who balance work and family life while undertaking higher education) universities have changed enrolment patterns and attendance modes. In 2002 the Department of Education, Science and Training (DEST) reported that 37% of students had attendance patterns other than internal full time modes (DEST, 2002). All these impacts and trends are greater in the regional universities as quantified by a range of authors including Luck, Jones, McConachie, et al. (2004) Owens, Thomson, Ross, et al. (2004).

New admission pathways linked to the changing demographics of the Australian population have resulted in an increasingly diverse student population. This change has implications for the nature of their engagement and the nature of their expectations. It requires that the pedagogy employed by universities meets the learning needs of a greater diversity of learners (Ireson, Mortimore, & Hallam, 1999, p. 213).

Diversity applies to a number of aspects of student identity, including race, ethnicity, class, gender, sexuality, age, and political and religious beliefs ... teaching and learning practices ... (James & Baldwin, 1997)

No longer can academics rely on standard prerequisite secondary school subjects or similar prior knowledge and experiences, particularly in first year university courses. Student background knowledge, motivation and learning experiences require reflection on course structure and delivery and teaching and learning. Whilst didactic teaching still has its place and is somewhat effective, more diverse and inclusive teaching and assessment practices are required to meet the changing expectations of both students and employers (Howell, Williams, & Lindsay, 2003; McCombs, 2000; Patel & Sobh, 2006).

The USQ Engineering Response

There is now significant pressure on universities to address graduate attributes both at a university and professional level (Brodie & Porter, 2008). Professional accreditation bodies, particularly in the area of engineering, have actively sought evidence of their required attributes being inculcated into students. The Faculty of Engineering and Surveying at USQ has responded by reforming the program on the basis of required graduate attributes. The faculty has embedded graduate attributes such as teamwork, communication (verbal and written), and problem solving as assessable items within several courses in their programs.

The faculty has also wrestled with the challenge of student diversity, and the impact of non-school leaving students on the assumed prior knowledge in its courses. It concluded that it can no longer assume that all students will have an adequate science and maths background from high school or previous studies. At the same time, many students already have some of the skills and knowledge that their degree program is intended to develop. How then can the university effectively use the period of a student's enrolment to develop each individual while ensuring that they meet all the attributes required in a modern engineer – in the 27 degree programs that it offers?

USQ has always offered diverse entry paths and alternative modes of study relative to older universities in Australia. By comparison with the DEST figure of 37% of students studying other than full time on-campus, approximately 76% of the students at USQ study off-campus, by distance education. The majority of USQ students is mature age and has returned to study to formalise work experience or perhaps to facilitate a major career change. Over the previous decade the university came to realise that teaching and learning practices had not taken into account the prior knowledge and experience of these students. Change has also been motivated by two other important factors: the awareness of the greater buying power of students as they demand value for their investments of money and time in their education and the increasing demands of employers to have students with 'different' graduate attributes from what universities traditionally focused on.

To accommodate diverse student backgrounds into the USQ first year engineering and surveying programs, the faculty implemented a strand of courses using the Problem Based Learning (PBL) paradigm. This approach was intended to inculcate a range of graduate attributes such as teamwork, communication, problem-solving, self directed learning, negotiation and conflict resolution skills in parallel with the development of skills in applying mathematics and engineering science. However, when planning began for the curriculum change, there was little evidence in the research literature to support the implementation of PBL for distance students working in virtual teams with no face-to-face contact.

In this paper we describe the implementation strategy and our effectiveness in delivering the core objectives of the foundational problem solving course in this strand. We attempt to show that the careful integration of PBL into the curriculum turned the disadvantage of diversity into an advantage for student learning. It has also proved a useful tool in supporting the transition to university for both school leavers and mature age students.

Course Implementation

The first stage we took in providing a transition mechanism for students from multiple backgrounds into engineering programs was to develop the course ENG1101 Engineering Problem Solving 1 to meet the following multiple objectives:

- To provide students with a general “feel” for the engineering profession during their first year of study;
- To reduce unacceptable attrition rates from a previously traditional foundation year based on the didactic teaching paradigm;

- To enable students to work as part of the engineering team, drawing on the strengths and experience of other engineering based professionals and para-professionals and team members;
- To provide students with the confidence to learn and to adapt to novel problem situations;
- To provide students with some basic factual knowledge in engineering science, and the skills to quickly extend this knowledge base.

