UNIVERSITY OF SOUTHERN QUEENSLAND

Faculty of Engineering and Surveying

Problem Based Learning for teams working in virtual space

A Dissertation Submitted by

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For the Award of

Engineering Doctorate

2010

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Abstract

Australia is facing a critical shortage of engineers at all levels of the profession – associates, technologists and professional engineers. Universities face three main challenges in responding to this predicted shortfall: the impact of technology and the information revolution both on higher education and the profession, the increasing diversity and choices of the student population, and the changing requirements of governments, professional accreditation agencies, industry and society.

Over the last decade, universities have implemented recommendations from accrediting agencies to demonstrate the competencies of graduates in a broad range of key graduate attributes such as teamwork, communication and problem solving, as well as lifelong and self-directed learning. Universities have also strived to open the access pathways to higher education, granting entrance to more students with a wider range of educational backgrounds and ages and who are looking for flexible study patterns, that is, something other than full time on-campus. This trend is likely to continue in the future. Whilst the efforts of universities have resulted in changes to curricula and teaching methodologies, technology and the global economy is beginning to demand, if not new skills, then extensions of the current graduate attributes: working in a multicultural environment; working in interdisciplinary, multi–skilled teams; sharing of work tasks on a global and around–the–clock basis; working with digital communication tools and working in a virtual environment. These attributes are difficult to attain through traditional, didactic educational programs.

The intent of this dissertation is to document the design, implementation and evaluation of an innovative curriculum strategy to respond to these demands. Problem Based Learning (PBL) meets the demands of the profession with respect to technical content and key graduate attributes. The addition of virtual teams[1], students working in a team in virtual space with no face–to–face contact, is original and meets future demands of the profession and changes in the higher education sector. The research spans several broad areas including student teams working in

[1] Virtual team is a term used in the literature to describe a team working in virtual space, communicating via electronic communication technologies. A full definition is given on page 36.

distance education, engineering education, assessment, staff professional development and problem based learning. It takes an overarching view and develops, through an action research methodology, a model of how to deliver PBL to students studying by distance education and in particular for delivery to a large and diverse student cohort.

The research process identified five key areas for successful delivery of course content, both technical knowledge and graduate attributes, to meet student learning outcomes and requirements. These areas include: staff training and changing staff attitudes, curriculum development beginning with basics of team development, individual learning goals, communication skills, development of a 'learning community' among the students and staff, reflection and reflective practice and effective assessment in line with course objectives.

The dissertation presents a case study of successful design and implementation. Evaluation and confirmation of the strategy has been evidenced by a significant contribution to the current body of knowledge through peer reviewed publications, national awards and the uptake of the concepts and resources by other institutions and academics.

The research findings reported in this dissertation has demonstrated that PBL is successful in delivering key graduate attributes to students working entirely in virtual space. This has application in responding to the demands for flexible education initiatives and the global engineering workplace.

Certification of Dissertation

I certify that the ideas, experimental work, results, analyses and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

Signature of Candidate   Date

Endorsement

Signature of Principal Supervisor   Date

Acknowledgements

I am greatly indebted to many colleagues and friends for their support, guidance and encouragement over the course of this project, its phases and documentation.

Firstly, thanks to my supervisors Professor Frank Bullen and Professor David Dowling for their excellent contributions and guidance.

Associate Professor Nigel Hancock, Sandra Cochrane and Patrick Danaher provided much support with proof reading.

Many colleagues have been part of the staff team, which implemented and trialled strategies and I am very grateful for their cooperation. Special thanks go to Ron Ayers, Chris Snook, Peter Gibbings, John Worden, Mark Porter and Rod Smith. These colleagues provided inspiration and motivation over many years in the quest to take the Faculty over the rough road to believing in PBL.

Lastly, thanks must go to my family, Ian, Ellen and Megan for always being there and always giving me the encouragement I needed.

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Summary of Innovations and Original Contributions

The principal innovation in this work is the integration of four separate areas within the Scholarship of Teaching and Learning, areas which have hitherto been essentially separate. These are Problem Based Learning, reflective practice in engineering education, distance education and virtual teams. The work presented in this dissertation advances some topics and then sets out a unification in the form of a single practical package. The unification also encompasses authentic assessment, community of practice, appropriate staff training and evaluation appropriate to the context. With this unification there have been contributions to the body of knowledge through peer reviewed publications and an uptake of materials developed by the author through the course of this project.

In 2000, when the work underpinning the dissertation began, there were no publications relating to student teams using Problem Based Learning when the teams were constrained to working *entirely* in virtual space. For practical reasons these teams could use only asynchronous (on–line) communication methods (i.e. not the telephone) and had no opportunity to meet face–to–face. Development of the program and support material has continued, making use of and evaluating new technologies and approaches (e.g. wikis) as they have become readily available. Recognition of student requirements, backgrounds and varying personal access to technology remains critical.

This work has the potential to create truly global engineering graduates by linking students across the world working in virtual teams and sharing tasks on an around–the–clock basis: a requirement for engineering graduates which is just emerging in the engineering education literature.

Developing, supporting and assessing teamwork skills in students have traditionally been problematic, particularly in engineering education when the priority has always been on ‘technical content’. However with the increasing emphasis on graduate attributes in engineering education (for example teamwork and communication), an increasingly diverse student cohort and the uptake of technology to deliver learning outcomes, teamwork and more importantly student learning about and through teams has taken on new dimensions. A major outcome of this dissertation is the proposal of a model, illustrated in Figure I and discussed in detail in Chapter 6, which describes the interactions and barriers to student learning when confronted with the mix of teamwork and technology. Whilst this model was developed and tested for teams working in virtual space, it applies equally well to traditional on–campus teams and provides a structure for curriculum development for team and collaborative learning projects to maximise student learning and minimise the pitfalls and frustrations encountered by academics and students alike.

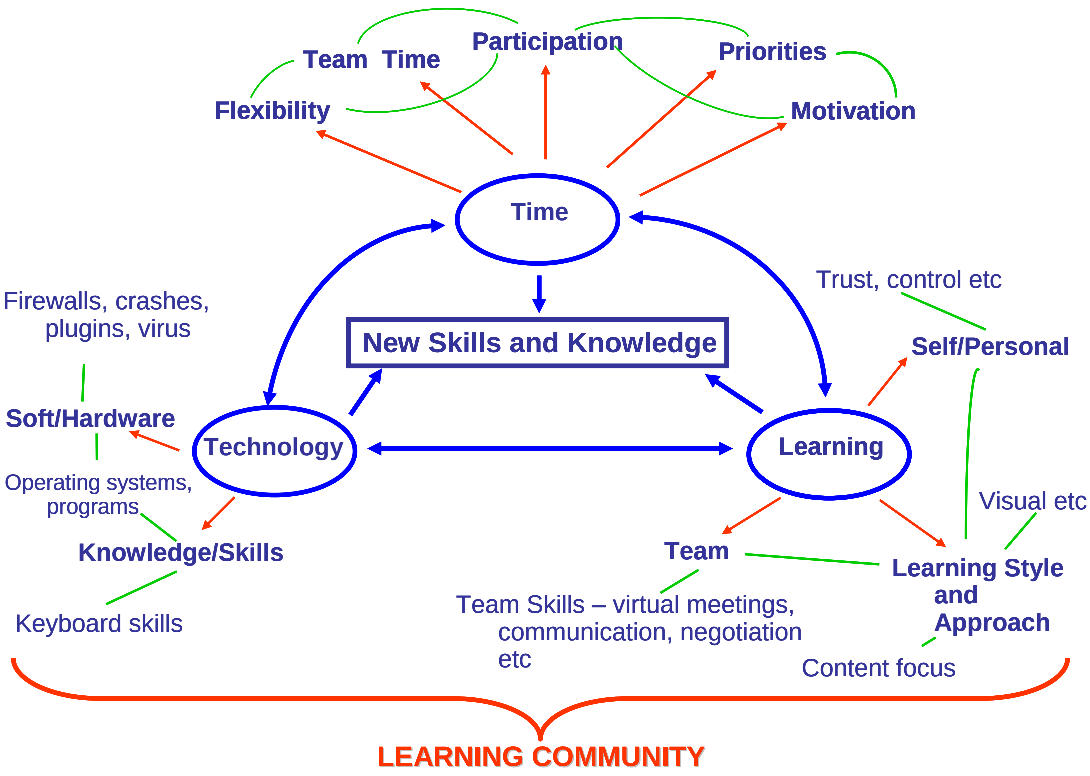

Figure I Barriers to student participation in teams

It is vital to effectively incorporate key graduate attributes into the engineering curriculum, a fact recognised by educators and industry alike. Outcomes of this work presents not only a development which supports curriculum change and effective delivery of both technical content and graduate attributes but looks to the future to ensure the education of engineers with skills to meet the challenges which lay ahead.

Recognition of Innovation

The work represented in this dissertation has been reviewed and its merit recognised by several external bodies in the form of university and national award as listed following. These awards are team awards as they recognise the *implementation* of the innovation and hence work of the teaching team. The major innovations and core development of the package are that of the author except where noted in the dissertation.

Awards

2008 Australasian Association for Engineering Education – Innovation in Curricula, Learning and Teaching "*Engineering Problem Based Learning Strand"* (Team Leader)

2007 Carrick Award for Australian University Teaching (now Australian Learning and Teaching Council ALTC) – Innovation in Curricula, Learning and Teaching "*Engineering Problem Based Learning Strand"* (Team Leader)

2006 Carrick Institute Citation (now ALTC) –"*Educating Engineers for the 21st Century – Successfully designing and delivering the world's first Problem–Based Learning course for distance engineering students*" (Team Leader)

2005 Finalist in Australian Awards for University Teaching (AAUT) Enhancement of the Quality of Teaching and Learning, Institutional Awards Category, "Educating Engineers and Surveyors for the 21st Century" (Team Leader)

2005 Australasian Association of Engineering Educators – Excellence in a Curriculum Team Project in Engineering Education (Team Leader)

2003 USQ Award for Excellence in Design and Delivery of Teaching Materials (Team Leader)

Use and Uptake of Materials

A number of course materials have been adopted by other courses.

Reflective Writing Guide:

- Used in CDS2002 Independent Project 1 from the Bachelor of Human Services program, Faculty of Business, USQ
- Used in Graduate Certificate in Tertiary Teaching and Learning, Faculty of Education, USQ
- Adapted for use in ENG8300 Self assessment portfolio from the Master of Engineering Practice program, Faculty of Engineering and Surveying, USQ
- Adapted for use in the OBL (Outcomes Based Learning) and Technology Enhanced Assessment Initiative at the Centre for Learning, Teaching and Technology (LTTC), The Hong Kong Institute of Education, Hong Kong

Peer and Self Assessment Resources:

- Used in ACC3101 Accounting Information Systems, Faculty of Business, USQ

All course materials have been reviewed and used, with acknowledgement, for the:

- 2008 ALTC Competitive Grant – "Business education in the 21st century: Examining the antecedents and consequences of student team virtuality (2008)"
- EDO3562 Teaching everyday science (Faculty of Education, University of Southern Queensland)

1 Introduction

Over a decade ago, Brisk (1997) stated in a paper sharing his views on engineering education for 2010 that, "*…engineering education must fully exploit telecommunications and information technology to improve teaching and learning…"* and that "*…engineering educators will move from simply passing on knowledge to becoming facilitators for students' learning…*" He also believed that engineering education should exploit technology to provide distance education services that achieve an improved use of resources and self paced learning. It is now timely to ask, are these improvements being realized, and how far has engineering education progressed in achieving the goals espoused more than a decade ago (Brodie & Porter 2008; Brodie 2009b).