Most of these objectives are the subject of ongoing discussion within the global engineering profession. Employers are increasingly dissatisfied with graduates who are not “job ready” and see the need for additional training as a weakness. Furthermore, recent literature is pointing to the need for graduates to expand general teamwork skills to include 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 (National Academy of Engineering 2004; Thoben & Schwesig, 2002).

The developmental team decided that the objectives could be best met using a PBL approach. The resulting course was delivered by a team of academics under the leadership of a single Examiner (Course Coordinator). The academic staff served as facilitators for teams of up to eight students. It was recognised that the team size was greater than that recommended in the literature, but resource limitations made this size necessary. For the same reason, most facilitators had to work with at least eight student teams (both on-campus and distance) at the one time.

Distance students were formed into “virtual teams.” These teams made extensive use of email and electronic chat rooms to hold virtual meetings, and sometimes asynchronous meetings using discussion forums when members worked across different time zones or had different study patterns. On-campus students were able to use traditional face-to-face methods of teamwork, employing meetings during the week in timetabled classrooms and the use of the university library. Our research showed that these on-campus teams utilised the flexibility offered by *virtual teamwork* and the available online resources, at the same level as did the distance teams (Brodie, 2006; Brodie & Gibbings, 2007).

The university library has considerable online resources available to students, including journals, databases and search engines, and these were extensively used by the student teams. All teams were given the same tasks and projects, and negotiated team roles in accordance with individual learning objectives which were set as part of the individual assessment items.

Assessment in the course has evolved over time. It is now based on the submission of three team projects to be completed in a 15 week teaching semester, plus three individual reflective portfolios of learning (Gibbings & Brodie, 2008). The projects were designed as open-ended problems, carefully crafted to lead the students to meet the course objectives. Each successive project requires more independent work from the student team and less assistance from the facilitator. Each one allows the students to draw on their previous life experiences and to assist each other with their learning.

Students negotiated project tasks based on prior knowledge and experience. In this way they were able to assist their other team members. There is evidence in the

portfolios that considerable peer-assisted learning took place, especially in the more successful teams.

On-campus and distance teams have faced different difficulties in facilitating peer learning. On-campus teams could meet face-to-face, but they did not have the diversity of age and engineering work experience prevalent in distance teams. They were, however, more up-to-date in their computer knowledge. General computer knowledge (email, chat, file management and word processing) and keyboard skills are particularly useful in the course. Distance teams had more engineering or technical knowledge but many distance students have lacked skills in or are nervous about using communication technologies, e.g., Windows Live Messenger.

In contrast, distance teams have always shown considerable diversity in education background, age and relevant work experience. Their difficulty has lain in skill limitations for facilitating and monitoring peer-assisted learning by electronic communication using chat rooms, electronic discussion boards and team Wiki pages.

However, a remarkable major outcome was that distance team members reported more peer-assisted learning than did on-campus teams despite their distance and communication difficulties. This finding was validated by a thematic analysis of reflective portfolios. During the initial course delivery period, some success was noted in this area, but it was also a frequent observation by course facilitators that similar tasks were undertaken in each project by the same student: For example those that knew how to use and have access to a specialist CAD package would always elect to do the technical drawings. Of course, this is true of 'real-life' teams where a specialist does tend to stick to a particular area of expertise, but peer-assisted learning is a valuable asset in cooperative and collaborative learning and we did not want it to be inhibited by such specialisation. The problem has been minimised in more recent offers by a task schedule attached to the beginning of each project, which shows the teams that academics are monitoring participation and allotment of tasks in the team. Also, progress towards individual learning goals is evaluated through the reflective portfolios.

The portfolios are used as the major assessment item and students are now asked to assess and evaluate their prior knowledge and experience with respect to the course aims and objectives. Students have been asked to identify at least five individual learning goals which they will achieve during the semester. They had to plan how these goals would be met and demonstrate the achievement of these tasks in either their portfolio or team projects (via a task schedule) during the course of the semester. These individual learning goals were then discussed with their team to identify synergies and help match prior knowledge to individual learning goals of team members. Evidence of peer mentoring within became part of the 'team reflection' which was completed for each project and teams were rewarded for this via the assessment criteria.

To assist with both learning and the meeting of course outcomes, a variety of resources were provided to students. A course home page was used to deliver the projects on the Web, together with late news on the course and many links to online learning resources. This was a novel departure from our traditional distance student study package format which is print based. A printed 'Resource Book' was provided to supplement those students who may not have regular and easy access to any form of library (community or professional).

This Resource Book contains a wide range of information which students can use as they wish. It contains information on connecting to the Internet, word-processing and spread-sheeting as well as technical information to support the projects. Considerable care was taken when producing the Resource Book. Where possible, technical information was supplied from generic sources rather than engineering text books. For example, one project dealt with temperature and heat. Information relating to this topic was taken from a medical/nursing text which covered the topics of radiation, convection and conduction but from an entirely different perspective to what an engineering student would normally associate with these technical terms. Students had to learn to apply knowledge, not just learn the facts.

The different topics covered by the projects again draw on the diversity and the use of prior knowledge within the teams. Project topics have covered a wide variety of areas over the years and allowed students to source information from unusual sources and so reveal the diverse background of many of our distance students. For example one project was framed around the ‘new car smell’ – *“I know something about this as my dad is a car salesman”* (Comment from student communication log); another forensic project dealt with the death of a baby locked in a car – *“I really felt my medical background, (I’m a nurse) would help me [to] contribute significantly to this project”* (Comment from student portfolio).

Methodology

Methods of evaluation have included anonymous evaluation surveys, completed online at the end of each semester. These results have been compared with student reflections in their portfolios, unprompted student communications with academics and to a smaller extent informal communication with employers. Additional data were gained from the student use of the Learning Management System (LMS) which hosts the team discussion forums, chat rooms, and electronic submission of assessment items. These data included number, frequency and content of student postings, hours of student interaction on the LMS and edits to the student Wiki pages. This LMS data were specific to each semester of offer, but generalisations and trends can be predicted.

The surveys covered three main areas or topics

- student learning – this tested the students’ own perceptions of their skills and learning in areas such as teamwork, communication and problem solving;
- course – this was a modified version of the standard university feedback survey delivered to all students in all courses. It included questions relating to the course materials, support and assessment;
- facilitator – again this survey was modified from the standard university survey to suit the course pedagogy and related to the standard of support offered by the facilitator in helping students meet individual and team goals.

Space limitations in this paper prevent a full discussion of the results of the three surveys and the data presented here are based on a subset of questions from the student learning survey.

These responses have been validated by a thematic analysis of reflective portfolios. Unprompted reflections were categorised into three main themes: technical and academic (includes problem solving strategy and application or understanding of technical theory), social and group (includes teamwork, conflict resolution, peer learning etc.) and individual components (learning style, barriers to learning etc.).

Results

Results from the student learning survey from eight course offerings (858 respondents with an average response rate of 62.3%) showed that 68.6% of the student cohort were already in full-time employment during their studies. 27% of the respondents were studying on-campus while the remainder were located at a distance from the university (5% of respondents did not answer this question).

Most respondents were based in Australia, although 2% were from Africa and 4% were from Asia. This, however, is not a clear representation of the ethnic diversity of the class as the survey referred to ‘citizenship’ rather than ethnicity.

The surveyed age profile is shown in Figure 2. It shows that while the majority of students were still less than 25 years old, 49% were older. Examination of enrolment data suggests that only approximately 12% of our student cohort consisted of direct school leavers (criterion was a maximum of one year in paid employment, i.e., aged 17, 18 or 19 years). The number of older students reflects the high proportion of our students in paid employment, either studying part-time or returning to study.