In the early part of this decade, engineering accreditation bodies worldwide reviewed their national guidelines for engineering education to determine whether universities were actually delivering graduates ready for employment and, more importantly, able to cope with the future requirements of the profession. These reviews resulted in a refocusing of the engineering curriculum to *outcomes* rather than *process.* The reviews also recognised the need for the inclusion of the key graduate attributes of teamwork, problem solving, communication and lifelong learning within the curriculum (IEEE 1996; IEAUST 1999; Engineering Council UK (EC UK) 2003; Engineers Australia 2004; ABET 2007). Today, the recommendations of these reviews have been implemented and as well as addressing the traditional math, science and engineering fundamentals, and discipline specific knowledge, faculties must also *demonstrate* graduate acquisition of a broad range of key graduate attributes (Felder et al. 2000). Graduate attributes from Engineers Australia and ABET are listed in Table 1-1 as being typical for those specified by accrediting bodies worldwide. The table attempts to bracket like attributes from these two bodies.

Table 1-1 Comparison of graduate attributes from Engineers Australia and ABET

Engineers Australia	ABET Criteria 2008–2009
1. Ability to apply knowledge of basic science and engineering fundamentals	(a) An ability to apply knowledge of mathematics, science, and engineering (k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
2. Ability to communicate effectively, not only with engineers but also with the community at large	(g) An ability to communicate effectively
3. In–depth technical competence in at least one engineering discipline	(b) An ability to design and conduct experiments, as well as to analyze and interpret data
4. Ability to undertake problem identification, formulation and solution	(e) An ability to identify, formulate, and solve engineering problems
5. Ability to utilise a systems approach to design and operational performance	(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
6. 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	(d) An ability to function in multidisciplinary teams
7. Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development 8. Understanding of the principles of sustainable design and development	(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (j) A knowledge of contemporary issues
9. Understanding of professional and ethical responsibilities and commitment to them	(f) An understanding of professional and ethical responsibility
10. Expectation of the need to undertake lifelong learning, and capacity to do so	(i) A recognition of the need for, and an ability to engage in life–long learning

This table illustrates the similarities between the graduate attributes prescribed by the two major accreditation agencies, as well as the need for engineers to develop more than just technical knowledge. A significant level of common attributes should exist, given that both agencies are signatories to the Washington Accord[2] (Brodie 2009b). Engineers now require a great depth and breadth of skills and knowledge and engineering educators must deliver an 'education' and not just training in a technical discipline. Engineering students and professionals require good communication and teamwork skills and an understanding of the fluid and dynamic global, social and cultural environments in which they work (Brodie & Porter 2004).

Whilst delivering these skills in a traditional setting may require new teaching methodologies and a changing role for academics, current literature also goes on to suggest that desirable graduate attributes should be expanded to include working globally in a multicultural environment; working in interdisciplinary, multi–skilled teams; sharing of work tasks on a global and around–the–clock basis; working with digital communication tools and working in a virtual environment (Thoben & Schwesig 2002; National Academy of Engineering 2004; Jamieson 2007a). If these skills are to be incorporated into engineering education in a meaningful way, it will require a significant change in teaching methodologies and technologies, and may hasten the incorporation of what is currently seen as innovative or even radical approaches to education.

Problem based learning, project based learning, cooperative learning and active learning are just some of the terms now populating engineering education literature. Each of these approaches uses a constructivist paradigm which, when correctly resourced and implemented, can deliver the more recently recognised valuable graduate attributes of communication, teamwork and problem solving. Currently none of these approaches fully utilise the broad spectrum of electronic communication technologies for delivery and as such have not successfully been incorporated in the pedagogy of online learning.

[2] *"The Washington Accord was signed in 1989. It is an agreement between the bodies responsible for accrediting professional engineering degree programs in each of the signatory countries. It recognizes the substantial equivalency of programs accredited by those bodies, and recommends that graduates of accredited programs in any of the signatory countries be recognized by the other countries as having met the academic requirements for entry to the practice of engineering. The Washington Accord covers professional engineering undergraduate degrees. The signatory countries of the Washington Accord are Australia, Canada, Ireland, Hong Kong, New Zealand, South Africa, United Kingdom, and the United States."* (http://www.washingtonaccord.org/wash_accord_faq.html accessed 24/8/04)

Thus to deliver the requirements of ‘virtual environments’ and electronic communication skills, technology such as discussion boards/forums, synchronous chat rooms, email and web 2.0 technologies (such as wiki) must be integrated into the delivery of meaningful content. Most importantly, these new delivery systems must cater to the individual learning style of students. The ever increasing existence and application of fast developing technologies therefore provides both opportunities and serious challenges to engineering and engineering educators (Shuman et al. 2002).

Many of these technologies are already being utilized by universities with varying degrees of success to supplement delivery of existing courses and to tap into the new market of distance and online education (Brodie 2006). Likewise, virtual teams and associated research are making their way into education literature. However, this still remains a recent trend and most, if not all, publications still refer to the need for face–to–face interaction to establish initial communication and trust before moving to a semi–virtual environment.

Curriculum revitalisation

In 2000, the Faculty of Engineering and Surveying (FoES) at the University of Southern Queensland (USQ) began planning for its Engineers Australia (EA) accreditation review. A curriculum design project was undertaken across all engineering disciplines to plan the incorporation of the new requirements for accreditation. These requirements placed an increased emphasis on graduate attributes such as teamwork, communication, problem–solving and life long learning (Dowling 2001b; Dowling 2001a).

The main project outcome was the development of a ‘strand’ of four integrated courses based on a problem based learning paradigm. The strand was designed to sequentially and progressively strengthen and extend the students’ teamwork and communication skills, as well as key technical knowledge, problem solving skills and analytical and independent learning skills. Four traditionally taught courses – Physics and Instrumentation; Data Analysis; Numerical Computing; and Computers in Engineering – where removed from the curriculum and replaced with the problem based learning (PBL) courses creatively called *Engineering Problem Solving 1, 2, 3* and *4* (Course codes ENG1101, ENG2102, ENG3103 and ENG4104).

The new curriculum design and delivery also had to cater for a diverse student cohort that had widely differing backgrounds in terms of existing skills, knowledge and experience. For example, the USQ cohort has approximately 20% on–campus students while the remaining 80% study by distance. The average student age is 35, with a 16 to 70 year age band. As a result, the students bring to their university studies a wide range of knowledge and work experience, often in engineering or a similar technical field. They have a wide range of technical knowledge and life skills that must be recognised and utilised within courses wherever possible.

Students are encouraged to set individual learning goals and to mentor team members by sharing their prior knowledge and skills. Students reflect on their own learning experiences, and evaluate the progress of the team as well as their own learning. This sets the foundation for their success in the strand.

The articulation and scaffolding that occurs within the strand seeks to ensure that the learning is reinforced and extended in both graduate attributes and key technical areas. The problems undertaken by the teams become increasingly complex and teams must acquire and apply appropriate technical knowledge to solve these problems. The technical, research, critical analysis and evaluation skills of individual students significantly improve during their progression through the strand while the emphasis on developing communication and teamwork fundamentals and the assessment of reflective writing has a decreasing emphasis. This articulation and scaffolding of the curriculum is shown in Figure 1-1.

There is strong consistency in assessment throughout the strand but still catering for individual course specifications and objectives. The assessment ranges from a focus individual and team reflections, to development of numerical and simulation solutions for a wide range of real–world engineering problems.

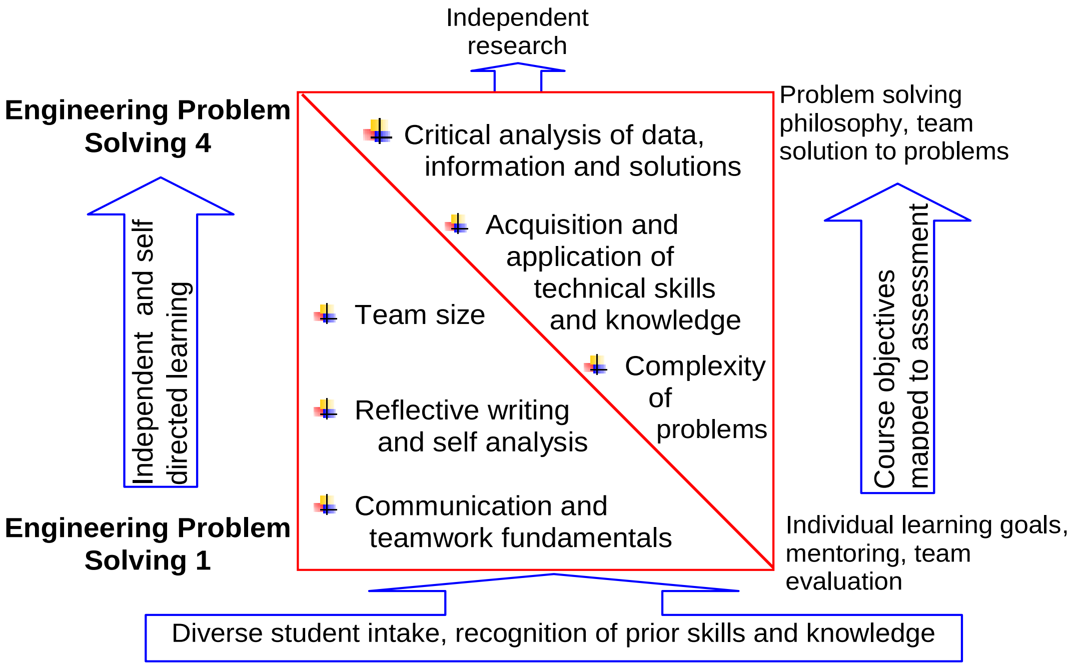

Figure 1-1 Scaffolding and articulation of the PBL courses in the Problem Solving Strand

The dissertation includes a description of the design, implementation, evaluation and continuous development of the first of the courses in this strand, ENG1101 *Engineering Problem Solving 1*. An innovative component and innovation of the course was to 'deliver' ENG1101 to students via virtual teams utilising a range of electronic communication systems whilst ensuring both technical content and graduate attributes are developed and attained. As this was the first course in the PBL strand offered to the student cohort, the course design, including communication strategies, curriculum, staff development, problem design strategies and requirements, became the model for subsequent courses.

While PBL is not new to higher education, its application to distance education with students working in virtual teams has been sparsely discussed in the literature. There have been numerous references to PBL for distance students in various disciplines, however in nearly every case these students or student teams are required to meet face–to–face at least once during the course and often team members work entirely in a face–to–face mode. Alternatively, the literature describes courses that are not true interpretations of PBL, but simply use some form of technology to deliver course content as outlined in Table 1-2.