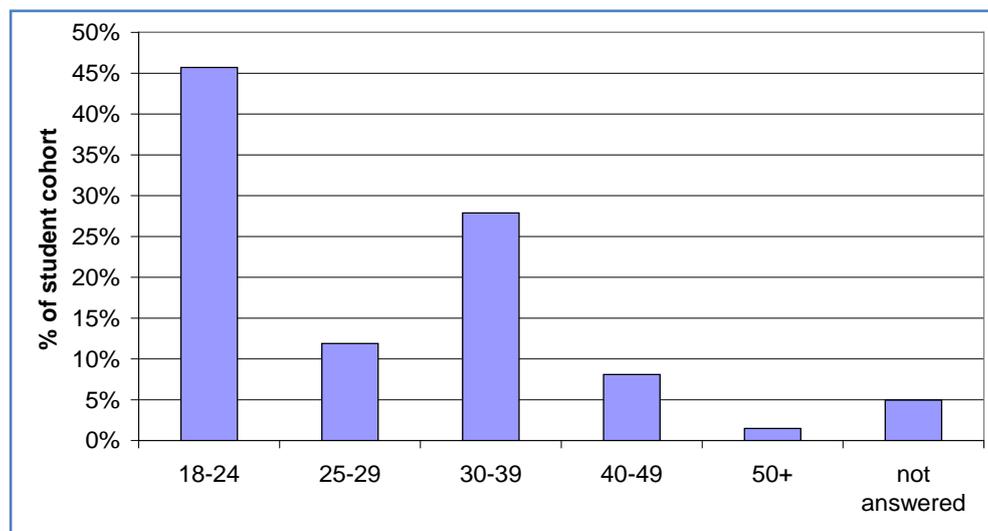


Figure 2 Profile of Student Age

We also found that 41% of the students were studying in the professional, four-year Bachelor of Engineering/Spatial Science Degree program as shown in Figure 3. The remaining students were studying in the para-professional two-year Associate Degree and three-year Bachelor of Engineering Technology programs. However, the relatively high numbers of students studying the two year Associate Degree has been a recent phenomenon with enrolments (as a percentage of total) up from 16% in 2002. Students were represented from all nine major disciplines although these are collapsed into the five groups for purposes of comparison as shown in Figure 4.

Each major (electrical and electronic; computer systems; mechanical and mechatronic; surveying and GIS; agricultural and environmental; civil) and program has different required outcomes with respect to student learning. The differences in these requirements present a further layer of diversity that must be addressed in the curriculum. The curriculum of the course ENG1101 Engineering Problem Solving 1 was designed to take students with a range of backgrounds and prior knowledge, a range of academic ability, undertaking a range of career paths and prepare them with attributes required by the professional accreditation bodies and the university system.

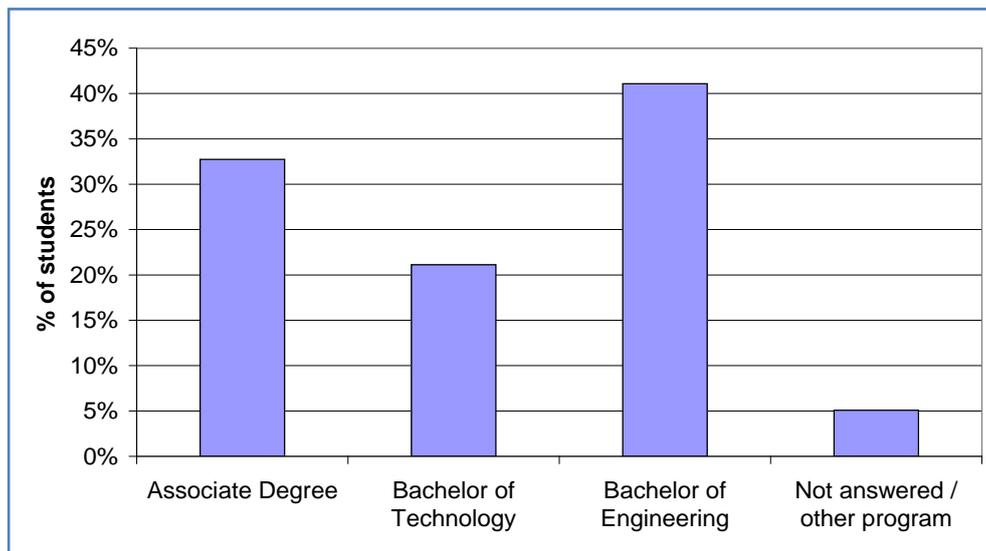


Figure 3 Profile of Students in engineering programs at USQ

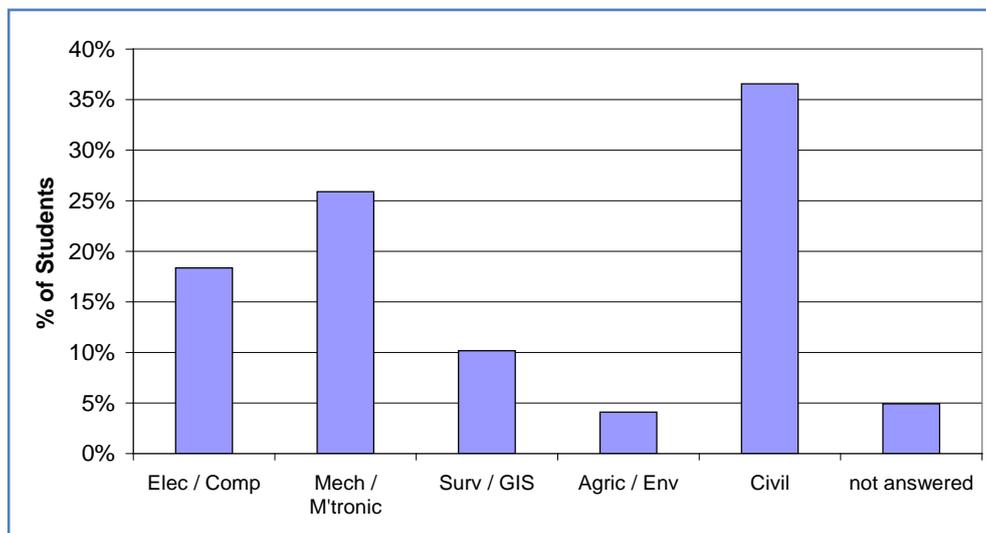


Figure 4 Profile of Students in engineering majors at USQ

The PBL-based course ENG1101 Engineering Problem Solving 1 at USQ continues to evolve and develop with each course offering. Its success has been greater than the developmental team initially expected. While some students initially disliked this form of learning, and preferred a lecture and formal tutorial format, the majority were very positive in their response to the course based on the feedback from their submitted portfolios as demonstrated from the following comment from the student evaluation surveys:

Through real projects and virtual teamwork, this course highlights essential attributes that engineering students require so as to learn and adapt to the ever-changing environment that today's engineers must interface with. Individually, ENG1101 has given me the opportunity to evaluate my abilities and assess areas for personal growth. More importantly, it has given me confidence in knowing that engineering is for me.

Figure 5 shows that only 27% of students retained a preference for lecturing as the main mechanism for presenting course material. Another 30% had no opinion on this matter, leaving 44% of engineering students who indicated a preference for PBL. This result has changed significantly over the seven years the course has been offered. Results from the first year of implementation (two offerings) showed 43% of students (113 respondents from 444 students enrolled) retained a preference for lectures and traditional study notes as the main mode for learning. It was possible that a dislike of teamwork and the lack of a suitable electronic delivery platform (Learning Management System) influenced this result. Staff facilitators in the course also suggested that the increased workload was a significant factor, and weaker students who would normally not start studying in earnest until several weeks into the semester were particularly against this form of learning because peer pressure forces them to contribute from the start of the semester.

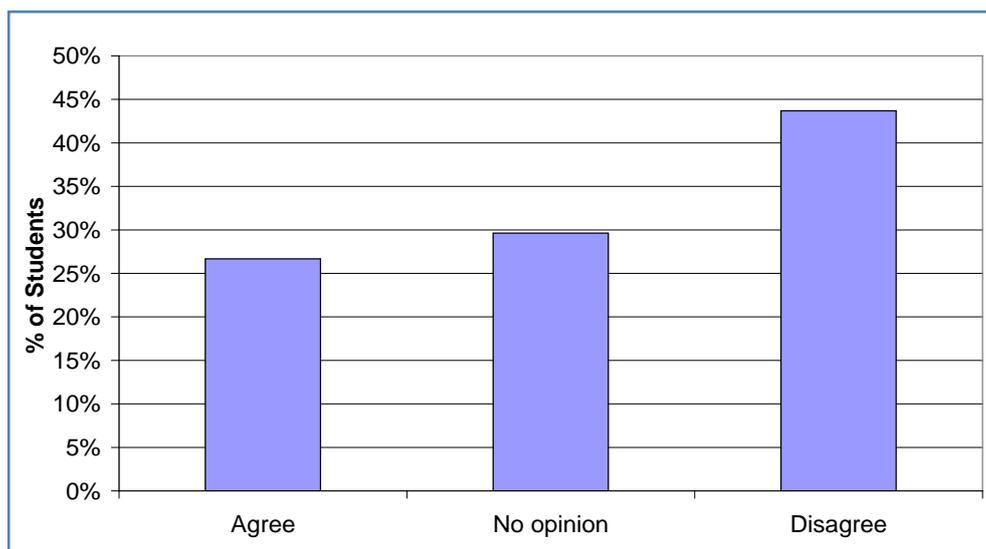


Figure 1 Student response on preference of lecturing for course delivery

Figure 6 shows a more general response from all the students to the statement that their knowledge learnt in the course was not retained as well as that learnt in traditional courses. Initially, in 2002 the results were fairly evenly distributed with 43% of students disagreeing with the statement and so supporting a PBL approach. Almost one quarter of respondents (23%) had no opinion on this option. By 2008, with continuous improvement in the course design, staff training in facilitating teams and changes to assessment there had been a significant shift in student opinion with 56% of students disagreeing with the statement and therefore supporting the PBL approach. These results suggest that the learning of basic facts involving engineering science can be at least as effective in the PBL courses as it is in other didactic courses and offers many other advantages for student learning and transitioning to university.