Table 1-2 Examples of literature discussing PBL in a virtual environment

Author, Title	Notes
King & Mayall (2001). "Asynchronous Distributed Problem Based Learning"	Graduate course on educational psychology using PBL, no teamwork
Wilcznski & Jennings (2003) "Virtual Teams for Engineering Design"	Capstone course on engineering design, does not use PBL, on–campus students utilising electronic communication, document management etc
Miao (2000) "Supporting Self directed Learning Processes in a Virtual Collaborative Problem Based Learning Environment"	Four day course, "virtual collaborative" environment refers to use of electronic whiteboard and resource sharing software. Students work entirely face–to–face.
Paja et al (2005) "Platform for Virtual Problem–Based Learning in Control Engineering Education"	Not team based, PBL by presentation of all material in an electronic (virtual) media; remote labs
Kolmos et al (2006) "Design of a virtual PBL Learning environment – Master in Problem Based learning (MPBL)"	Extensive use of video conferencing which does not suit differing time zones; trial program; very small cohort of graduate education students; results of program are 'inconclusive'.

Typically, the literature on "distance PBL" refers to a course delivery process where students are either working away from the main campus on a satellite campus, or normal teamwork is supplemented by electronic communications with the lecturer, tutor or other team members (Brodie 2006). Wilczyski & Jennings (2003) note that "*…a general framework has not yet been presented to guide the formation and management of Internet–based design teams within engineering education*". Also, there is a distinct lack of published information on situated learning in virtual teams (Robey et al. 2000).

Thus, when the implementation of ENG1101 was commenced at USQ, PBL for virtual teams was largely undocumented and the academic team found itself at the forefront of a new and exciting research area. The successful design and implementation of PBL, and in particular PBL for virtual teams, in distance education hinges on a number of key and interrelated areas which will be discussed and explained later in the dissertation. The key areas are:

- Curriculum development beginning with the basics of team development, individual learning goals of a diverse student cohort, communication skills and other graduate attributes
- Development of a ‘learning community’ among the students and staff
- Effective support and scaffolding for virtual teams including *online* facilitation, often in an asynchronous mode
- Reflection and reflective practice
- Effective assessment in line with course objectives
- Staff training and the need to change staff and student attitudes to teaching and learning.

An investigation of PBL for distance education students working in virtual teams touches on many issues – PBL, engineering education, distance and online education, teamwork, virtual teams, assessment and staff development. Each of these is a broad and complex area of research in itself and a review of the literature shows the complexity of interaction and overlaps. This web of interactions is depicted via the concept map in Figure 1-2. Thus, each section of the dissertation forms part of a three dimensional jigsaw, which must be seen in the context of its application to a new area – PBL in virtual teams for engineering education.

The current literature can be categorised into the following broad areas:

- PBL and PBL in engineering education where PBL becomes a complete curriculum or PBL is seen a partial implementation in discrete courses within a whole program of study.
- Virtual ‘teams’ (teams working in virtual space) – working collaboratively ‘online’ but not necessarily as a ‘team’; Virtual teams in business or organisations.
- Online and distance education (but not using a PBL paradigm).
- Assessment of teams, teamwork and in PBL
- Staff training or professional development

Another large and relevant area for discussion is that of the current state of engineering education and the future requirements for graduates and hence the consequences for the institution in question.

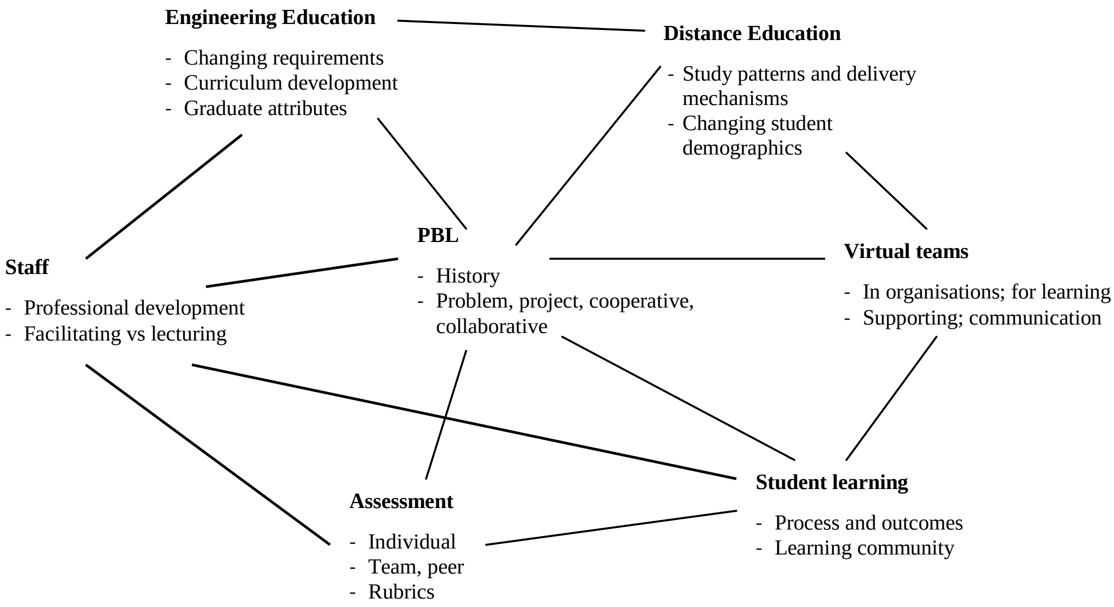

Figure 1-2 Concept map of major interactions and overlaps in distinct research areas

Very little literature combining all of these areas, especially at the undergraduate level and more specifically in engineering education was found.

The innovation of the work underpinning this dissertation is categorised by:

- Embedding key graduate attributes which meet not only current industry requirements, but that also target the future needs of the global industry
- No face–to–face contact between student team members and between students and the academic *facilitator*. Students work in true virtual teams, separated by time, geography and often a societal context
- High level of student interaction and engagement with learning objectives delivered via a PBL paradigm, with modifications to suit the student cohort
- Developing a learning community for both staff and students.

Analysis of data collected over several years, using anonymous student surveys, thematic analysis of reflective portfolios and discussion board postings, shows that key graduate attributes of teamwork, communication, self directed learning and problem solving can be achieved by using PBL in which students work in true virtual teams.

1.1 Organisation of Dissertation

This dissertation is the synthesis of a body of work which has been extensively peer reviewed and published (See section Publications directly related to the Award of Engineering Doctorate (EngD) on page 11). These publications are supported by other peer reviewed publications as listed on page 17. The dissertation is organised in 10 chapters as summarised below.

Chapter 1 Introduction and Overview: This chapter provides the overview for the dissertation. Where appropriate, all publications by the author have been cited in this chapter. This chapter also provides lists of publications directly related to, and supporting, the work of the dissertation. Papers are listed by topic and also arranged by year of publication.

Chapter 2 Literature Review: – This chapter summarises literature in each of the key topics. In some areas e.g. virtual teams, where there is extensive literature, only literature relevant to distance education or education has been selected.

All Brodie and Brodie et al publications which have been used in this dissertation have a literature review or background section relevant to the topic. Where appropriate, sections of these publications have been reused in this chapter.

Chapter 3 Education Requirement and Context: This chapter gives the rationale for curriculum change and its implementation at USQ. The actual implementation of the course was undertaken by a team of academics; however, the fundamental development, strategies for implementation and evaluation was the work of the author of this dissertation unless otherwise cited.

Chapter 4 Methodology: This dissertation is the compilation of numerous publications spanning several years. Each publication contributes to the body of knowledge on a particular area and has adopted a particular methodology depending on the area of investigation and the time the investigation was undertaken. The over arching methodology of the dissertation is one of Action Research and the chapter describes the development not only of the research into separate but interconnected fields, but also the growth of the author as a researcher, gaining knowledge, skills and experience in the field of engineering education.

Chapters 5 to 9: Summarises the related publications which directly support the work of this dissertation. The sources of publications are provided for reference. Research has been published (or is in press) by a number of international journals including the International Journal of Engineering Education (IJEE), European Journal of Engineering Education (EJEE) and the Australasian Journal of Engineering Education (AJEE) and national and international peer reviewed conferences.

Chapter 10 Conclusion: This final chapter summaries the achievements and outcomes of the work of the dissertation.

Appendix A: The appendix contains copies of selected publications.

1.2 List of Papers

For clarity, all publications are listed twice. Firstly arranged by topic to show the breadth of work and contributions to the body of knowledge in specific areas by the author and secondly, by year of publication to show the development of the research and research methodology over the period of the project.

1.2.1 Publications directly related to the Award of Engineering Doctorate (EngD)

Peer Reviewed Journal and Conference Publications – arranged by topic

PBL in Distance Education

Brodie, L. 2009, 'eProblem Based Learning – Problem Based Learning using virtual teams', *European Journal of Engineering Education*, vol. 34, no. 6, pp. 497-509.

Brodie, L. 2009, 'Transitions To First Year Engineering – Diversity As An Asset', *Studies in Learning, Evaluation, Innovation and Development* vol. 6, no. 2. pp 1-15

Brodie, L. & Porter, M. 2008, 'Engaging distance and on-campus students in Problem Based Learning', *European Journal of Engineering Education*, vol. 33, no. 4, pp. 433-443.

Brodie, L. & Porter M. 2006, 'Problem based learning for on-campus and distance education students in engineering and surveying', *Proceedings of The Internal Conference on Innovation, Good Practice and Research in Engineering Education*, vol. 1, eds Doyle S & Mannis A, The Higher Education Academy, Liverpool, England, pp. 244-255.

Virtual Teams and the use of a Learning Management System

Brodie, L. 2009, 'Virtual Teamwork and PBL - Barriers to Participation and Learning', paper presented to the *Research in Engineering Education Symposium (REES)*,20-23 Jul, Cairns, QLD, Australia.

Cochrane, S., Brodie, L. & Pendlebury, G. 2008, 'Successful use of a wiki to facilitate virtual team work in a problem-based learning environment', *AAEE*, Yeppoon, QLD.

Brodie, L. 2007, 'Problem Based Learning for Distance Education Students of Engineering and Surveying.', *Connected - International Conference on Design Education*, Sydney.

Brodie, L. 2006, 'Problem Based Learning In The Online Environment – Successfully Using Student Diversity and e-Education', *Internet Research 7.0: Internet Convergences*, Hilton Hotel, Brisbane, Qld, Australia,

Learning Community (Community of Practice)

Brodie, L. & Gibbings, P. in press, 'Connecting learners in Virtual Space – forming learning communities', in L. Abawi, J. Conway & R. Henderson (eds), *Creating Connections in Teaching and Learning*, Information Age Publishing.

Gibbings, P. & Brodie, L. 2008, 'Team-Based Learning Communities in Virtual Space', *International Journal of Engineering Education*, vol. 24, no. 6, pp. 1119-1129.

Brodie, L. & Gibbings, P.D. 2007, 'Developing Problem Based Learning Communities in Virtual Space', *Connected 2007 International Conference on Design Education*, University of New South Wales, Sydney, Australia.

Assessment

Brodie, L. & Gibbings, P. 2009, 'Comparison of PBL Assessment Rubrics', paper presented to the *Research in Engineering Education Symposium (REES)*,20-23 Jul, Cairns, QLD, Australia.

Brodie, L. 2008, 'Assessment strategy for virtual teams undertaking the EWB Challenge', paper presented to the *Australasian Association of Engineering Educators*, Yeppoon, QLD, 7-10 December 2008.

Gibbings, P. & Brodie, L. 2008, 'Assessment Strategy for an Engineering Problem Solving Course', *International Journal of Engineering Education*, vol. 24, no. 1, Part II, pp. 153-161.

Brodie, L. 2007, 'Reflective Writing By Distance Education Students In An Engineering Problem Based Learning Course', *Australasian Journal of Engineering Education*, vol. 13, no. 1, pp. 31-40.

Gibbings, P. & Brodie, L. 2006, 'Skills audit and competency assessment for engineering problem solving courses', *Proceedings of The Internal Conference on Innovation, Good Practice and Research in Engineering Education*, vol. 1, eds Doyle S & Mannis A, The Higher Education Academy, Liverpool, England, pp. 266-273.

Gibbings, P. & Brodie, L. 2006, 'An Assessment Strategy for a First Year Engineering Problem Solving Course', *17th Annual Conference of the Australasian Association for Engineering Education*, Australasian Association for Engineering Education, Auckland, New Zealand, p. 33.

Academic Staff Training and Professional Development

Brodie, L., Aravinthan, T., Worden, J. & Porter, M. 2006, 'Re-skilling Staff for Teaching in a Team Context.', *EE 2006 International Conference on Innovation,*

Good Practice and Research in Engineering Education, Liverpool, England, pp. 226-231.

Journal and Peer Reviewed Conference Publications – arranged by year of publication

2010

Brodie, L. & Gibbings, P. in press, 'Connecting learners in Virtual Space – forming learning communities', in L. Abawi, J. Conway & R. Henderson (eds), *Creating Connections in Teaching and Learning*, Information Age Publishing.

2009

Brodie, L. 2009, 'eProblem Based Learning – Problem Based Learning using virtual teams', *European Journal of Engineering Education*, vol. 34, no. 6, pp. 497-509.

Brodie, L. 2009, 'Transitions To First Year Engineering – Diversity As An Asset', *Studies in Learning, Evaluation, Innovation and Development* vol. 6, no. 2.pp 1-15

Brodie, L. 2009, 'Virtual Teamwork and PBL - Barriers to Participation and Learning', paper presented to the *Research in Engineering Education Symposium (REES)*,20-23 Jul,, Cairns, QLD, Australia.

Brodie, L. & Gibbings, P. 2009, 'Comparison of PBL Assessment Rubrics', paper presented to the *Research in Engineering Education Symposium (REES)*,20-23 Jul,, Cairns, QLD, Australia.

2008

Gibbings, P. & Brodie, L. 2008, 'Assessment Strategy for an Engineering Problem Solving Course', *International Journal of Engineering Education*, vol. 24, no. 1, Part II, pp. 153-161.

Brodie, L. & Porter, M. 2008, 'Engaging distance and on-campus students in Problem Based Learning', *European Journal of Engineering Education*, vol. 33, no. 4, pp. 433-443.

Brodie, L. 2008, 'Assessment strategy for virtual teams undertaking the EWB Challenge', paper presented to the *Australasian Association of Engineering Educators*, Yeppoon, QLD, 7-10 December 2008.

Gibbings, P. & Brodie, L. 2008, 'Team-Based Learning Communities in Virtual Space', *International Journal of Engineering Education*, vol. 24, no. 6, pp. 1119-1129.

Cochrane, S., Brodie, L. & Pendlebury, G. 2008, 'Successful use of a wiki to facilitate virtual team work in a problem-based learning environment', *AAEE*, Yeppoon, QLD.

2007

Brodie, L. 2007, 'Reflective Writing By Distance Education Students In An Engineering Problem Based Learning Course', *Australasian Journal of Engineering Education*, vol. 13, no. 1, pp. 31-40.

Brodie, L. 2007, 'Problem Based Learning for Distance Education Students of Engineering and Surveying.', *Connected 2007- International Conference on Design Education*, Sydney.

Brodie, L. & Gibbings, P.D. 2007, 'Developing Problem Based Learning Communities in Virtual Space', *Connected 2007 International Conference on Design Education*, University of New South Wales, Sydney, Australia.

2006

Brodie, L. 2006, 'Problem Based Learning In The Online Environment – Successfully Using Student Diversity and e-Education', *Internet Research 7.0: Internet Convergences*, Hilton Hotel, Brisbane, Qld, Australia,

Brodie, L. & Porter M. 2006, 'Problem based learning for on-campus and distance education students in engineering and surveying', *EE2006 International Conference on Innovation, Good Practice and Research in Engineering Education*, vol. 1, eds Doyle S & Mannis A, The Higher Education Academy, Liverpool, England, pp. 244-255.

Brodie, L., Aravinthan, T., Worden, J. & Porter, M. 2006, 'Re-skilling Staff for Teaching in a Team Context.', *EE 2006 International Conference on Innovation, Good Practice and Research in Engineering Education*, vol. 1, eds Doyle S & Mannis A, The Higher Education Academy, Liverpool, England, pp. 226-231.

Gibbings, P. & Brodie, L. 2006, 'Skills audit and competency assessment for engineering problem solving courses', *Proceedings of The Internal Conference on Innovation, Good Practice and Research in Engineering Education*, vol. 1, eds Doyle S & Mannis A, The Higher Education Academy, Liverpool, England, pp. 266-273.

Gibbings, P. & Brodie, L. 2006, 'An Assessment Strategy for a First Year Engineering Problem Solving Course', *17th Annual Conference of the Australasian Association for Engineering Education*, Australasian Association for Engineering Education, Auckland, New Zealand, p. 33.

1.2.2 Supporting Publications

Journal and Peer Reviewed Conference Publications — relevant publications supporting the innovations and research

Brodie, L & Loch, B. 2009, 'Annotations with a Tablet PC or typed feedback: does it make a difference?' In: *AaeE 2009: 20th Annual Conference for the Australasian Association for Engineering Education: Engineering the Curriculum*, 6–9 Dec 2009, Adelaide, Australia.

Brodie, L., Zhou, H. & Gibbons, A. 2008, 'Developing a Software Engineering Course using Problem Based Learning', *Engineering Education*, vol. 3, no. 1, pp. 2-12.

Sabburg J., Fahey P., Brodie L. 2006 'Physics Concepts: Engineering PBL at USQ. Australian Institute of Physics' *17th National Congress 2006*, Brisbane, Australia, 3–8 December 2006 p 1–4 (paper no 105) http://www.aip.org.au/Congress2006/136.pdf

Brodie, L.M. & Porter, M.A. 2005 ,'Responding To Changing Demands In Engineering Education – PBL For Distance And On–campus Students'. *The Higher Education Academy – Engineering Subject Centre* online at http://www.engsc.ac.uk/downloads/pbl_aus.pdf

Brodie, L. & Porter, M. 2004, 'Design, Implementation and Evaluation: an entry level Engineering Problem Solving course for on-campus and distance education students'. *5th Asia Pacific Conference on Problem Based Learning – Pursuit of Excellence in Education*, Petaling Jaya, Malaysia, 15–17 March, 2004

Wood, D. & Brodie, L. 2004, 'Student Perspectives on Engineering Problem Based Learning – The Portfolios'. *5th Asia Pacific Conference on Problem Based Learning – Pursuit of Excellence in Education*, Petaling Jaya, Malaysia, 15–17 March, 2004

Brodie, L. & Borch, O. 2004, 'Choosing PBL paradigms: Experience and methods of two universities', *Australasian Association of Engineering Educators Conference*, eds Snook C & Thorpe D, Faculty of Engineering and Surveying, USQ, Toowoomba, QLD, University of Southern Queensland, Toowoomba, Australia, pp. 213-223.

Brodie, L. & Porter, M. 2004, 'Experience in Engineering Problem Solving for On-campus and Distance Education Students', *Australasian Association of Engineering Educators Conference*, eds Snook C & Thorpe D, Faculty of Engineering and Surveying, USQ, Toowoomba, QLD, University of Southern Queensland, Toowoomba, Australia, pp. 318-323.

Brodie, L. & Porter, M. 2001, 'Delivering Problem Based Learning courses to engineers in on–campus and distance education modes'. *3rd Asia Pacific Conference on Problem Based Learning.* Yeppoon, 9–12 Dec.

Porter, M.A. & Brodie, L. 2001, 'Challenging tradition: Incorporating PBL in Engineering Courses at USQ'. *3rd Asia Pacific Conference on Problem Based Learning*, Yeppoon, 9–12 Dec.

2 Literature Overview

This chapter summarises the literature in each of the key topics as outlined in Figure 1-2. The chapter is in five main sections:

- PBL, engineering education and distance education
- Connections between engineering education, teamwork and teams work in virtual space
- Assessment practices for teams and PBL
- learning communities and the need and advantages of establishing them
- staff training and professional development.

In some areas e.g. virtual teams, where there is extensive literature, only literature relevant to distance education or education has been selected.

2.1 Problem Based Learning (PBL), Engineering Education & Distance Education

2.1.1 History of Problem Based Learning (PBL)

Most current literature points to McMaster University in Canada as beginning the implementation of (modern) PBL with the introduction of the methodology into its medical schools in the 1960's. Its intellectual history however, is much older (Brodie & Borch 2004). Thomas Corts of Samford University sees PBL as "…a newly recovered style of learning". He believes that "…it embraces the question–and–answer dialectical approach associated with Socrates as well as the Hegelian thesis–antithesis–synthesis dialectic" (Rhem 1998). In short, PBL is about student engagement in problem solving, active questioning, finding and *applying* information, all of which have been recognised as the keys to motivation and effective education for many generations. However, for some time universities have supported a 'coverage' model reflected in standard chalk and talk delivery of 'content' delivered to a class.

This transmission model, whilst giving economies of scale, is becoming difficult to justify and sustain for a number of reasons. First, there is a better understanding of the cognitive and metacognitive approaches to learning, especially in adults, and the recognition of the need for different approaches to knowledge transmission and acquisition. Second, is the 'information explosion' – with more information becoming more readily available. What students now require is a fundamental *understanding* of key content, ability to find information, evaluation and critiquing of this information; and its application to new and unique situations with intellectual rigor. Hence problem solving and a PBL approach have been "newly recovered" in the last two decades (Rhem 1998).

Rhem (1998) also suggests that PBL is successful because of, "The way the world works now, it's about working together. What students learn about collaboration, different approaches to a problem, cooperation and responsibility, makes their learning in PBL courses multisided, richer, and … deeper".

The educational and philosophical theories underpinning PBL were not explicit in early PBL literature (Newman et al. 2001; Rideout & Carpio 2001) and the pioneers of the McMaster program had no background in either education or psychology. They simply thought that learning in small teams, using authentic cases and problems, would make medical education more interesting and relevant for their students (Barrows 2000; Newman et al. 2001). This PBL methodology is now currently used in more than 80% of medical schools in the USA (Vernon & Blake 1993; Ribeiro & Mizukami 2005a) and is an entrenched component of medical school programs in Canada, the United Kingdom, the Middle East and Asia (Blight 1995; Finucane et al. 1998). In Australia, it was predicted that by the year 2000 more than 50% of Australia's doctors will have graduated from schools with PBL–based curricula (Finucane et al. 1998). This number has been more than exceeded with many of the largest medical schools in the country with large student intakes (e.g. University of Queensland, Sydney University, Monash University) moving to a PBL curriculum (Stephen & Paul 2000).