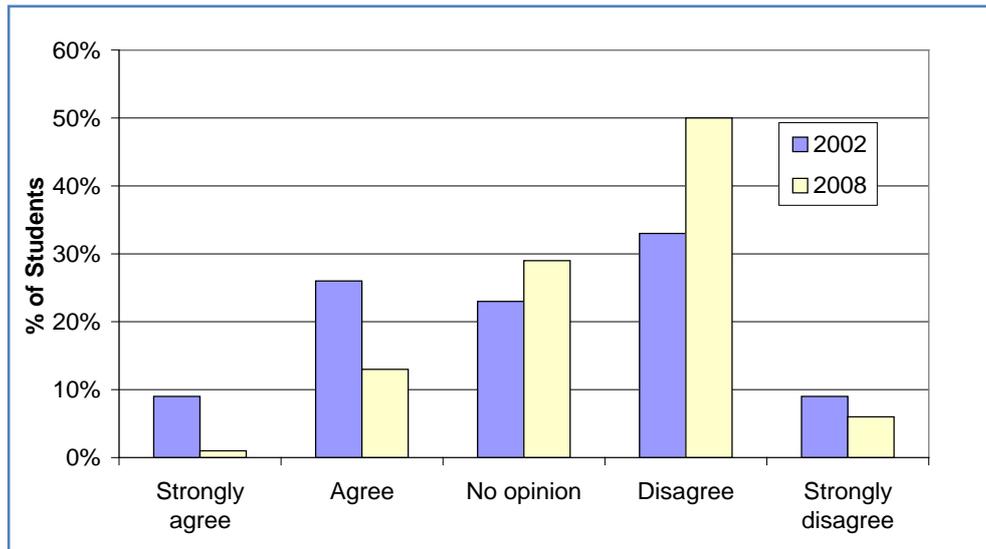


Figure 2 Student response to retention of knowledge being less than in Traditional subjects

The success of our course is further supported by Figures 7 to 9. Figure 7 shows that in 2008 55% of students thought that the PBL course had increased their ability to learn, with 26% unsure of this effect, but again there was a significant improvement in student self perceptions from 2002. Figure 8 further indicates that student confidence in their ability to independently learn new concepts was also increased. 66% of respondents either agreed or strongly agreed with this question and 17% were undecided.