PBL has since been incorporated into a wide range of professional studies including nursing, dentistry, social work, management, engineering and architecture (Boud & Feletti 1997) and has spawned a plethora of educational terminologies with an almost unclassifiable array of categories (Barrows 2000).

The literature presently discusses Problem Based Learning, Project Based Learning, Inquiry Based Learning and Project Orientated Problem Based Learning among others as quasi separate themes. These are all used to describe a range of instructional strategies but with conceptual similarities. The common core is that all rely on open–ended scenarios, which have more than one approach or answer and stimulate student interest. Learning is defined as being *student centred* while the teacher or instructor takes on the role of *facilitator*. Students work in cooperative groups and individually and collectively seek and use multiple sources of information. Learning is active and self directed and key skills of problem solving, communicating and researching are fostered along with acquiring and transferring knowledge to novel or new situations. Formal teaching as such does not occur, but facilitators pay close attention to the *process* of enabling the students' autonomy and self direction in undertaking the problem or project. The importance that the group or 'team' brings to the mix is that of the additional inducement of peer collaboration, mentoring and peer assessment.

However, there are two main distinctions that can be made between project based and problem based learning. In problem based learning the overall goals and the problems are set by the teachers while the solution pathways are not. Project based learning requires the students to set their own learning objectives and decide on their own learning strategies. In addition, project based learning typically induces the goal of producing a product or artefact. Problems will be encountered which add to the learning experience, but these problems may or may not be solved. Projects reflect real–world practices and the *process* of producing the product is as valuable as the end result itself (Brodie 2008a).

The instructional strategies of problem and project based learning are widely considered to provide students with opportunities to develop skills in communication, collaboration, self direction and informed decision making. A number of contemporary studies and meta–analyses show that whilst learning remains consistent between traditional and project/problem based delivery, student motivation and experience is improved in PBL (Greening 1998; Thomas 2000; Newman et al. 2001; Newman).

The PBL strand at USQ, developed by the author, embraces elements of both problem and project based learning. Thus for the purpose of this dissertation PBL is defined as:

> *…a constructivist learning paradigm where small groups of students, engage in cooperative learning and collaborative problem solving to solve problems in complex and authentic projects. These projects pursue specified learning outcomes that are in line with academic standards and course objectives with assessment focusing, to a varying degree, on the project outcome versus team and individual process* (Brodie & Borch 2004; Brodie 2007a).

2.1.2 Theory of Problem Based Learning

> *In its original form, a PBL curriculum is delivered in a set of problems which provides the starting point for the learning process. Problem–based learning constitutes the backbone of such a curriculum. Other educational methods such as lectures and skills training are present, but only to support PBL* (Perrenet et al. 2000).

Traditional education tends to approach learning by presenting concepts in identifiable blocks, in a linear, or at least logical, sequence. Implicit in this approach is the belief that learning amounts to acquiring a set of ‘rules’ which much be practiced separately to be learnt and only then can be applied. The ‘practice’ relies on applying the rules to similar situations and with enough practice comes understanding and then the knowledge and rules can be applied to new or novel situations (Norman & Schmidt 2000).

Presenting students with the knowledge they need in a lecture format is efficient and relatively easy for both student and academic. It is a transmission model which presents the content to potentially large number of students at one time. However lecturing does not take into account the ability of the student to remember, reason and apply the knowledge even in a similar situation. In short, *learn* the content. Students may not appreciate later usefulness of the knowledge and in a lecture there is little concern for their future self–learning skills (Barrows 1984; Perrenet et al. 2000).

Educational psychology research of the last decade has shown that a "student is not an empty vessel waiting to be filled with new knowledge" and many traditional teaching practices resulted in surface learning (Sawyer 2006, pp. 2-5). In a traditional lecture situation it is the lecturer who is active – preparing and delivering material and the student who passively receives the content (Brodie & Borch 2004). However, productive and 'deep' learning is an active process. Students must engage with the material, deconstructing, constructing and reconstructing ideas and knowledge. PBL is an approach consistent with these needs.

PBL is based on the principles of adult education and cognitive psychology (Knowles 1990; Norman & Schmidt 1992). Barrows (1984) describes a cycle of three phases of PBL:

1. Students first encounter a problem, as opposed to a fact or theory. The problem is discussed and deconstructed usually in a small group setting.
2. The problem and discussion motivates the student to undertake self directed study and research framed by prior knowledge, understanding and gaps within these areas.
3. New knowledge is applied and learning summarised by reflection.

These steps may be repeated with a new problem, or an iterative approach to the initial problem may be used. Koshmann et al (1994) extended the three step process and identified five fundamental steps for students in problem based learning:

1. Project / problem formulation
2. Development of a solution through a self–directed learning approach
3. A re–examination of the problems to test the proposed solutions
4. Abstraction where the solutions are contextualised with other known cases
5. A final reflection stage where the students reflect and critique their learning process seeking to identify areas for future improvement.

When these stages of PBL are addressed correctly, Perrenet et al (2000) states that three main objectives for education are simultaneously met:

1. Acquisition of knowledge that can be retrieved and used in a professional setting
2. Acquisition of skills to extend and improve one's own knowledge
3. Acquisition of professional problem–solving skills and the integration of skills from many relevant disciplines.

From an institutional perspective, PBL also offers advantages. When correctly resourced and implemented it provides learning which:

1. Is student centred and motivational
2. Is highly relevant to education for a 'profession'
3. Is adaptable to student needs and learning styles
4. Promotes problem solving, interpersonal skills, teamwork, self directed learning, critical thinking skills and deep learning (Barrows 1984)

Given these advantages, PBL has now been adopted by many disciplines and is practiced very differently in different institutions (Maudsley 1999; Norman & Schmidt 2000; Duch 2001; Kolmos 2002; Mills & Treagust 2003; O'Kelly et al. 2006). It is therefore no surprise perhaps that this diversity has also led to misapplications and misconceptions which may lead to a failure to achieve anticipated learning outcomes (Savery 2006). In this regard Boud and Feletti (1997, p. 5) described several possible issues, all of which are related to the fundamental principles of PBL.

First, PBL is a 'curriculum design' not merely replacing lectures with 'problems' for discussion. Second, there is often insufficient investment in appropriate learning resources. In some cases academics and even institutions "…hold a naïve view of the rigor required to teach with this learner–centred approach" (Savery 2006).

Barron et al (1998) identify four design principles for PBL:

1. defining appropriate learning goals,
2. providing scaffolds including resources,

3. ensuring opportunities for formative self assessment and revision, and
4. developing social structures.

Whilst these are obviously four important areas, they neglect the important area of staff training and development, and the necessary commitment from staff at all levels. They also minimise research and development on the nature and type of problems to be used, the need for reflection and the overall assessment strategy, summative as well as formative. The change to PBL implies an overall pedagogy encompassing learning objectives, learning resources, appropriate assessment methods, evaluation strategies and professional development for staff, all of which must integrated and satisfactorily addressed.

The role of staff (teacher or instructor) in PBL moves from a traditional lecturer, a conveyor of knowledge and content, to a supervisor or facilitator (Brodie & Borch 2004). O'Hara–Deveraux and Johnansen (1994) define facilitation as "the art of helping people navigate the processes that lead to agreed upon objectives in a way that encourages universal participation and productivity". For the academic there is a greater emphasis on designing and preparation, guidance and support, managing and delegating, rather than lecturing and tutoring.

Reflection by both staff and students is a very important part of the learning process and the theory on learning and reflection comes from a number of different sources. It is founded on Kolb's (1984) work on the learning cycles and Schon's (1987) theory about reflection. Students must be given time to synthesize their new knowledge and reflect upon what they have discovered. This is particularly important in PBL where learning is sometimes covert – problems and projects are solved without the student being aware that skills and knowledge have been acquired and enhanced (Brodie 2007b).

Most literature on the topic of reflection in PBL revolves around individual reflection – what did I learn? how did I learn? what could I do better? etc. However, the author has previously shown (Brodie 2005; 2007b) that students must be allowed, and prompted if necessary, to reflect as a group as well as individually. This is essential to inculcate sufficient grounding in team *processes*, and particularly so when working in virtual teams. Reflection, therefore, should be a key part of the implementation and assessment plan (Brodie 2007b; 2008a).

To summarise, the key components for successful PBL include the following:

1. A high level of research and development on the scenarios and resources given to students. The problems/projects must be real world, ill structured, applicable to the profession and include a wide range of disciplines.
2. Recognition of the difference between PBL and problem solving.
3. Commitment from staff.
4. Appropriate assessment.
5. Time and recognition of the need for reflection from both staff and students.

2.1.3 Problem Based Learning in Engineering Education

Interest in problem based learning (PBL) arose in engineering higher education in the mid 1990s when employers found fault with current programs that failed to equip graduates with collaborative problem solving skills required for a lifelong learning and the reality of the work place (Cawley 1991; Hadgraft 1991; Wilkerson & Gijselaers 1996; Boud & Feletti 1997; Brodeur et al. 2002; Fink 2002).

Dym et al (2005) found that, in most engineering curricula, the first two years are devoted to the basic sciences and until the 1990s this approach had changed little since the 1950s. The resulting graduates were perceived to be unable to practice in industry on graduation due to the change in focus from practical skills to theoretical knowledge. Researchers (e.g. Dutson et al. 1997; Davis et al. 2003) reported that, with the focus entirely on engineering sciences, students could understand the technical components of design but lacked the professional skills necessary *for* design – teamwork, communication, problem solving and the *application* of technical knowledge. Traditional engineering curricula surmise that students develop these skills automatically but academics and employers now doubt that this is the case.

Solving a design problem involves a process of analysing, modelling, experimenting and realising; a procedure in which many choices have to be made. Developing new products and methods, and applying existing knowledge to new situations are key professional activities of engineers (Perrenet et al. 2000) and require much more than just technical knowledge.

All accredited university programs were considered to have successfully met the technical responsibilities of the profession but the development of other professional attributes such as teamwork and communication was largely seen as the responsibility of employers. However, in an increasingly competitive market, employers want 'job ready' graduates skilled within their discipline but fully capable to commence work in the modern engineering team.

In addition, the breadth of professional knowledge has grown significantly with the information explosion and the rapid changes in technology. Thus, much of what is currently taught to students in the traditional lecture will quickly be out of date. Jamieson (2007a) stated, in her keynote address for the 2007 IEC DesignCon Conference in the USA, that "the half–life of an engineer's knowledge is estimated to be less than five years" and in "ten years 90% of what an engineer knows will be available on the computer." How will, and how should, this influence engineering education?

Table 2-1 shows the three fundamental cores of an engineering education at Purdue University. The University perceives this set of skills, knowledge and attributes as necessary requirements for future graduates. The *abilities* and *qualities* are seen as just as important as the technical knowledge areas.

Table 2-1 Requirements for engineers of the 21st century
(adapted from Jamieson 2007b)

Abilities	**Knowledge Areas**	**Qualities**
Leadership	Science and math	Innovative
Teamwork	Engineering fundamentals	Strong work ethic
Communication	Analytical skills	Ethically responsible in a global, social, intellectual and technological context
Decision making	Open–ended design and problem solving skills	Adaptable in a changing environment
Recognize and manage change	Multidisciplinarity within and beyond engineering	Entrepreneurial and intraperneurial
Work effectively in diverse and multicultural environments	Integration of analytical, problem solving and design skills	Curious and persistent continuous learners
Work effectively in the global engineering profession		
Synthesize engineering, business, and societal perspectives		

This is not to diminish the need for discipline specific technical knowledge, but this knowledge must be put in context with other requirements and more importantly future requirements. Currently employers criticise universities for the lack of complementary skills (abilities and qualities) in graduates (Whelan & Boles 2002; Davis et al. 2003; Dym et al. 2005) and increasingly universities are looking to improve and increase what used to be seen as soft skills such as lifelong learning, creative thinking, problem solving, communication etc in their graduates. This is emphasised in recent reports such as the American Society for Engineering Education Green Report (ASEE 2008), the report for The Millennium Project at the University of Michigan (Duderstadt 2008) and the National Academy of Engineering (NAE 2004) publication "The Engineer for 2020: Visions of Engineering in the New Century". PBL is a suitable methodology to deliver such changes whilst still retaining, and perhaps even strengthening, the acquisition and appreciation of critical discipline knowledge and fundamental skills.

Technical knowledge and the fundamental skills of mathematics and physics taught in isolation from the wider engineering picture can be difficult to grasp and students, especially in the early years of their education, find this de–motivating (Dym et al 2005). Giving students the opportunity to learn and practice fundamental skills in an authentic engineering setting helps students learn, retain and expand their knowledge.

PBL is an ideal way to provide authentic and content rich experiences for students. In PBL, students work in a team environment critiquing and reviewing work and engaging in collaborative knowledge building. It has been proven to improve retention and "transfer and reasoning strategies" (King & Mayall 2001).

Hassan et al (2004) reviewed and summarised the use of PBL worldwide, specifically in engineering education. Whilst this summary is not exhaustive or complete, it does demonstrate that PBL in engineering education is well grounded pedagogically and has wide implementation (in universities in UK, USA, Canada, Australia and Asia). PBL also has many interpretations from single courses to the widely known Project Organised Problem Based Learning (POPBL) at Aalborg University (Brodie 2009b).

The transition for PBL, from the conventional face–to–face mode to distance education, has been much slower. Taplin (2000) suggests that the predominant view, held by educationalist and researchers, is that it may not be appropriate for distance education due to a perceived need for face–to–face contact and direct student support mechanisms. Price (2004) indicates that PBL "…should not, in theory, be well suited to distance learning mode of study" due to the difficulty to adequately accommodate the PBL process and the variety of problems that could be identified for study. There are several examples of PBL used in a quasi–distance education mode where the internet is used for part of the course delivery, but application of PBL to distance education and students working in virtual teams using a variety of electronic communication systems was largely undocumented until more recent times (Brodie 2009b)

Sage (2000) published the result of an online problem based learning course for eight graduate students studying a six week summer course. The students were distributed geographically and were supported by two 'teachers' and additional telephone interviews. Although this was clearly a very limited study, Sage concluded that "online [asynchronous] delivery does not support PBL or other collaborative problem solving strategies" as students could not deal with the complexity of the problems and the task management involved. She concluded that virtual team work is not workable for students without the use of synchronous [social] communication technologies (telephone) and who have little or no background in a 'constructivist learning environment'. Sage reported that the course stretched the students far past their own 'zones of proximal development' in which they could appropriately learn.

Given this publication, the present author must emphasise that the work presented in this dissertation indicates that not only that PBL is suited to distance education, using virtual teams, but also it is delivering many advantages to staff and students. Furthermore with sound pedagogy and appropriate assessment practices, PBL is particularly useful in effectively using the prior skills and knowledge of a diverse cohort of students to engage in mentoring and peer assistance that meet key content and educational requirements.

Most universities in Australia offer a common first year for engineering, mainly for economic reasons (Whelan & Boles 2002; Bartier et al. 2003). This commencing year must deliver key fundamental technical knowledge on which future discipline specific knowledge can be built (Dym et al. 2005). However it is increasingly recognised that the first year at university needs to deliver more to students than fundamental [technical] knowledge. Social integration, professional awareness, and generic skills and qualities such as "critical thinking and intellectual rigour" (Baillie 1997) are part of the total education experience.

Increasingly, universities are accepting a wider range of students into their programs than in past decades. These students have different educational backgrounds and programs require differing outcomes despite having a common year (Brodie & Porter 2008). Australian universities, particularly smaller regional universities, can no longer rely on having a homogenous student cohort in terms of prior knowledge and experience. Recognition of prior knowledge and flexible entry pathways are key issues for universities to address, particularly in the first transitional year to tertiary study. PBL, which effectively uses individual prior learning and peer collaboration and mentoring, is an effective way to integrate students socially and educationally and to deliver key attributes required by professional engineers.

2.1.4 Distance Education and eLearning

The history of distance education is long and varied and is not a new phenomenon in higher education (Brodie 2006; Gibbings & Brodie 2008b). It dates from the 1840s with Sir Isaac Pitman and his correspondence courses in shorthand and in the 1870s with correspondence courses created to **"…**encourage studies at home for the purpose of educational opportunities for women of all classes in the society" (Nasseh 1997). Radio in the 1940s and television in the 1950s and 60s (Rumble 2001) were used with varying results. However, in the last three decades the rapid advances in distance education have been powered by technological change (Frick 1991, Rumble 2001).

Keegan (1986, p31) defines distance education as the combination of the two fields of Distance Teaching and Distance Learning. Distance teaching applies to the development of teaching materials, the instructional design and the pedagogy of the delivery including assessment strategy. The design must cater to the target group of students and include their general education and previous study experiences as well as specific prior knowledge of the subject (Holmberg 1995 p 37). Course design however, does not always translate to *learning*, as seen from the students' perspective. Distance education is a suitable term to bring together both the teaching and learning elements.

Sherry (1996) cites several authors and defines three hallmarks of distance education, namely:

- The separation of the teacher and learner in time and space (Perraton 1998).
- Students control their learning rather than the teacher (Jonassen 1992).
- Communication between student and teacher is through print or some form of technology (Keegan 1986; Garrison & Shale 1987).

These key areas effectively free students from the traditional academic structure of lectures and tutorials at a university campus. With the massification of education, changing economic and social patterns, and the boom in technology, particularly personal computers and the internet, distance and online education have become growth industries in Australia and worldwide (Brodie 2006). This growth has been supported by the recent maturing of research into learning within an online environment (Kehrwald et al. 2005). Consequently modern online courses are now usually designed on well recognised theoretical foundations. However, Zemsky and Massey (2004) report on the ‘failed uptake of eLeaning in America’ and suggest, at least from a student perspective, that eLearning has not developed as fast as anticipated. They suggest that this outcome is due to a failure to adequately investigate and address the needs of distance students.

In Australia, political, social and economic factors have effected major changes to higher education. In the last decade, overall undergraduate commencements have increased by 31% (Department of Education Science and Training (DEST) 2004). Now the probability of a person participating in higher education at some point in their lives has increased to 47% (DEST, 2004). The growth in student enrolments in tertiary education have resulted from an increased accessibility to education and an extended duration of study (Brodie 2009c).

In addition, universities now offer multiple entry pathways to undergraduate programs. Students entering university after completing secondary school now account for only 41% of commencing student admissions (Refer to Figure 2-1) growing by only 6% in the last ten years and resulting in their share of the commencing student cohort decreasing by almost 10% since 1991 (Brodie 2009c). Students admitted on institutional examination and employment experience have increased by over 200% and entry on the basis of prior non–secondary TAFE studies have increased by 177% (DEST, 2004).

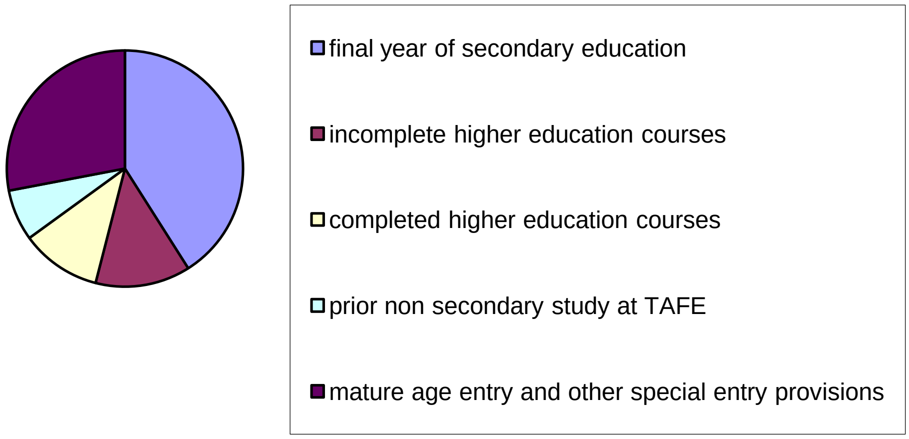

Figure 2-1 Mechanisms for entry to undergraduate programs in Australia
(Brodie 2009c)

To cater for the changing demographics – from school leavers who study full time and live at home through to students who balance work and family life and wish to undertake higher education – universities have permitted a greater flexibility in enrolment patterns and attendance modes. In 2002, the Australian Department of Education, Science and Training (DEST) reported that 37% of students had attendance patterns other than internal full time modes (DEST 2002).

Many universities, particularly in Australia and the USA, have responded to these changing study patterns by adding distance education to their modes of study. In the USA, 83% of governors of colleges identified “allowing students to obtain education anytime and anyplace via technology” as a critical characteristic of universities in the twenty–first century (de Alva 2000). The flexibility offered by distance education has been well known and its ability to reach students who would not normally have access to education is also well documented.

Today’s distance education students are interested in professional qualifications and “learning that can be done at home and fitted around work, family, and social obligations” (Bates 2004, p. 5). They require more flexibility in program structure to accommodate these other responsibilities (Howell et al. 2003). This flexibility is echoed in a recent student survey by the author that found that 92% of the distance student cohort indicated that without distance education opportunities, they would not be able to pursue a tertiary education.

To cater for these changing demographics the Faculty of Engineering and Surveying at USQ has developed articulated distance education programs with flexible entry paths as shown in Figure 2-2 below. This integrated and articulated approach is well regarded by both students and their employers (Dowling 2008).