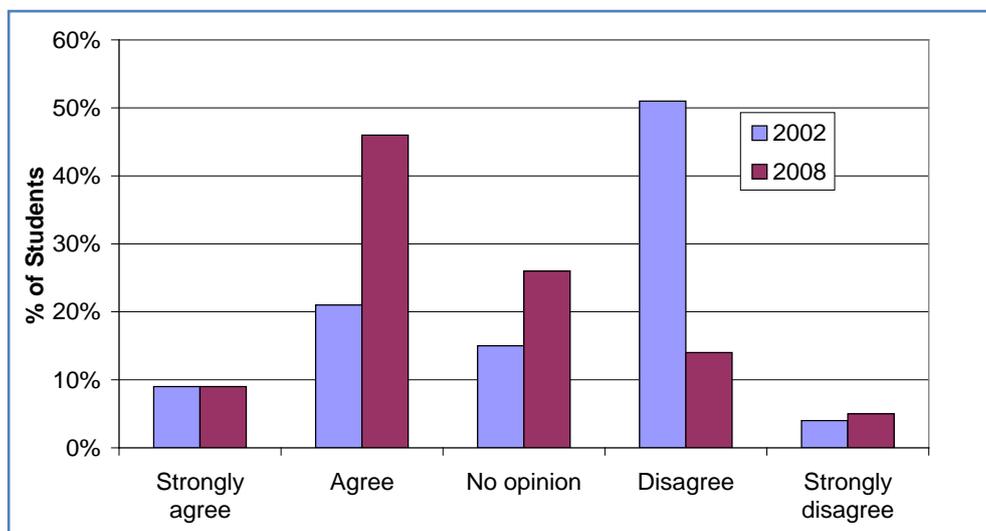


Figure 7 Student response to the course increasing learning ability

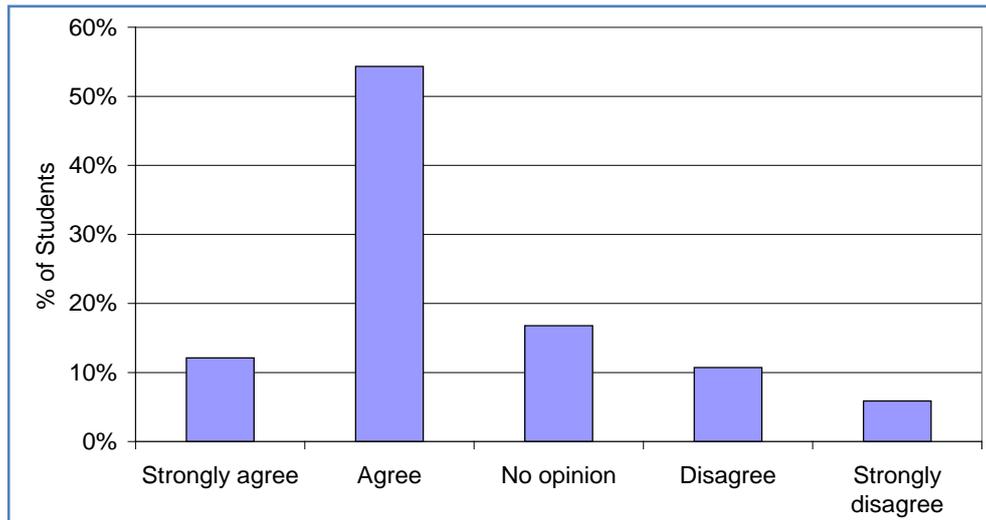


Figure 8 Student response to the course increasing their ability to undertake independent learning

Of even greater interest to the research team was the survey response to questions relating to key course objectives of enhanced problem solving skills and the effective use of prior knowledge in solving problems. Figure 9 shows that the vast majority of students thought these objectives had been achieved. 71% and 79% of respondents, respectively, either agreed or strongly agreed with these propositions. Only 14% and 13% were unsure of the effect.

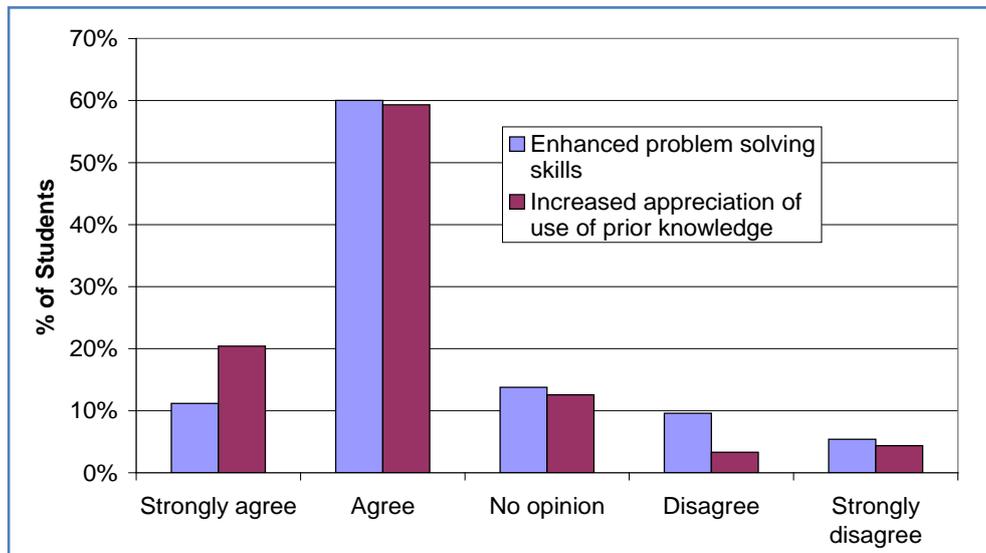


Figure 9 Student response to the PBL course enhancing their problem solving skills and increasing their appreciation of prior knowledge in solving problems

The student portfolios 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 realise that their learning experience has been significantly deeper through this course than it has in other traditionally taught courses.