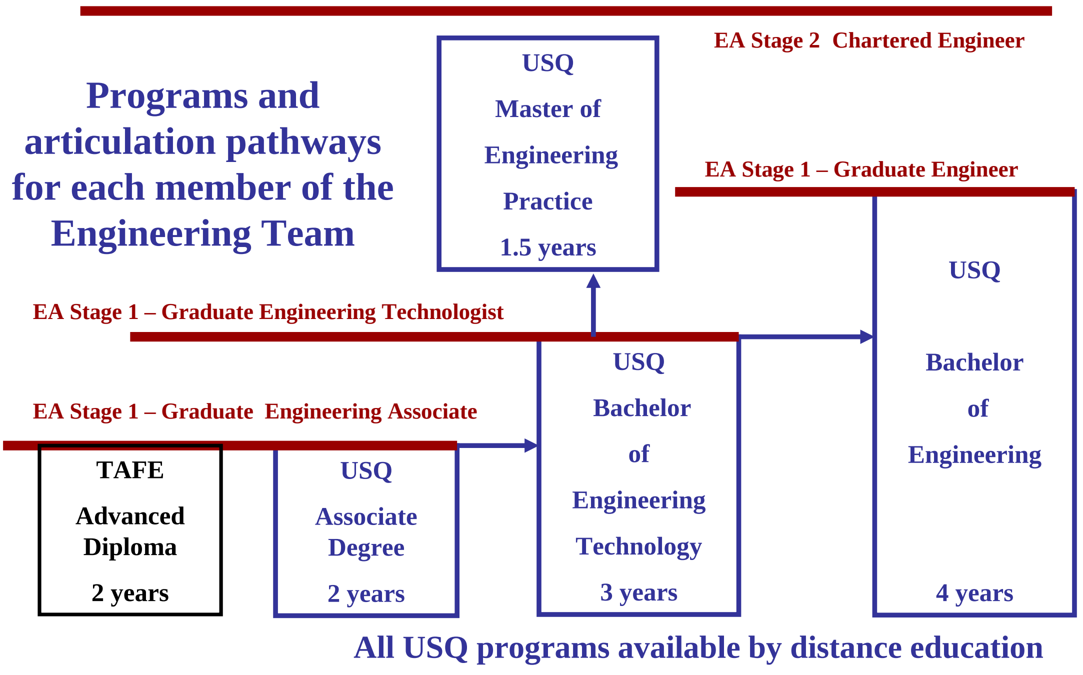

Figure 2-2 Articulation of Faculty programs
(Dowling 2008)

The flexible entry, articulation and high quality distance education programs encourages a diverse enrolment. Whilst the Australian average for enrolments other than full time on campus is approximately 27% (Brodie 2009c), USQ has approximately 80% of students studying via distance education (University of Southern Queensland 2009). These students are largely mature age, working in the engineering and surveying industry and have a varying set of pre-university learning and work experiences.

Usually a diverse student cohort is seen as a disadvantage or a problem for academics. At what level is lecture material pitched? how can you best maintain student interest and motivation? and how can progression and retention rates be maintained or improved? It is demonstrated in this dissertation that team based PBL, where peer mentoring and assistance is encouraged and rewarded, is one solution. This allows the course pedagogy to work with, and use to advantage, prior knowledge of the student cohort.

2.2 Nexus between Engineering Education, Teamwork and Virtual Teams

In 1966, Warren Bennis predicted that future organisations would have "…unique characteristics including task forces organised around problems to be solved by groups of relative strangers with diverse professional skills". This quotation, cited by Bellamy (1994), is a prelude to discussing the need for changing engineering education so that it adequately prepares students to meet the demands of the present and future engineering workplace. The particular points noted are an emphasis on teamwork as well as individual effort, instilling a sense of the social and business context and the rapidly changing globally competitive nature of engineering and the business frame in which it operates.

The engineering education reviews of the late 1990s began the slow evolution of integrating skills previously seen as 'soft' into the engineering curriculum and the move to outcomes based education ('Educating Engineers for a Changing Australia' 1996; IEEE 1996; IEAUST 1999; Rugarcia et al. 2000; ABET 2007). In addition, the early development of these skills within programs was seen as enabling improved academic performance. Many educational elements within the engineering curriculum are best experienced by students working in teams as effective teamwork and the corresponding interpersonal skills smooth the transition into the workplace.

However, in most 'traditional' universities much of the standard engineering curriculum still revolves around face–to–face lectures, tutorials and practicals. Integrated projects still tend to be the capstone of engineering programs and team projects are unfortunately largely regarded by both staff and students as millstones, something to be endured rather than a rewarding and worthwhile learning process. There are exceptions but even in innovative programs, there is often insufficient formal support and resources for the teamwork aspects of a program.

Effective preparation of students for teamwork, as opposed to just working in a group, involves the development of skills that aid team building and performance and reflective practice at both an individual and team levels. As discussed in Chapter 9, these skills are not usually well supported by engineering academics, even those who support the introduction of teamwork.

Engineering is a creative, team–based, problem solving profession which sits at the interface of the sciences and society, and is recognised as such by Engineers Australia in its program accreditation documents (Engineers Australia 2004). Students need the basic tools of engineering science and their applications to make informed decisions, validate, and actually solve problems, but equally fundamental is the need to do this in a team environment meeting ethical, business and organisational needs.

Organisational needs are changing. Globalisation, technology, flexible work practices and a shrinking skilled and experienced work force in the Western world are changing how many organisations operate and this trend is likely to continue. Many organisations remain structured around traditional face–to–face teams but Arnison and Miller (2002) argue that, increasingly, these conventional face–to–face teams may increase productivity by utilising technology for communication, file sharing and sharing work across offices, time zones and even other organisations.

These changes have been noted as impacting on engineers and engineering education for example by Thorben & Schwesig (2002), National Academy of Engineering (2004) and Jamieson (2007a) who all predict the need for desirable engineering graduate attributes to be expanded to include:

- Working globally in a multicultural environment;
- Working in interdisciplinary and multi skilled teams;
- Sharing of work tasks on a global and around the clock basis;
- Working with digital communication tools and
- Working in a *virtual* environment.

It follows that universities need to equip students with skills that help them cope with evolving technology and global demands of the profession. This leads to engineers working not only in face–to–face teams, but learning and applying appropriate skills and techniques to *virtual* teams.

2.2.1 Virtual Teams – teams in virtual space

A virtual team is usually defined as one whose members share a common purpose or goal and work interdependently. They are separated by distance and therefore perhaps time, cultural, organisational and international boundaries. Their common feature is that they are linked only by communication technologies (Lipnack & Stamps 1997; Robey et al. 2000; Noe 2002; Brodie 2008a). Teams are often assembled 'virtually' to work on a specific project and therefore are required to produce a 'deliverable' product such as a report, or to fulfil a specific need (Lipnack & Stamps 1997), hence the team will have a finite life span and may never physically meet.

The literature on virtual teams is considerable and spans many areas. In the fields of Information Systems, business and knowledge management, virtual teams are acknowledged as playing an increasing role in organisations (Powell et al. 2004). When reviewing the literature care must be taken not to confuse *teams* with virtual or networked organizations, virtual communities and forms of teleworking. Competition, globalization and flexible work practices are driving development and research in these areas. Similar to distance education, the growth is made possible by advances in technology. Email, discussion boards, the Internet (wikis and web pages), text–based chat and voice over the Internet, are allowing the formation and growth of virtual teams. The increasing popularity of virtual teams has given rise to a parallel growth in research in this area (Powell 2004).

This research covers adoption and use of dispersed teams, areas such as socio–emotional processes, task processes and outcomes with much of this literature focusing on comparisons of virtual and traditional teams (Powell 2004). Much of this published work has little relevance to the topics of PBL and engineering education, and is therefore considered to be outside the scope of this dissertation. In addition, much of the research on virtual teams generally, and virtual teams in distance education specifically, has appeared in the last 5 years. When the project described in the dissertation began in 2000 there was little useful or relevant literature in this area. Pauleen and Yoong (2001) stated “little has been written on how to build effective working online relationships between members of virtual teams”.

Literature describing the communication channels used by virtual teams covers true electronic communication technology such as email, chat and discussion board and also discusses the use of ‘sensory’ communication devices such as telephones, telephone conferencing and audio/visual conferences. The latter group of devices adds considerably to the information available to participants of conversations, discussions and debates. Voice intonation and facial expressions give substantial clues and extra subconscious information to participants. Pauleen and Yoong (2005) conclude that telephones (audio connections) are the most important relationship–building communication channel available. Their research goes on to state that setting up a videoconferencing communication channel between geographically separated members is essential in building trust, a major factor in the success of a virtual team.

Successful virtual teams often use a variety of technologies to enhance their communication (Lau et al. 2000), but most research agrees that working with electronic communication technologies alone is problematic without having first established personal relationships and trust within the team. If face–to–face meetings are not possible, then at a minimum, more sensory modes of communication such as videoconferencing must be utilised (Townsend et al. 1998; Furst et al. 1999; Warkentin & Beranek 1999; Pauleen 2005). However, Brodie (2007a; Brodie 2009a) and Brodie and Gibbings (2008b) have been able to show that in distance education, virtual teams have been able to develop into high performance teams without videoconferencing using instead a variety of non–sensory communication technology. This has been achieved through careful and considered use of appropriate technology, scaffolding, pedagogy and assessment. The pedagogy has been developed by incorporating theories on problem solving, reflective practice, traditional face–to–face teamwork, distance education and learning communities.

2.2.2 Virtual Teams in Education

In the rush to tap into new markets, utilise new technology and cater for changing student demographics, many universities around the world have turned to distance and in particular online education (Brodie 2006). Furthermore, Daiz (2002) contends that online students are becoming an entirely new cohort of higher education learners.

In both the USA and Australia, these students are generally older than their traditional counterparts and are interested in learning that can be done at home and fitted around work, family, and social obligations (Bates 2004 p5). Howell et al (2003) writes about mature age students:

> *They tend to be practical problem solvers. Their life experiences make them autonomous, self–directed, and goal and relevancy oriented - they need to know the rationale for what they are learning* (Howell et al. 2003).

Mature age students are motivated by professional advancement and external expectations but are nervous about their ability to succeed in distance learning due to the rapidly changing technology with which they may not have kept abreast of (Diaz 2002; Dortch 2003; Howell et al. 2003). Most of these motivational factors are supportive of the virtual team however some areas, such as technology may hinder full involvement. Barriers to full participation and learning in virtual teams are discussed in Chapter 6.

Whilst some students choose the independence and flexibility of distance or online education, they can also be disadvantaged by the isolation; the lack of ‘classroom community’, opportunities for discussion, debate and sharing of knowledge and the general social aspects of university education. Teamwork, and in particular virtual teamwork, can use the strengths of this student cohort whilst also supporting individual learning and social needs.

In designing a virtual classroom, the goal is not to duplicate the characteristics and effectiveness of the traditional face–to–face classroom but to use the powers of the computer to replace, and improve on, what normally occurs in the traditional classroom setting (Black 2002). Computers can be used to tailor the communication process to the nature of a specific application as well as to the nature of the individuals or groups undertaking the application. Studies on the use of computer–mediated communication facilities that form essential components of a virtual classroom have tended to support the perspective that, for mature motivated learners, this mode of learning can be more effective and more interactive than a traditional classroom experience (Hiltz 1993). These studies however focus on individuals and *groups*, as distinct from teams undertaking a shared task and working collaboratively to generate new knowledge. Virtual team work does offer a spectrum of significant advantages. Advantages of virtual teams in higher education, and in particular distance education, can be summarised as:

- The opportunity to create a learning community, particularly for distance education students (Brodie & Gibbings 2007b; Gibbings & Brodie 2008b);
- Working collaboratively to generate new knowledge (Hines et al. 1998; Brodie 2008b; Brodie 2009a);
- Managing own learning (Robey et al. 2000; Goold et al. 2006a);
- Flexibility in work hours and place of work (Goold et al. 2006a);
- Increased communication (Brodie 2006, 2009b)
- Faster response times to tasks (Arnison & Miller 2002; Morris & Marshall 2003);
- With the aid of computer technologies, individual participation and contribution to the conventional face–to–face team can be better measured to determine the effectiveness of the team (Arnison & Miller 2002; Goold et al. 2006a);
- The skills learnt in a virtual team environment are in high demand in most organisations (Black 2002; Kirkman et al. 2002);
- Allowing students to interact with individuals from many different societies, thus greatly improving their awareness and appreciation of culture in today's global world (Black 2002; Brodie & Porter 2008).