An unforeseen benefit of the course was its ability to help students transition to study by engaging them in an environment where they can meet fellow students. This has been acknowledged by on-campus and distance students equally.

For on-campus students, this course is undertaken in semester 1 and their first formal ‘lecture’ at university is an introductory session for these team-based activities. Students are placed in their team and a session of ‘icebreaking’ and problem solving activities is undertaken. The teams comprise all programs and majors (i.e., Associate Degree, Bachelor of Engineering etc.; within electrical, civil, mechanical etc.) thus allowing students to meet other students of the faculty who they may not normally see in their daily routine at university.

For distance students, studying can sometimes be a lonely and isolating experience. There is often little opportunity to meet other students studying even the same course much less a mixture of students from the same faculty. Figure 10 gives the student responses to the question that the course helped them to meet other students. 83% of students agree with this statement. This is further validated by written comments in the survey instrument under ‘the best aspect of the course’ and also in student portfolios.

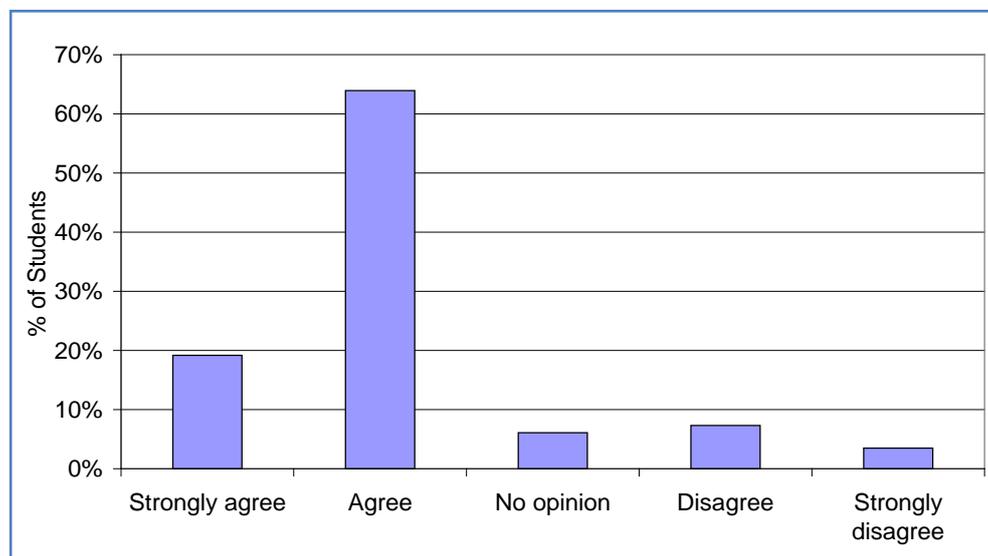


Figure 10 Student response to the PBL course helped them to meet other students

This social aspect of the course should not be underestimated in its benefit to student retention. Developing a social network and supportive peer group are known to be significant factors in retaining students at university (Aitken, 1982; Tresman, 2002).

Conclusion

We conclude that the careful integration of PBL courses into the engineering curriculum has turned a growing problem of student diversity to advantage. It has helped to ensure that students with diverse educational backgrounds transition to formal study by ensuring they have the opportunity to develop a social network and a better awareness of their own ability to learn, learn independently and acknowledge that they already bring significant skills and knowledge with them to university.

Co-operative and collaborative learning, through a PBL paradigm can be successfully integrated into a curriculum and offered to students studying in alternative modes (i.e., not full time, on-campus). Indeed, this diversity can add significantly to the team experience. Peer-assisted learning when encouraged and supported by both curriculum design and assessment is extremely useful. Students gain from the experience and staff are offered the opportunity to facilitate student learning, not just deliver content:

There were many advantages of being placed in a group of unfamiliar people. Each of our members had different backgrounds allowing us to share skills and knowledge. Encouraging poorly contributing members tested and instilled the motivator traits in all members. The number of problems to be solved within the limited time ensured students' time management skill were revisited and enhanced. The variety of problem settings gave reason for students to familiarize themselves with engineering terms and scenarios that may be advantageous in future professional life. Completion of reflective writing task[s] strengthened the meaning of each experience allowing students to truly reflect and learn from the course.
(Comment from Student Portfolio)

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