To realize these advantages, careful pedagogy, scaffolding and support systems must be in place because there are also disadvantages to be overcome. These disadvantages include:

- Difficulty in building and maintaining trust (Morris & Marshall 2003; Jarvenpaa & Leidner 2004; Kaisa & Blomqvist 2005);
- Loss of communication cues from facial expressions, voice tone and gestures (Cascio 2000; Karayaz & Keating 2005);
- Lack of skills in organising, running and facilitating teams (the recognition that these skills are different from running face–to–face meetings and teams)(DeRosa et al. 2004);
- Team problems obscured by technology (Brodie 2009a).

Competition, changing needs and student demographics has forced universities to embrace other structures in addition to the traditional centralised model where learning must take place at a particular time and place (on–campus). It has been argued that education needs to move to a model where it is decentralised, information–based and technology driven (Cyrs 1997; Howell et al. 2003; Kehrwald et al. 2005). The traditional delivery method of lectures, practicals and tutorials now has a major competitor in distance and online education.

The extent of interaction is the greatest difference between virtual and traditional teaching methods. In a strict lecture format, interaction levels are low (Brodie & Borch 2004) and are dependent on the academics to define the task (Geisler 2002). In virtual classrooms, collaborative learning in teams, problem solving and higher order thinking skills are enhanced by the use of technology and "…delivery of instruction is dependent on the team's collective effort in meeting the task with team–dependent timeframes and resources" (Geisler 2002).

Central to any university's mission is the transfer of knowledge and this transfer has been affected by technology.

> *It can be argued that the traditional methods of higher education can either embrace this new virtual world or become less relevant in the value it adds to society. How effectively institutions link the tools of technology with their educational vision and mission will determine their continued success in being a primary source of education in that society* (Geisler 2002).

2.2.3 Making Virtual Teams Work in a Learning Environment

Nohris & Eccles (1992, pp. 304-305) contend that "…you cannot build network organizations on electronic networks alone...If so,... we will probably need an entirely new sociology of organizations." However, organisational virtual project teams that utilise, to varying degrees, electronic communications are challenging this opinion. Numerous multinational companies are now cited in the literature as relying on teams that interact electronically to run everyday business, although as would be expected, the level of virtuality does vary and is dependent on the business being conducted and the organisational structures (Milstead & Nelson 2003; Peters 2003).

The literature is consistent in suggesting that virtual teams can be as successful as traditional teams, provided that:

1. The design of the team is structured properly;
2. The task is explained and structured well;
3. A face–to–face kick–off initiation is planned at the beginning of the task;
4. Social networking software or technologies which includes video and or voice link ups are used for the majority of meetings (Geisler 2002; Kaisa & Blomqvist 2005; Karayaz & Keating 2005; Alexander 2006; Goold et al. 2006a).

However, the author has demonstrated that virtual teams can be successful in delivering a team outcome, as well as meeting the individual learning goals of its members, without any face–to–face interactions and no social technology. This has been achieved through a careful analysis of the problems of virtual teams, an investigation of appropriate teamwork literature and implementation of principles of online and distance education. This has been synthesised and approaches and resources developed to support the learner and the team working in the virtual environment. This is further discussed in Chapters 6, 7 and 8.

The application of standard teamwork theory has been adapted where necessary for the virtual environment (Brodie & Gibbings 2007a; Brodie 2008b; Brodie et al. 2008; Brodie 2009b). Much of the theory of standard teams can be applied to virtual teams. Tuckman's 1965 famous model of forming, storming, norming and performing (in the 1970's the adjourning stage was added), can be applied to virtual teams, but times spent in each stage and strategies to move teams to the next stage, vary from standard face–to–face teams. Similarly the output (volume and quality of work) of teams compared with individuals, as proposed by Smith (2003), applies to virtual teams but again, time and strategies to improve team performance need modification to effectively apply to virtual teams.

Drexler et al (1999) models team performance. Figure 2-3 shows that this modified model lays neatly on Smith's (2003) model for team performance. This effectively demonstrates the functioning of virtual student teams and addresses more completely team dynamics than Tuckman's simpler four stage model.

In examining the literature, particular care was taken to distinguish between true virtual *teams* and *group interactive learning*. In the latter, groups of students discuss and interact, perhaps using electronic communication, but are not a team. Their outputs and assessments are still largely independent and individual (e.g. as cited by Jones et al 2001) as opposed to the unified outputs for the virtual *team*.

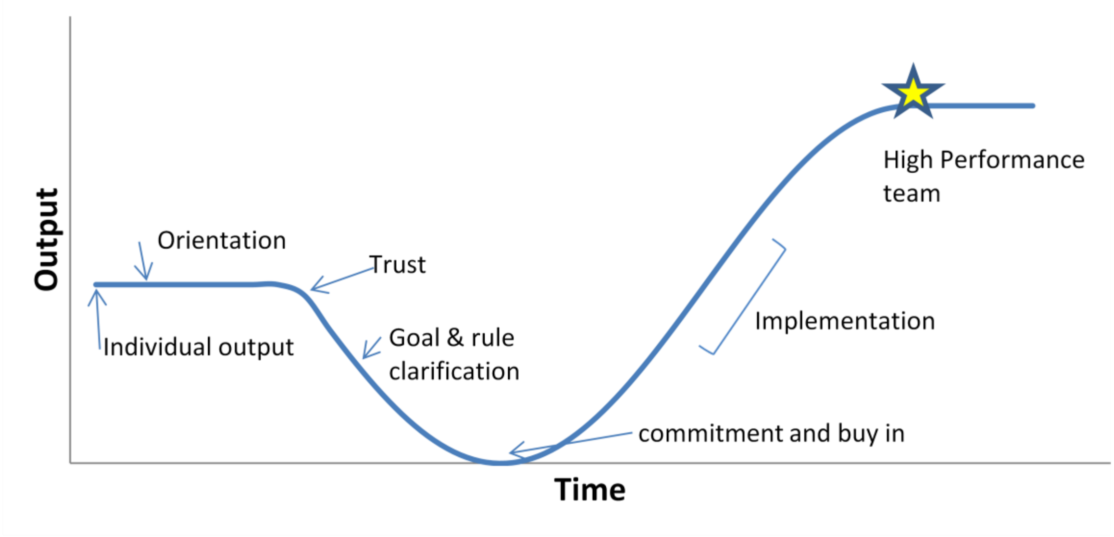

Figure 2-3 Team phases and team outputs

The inputs needed to develop virtual teams include independent members, cooperative goals, and multiple communications media (Lipnack & Stamps 1997; Vick et al. 2003; Powell et al. 2004). Throughout the development process, the members engage in interdependent tasks and share leadership.

Much of the business literature and research on virtual teams focuses on teams which have clear definition of roles, for example, there is a definite leader (the boss) who has authority and can set directions (e.g. Townesend et al 2000, Warkentin & Bernanek 1999, 2005). These directions may or may not be debated by the team, but there is a clear delineation of roles. This is not so in student teams unless clearly set by the instructor/academic. Students must decide the leader role and with this role there is no authority. Team members must learn to work cooperatively and interdependently, sharing leadership and tasks and constructing new knowledge and skills with respect to individual and team learning goals and prior knowledge and experience.

It has been discovered that with a mature or experienced student cohort, this lack of authority is often one of the biggest learning curves and is a major hurdle for students. It is often commented on in student reflections (Brodie 2009b). Student reflections also discuss trust (gaining and losing) within the team. Jarvenpaa and Leidner (2004) discuss trust within virtual teams and state:

> *Can trust exist in virtual teams? Noting the lack of shared social context in such teams, much of the theoretical and empirical literature on interpersonal and organizational trust would suggest a negative response to this question.*

However, trust within a virtual team is vital to, not only the success of the team meeting shared and individual goals, but to reduce the stress and uncertainty inherent in the technologically based environment. Trust in virtual teams can be discussed in three main areas – developing trust, promoting trust and maintaining trust.

Trust is maintained in a team when members believe that a person makes an effort, in good faith, to behave in accordance with the team commitments or ‘code of conduct’ (explicit or implicit), is honest and open in discussing such ‘rules’ or commitments and does not take advantage of others even if the opportunity arises (Cummings & Bromiley 1996).

The literature suggests that sharing experiences and social norms, good communication over time (repeated interactions) and the anticipation of future association are all factors which promote trust (Lewis & Weigert 1985; Bradach & Eccles 1989; Mayer et al. 1995). However, *developing* trust in a virtual team can be difficult, affected by many factors and described by many theories. These theories (e.g. social presence theory and Time Interaction and Performance (TIP) theory) do not clearly distinguish between groups and teams and these terms are used often interchangeably in the literature; however several aspects of these theories are useful in discussing the development of trust.

McGrath (1991b) describes research into groups which overcomes many of the limitations of previous empirical research [3]. His research and corresponding theories on groups revolve around 'everyday' groups and not groups formed specifically for research. He proposes that all group action involves one or another of four modes of activity as listed in Table 2-2. These particular modes and functions are easily and clearly related to teams formed for an education purpose those involved in PBL and those working as a virtual team.

Table 2-2 Modes and Functions to describe group activity

Modes	**Functions**
1. Inception and acceptance of a project	1. Problem solving and undertaking tasks performance
2. Solution of technical issues, problem solving	2. Support of members – participation, inclusivity, commitment
3. Conflict resolution	3. 'Group' welfare – roles of members, power and authority
4. Project execution	

The modes and functions of Table 2-2 do not create a fixed sequence of phases, but are dependent on the team, tasks, technology, and time (McGrath & Hollingshead

[3] McGrath (1991b) reviewed a wide range of empirical studies which form the foundation of many group theories. He proposes that these investigations have used groups which

- perform single and relatively simple tasks and does not cover groups deciding on task allocation or task order
- have a constant membership
- are never without essential materials, resources or personal
- don't have 'freeloaders' or deal with disputes (unless this is the purpose of the research)

These limitations suggest that many theories are not directly applicable to teams, virtual teams or teams in an educational setting.

1994). A high–performing team will engage in all functions and modes but the technological constraints of a virtual team may limit engagement and hence the development of trust may be inhibited (McGrath 1991a; Warkentin et al. 1997; Jarvenpaa & Leidner 2004).

Short et al (1976), in presenting a social presence theory, also question the possibility of developing trust in virtual teams. This theory suggests the necessity of communication cues to convey trust, attentiveness and other personal traits may not be present in computer based communication media. This is certainly true and misunderstandings due to communication media e.g. lack of intonation and facial expressions in the typed word (chat, email and discussion boards) can occur. Several empirical studies cited in the literature have also found this occurring (Adler 1995; Chidambaram 1996; Walther 1997; Goold et al. 2006b). However, more recently Brodie (in press) has found that team relationships including a high level of trust can be developed and fostered in virtual teams.

Walther's (1997) social information processing theory proposes that exchange of social information required to develop trust is not limited by computer–mediated communication. The only difference in this electronic communication from face–to–face communication is a slower rate of transfer. Thus communication is more a function of the context, setting, and timing than the characteristics of the media (Zack 1993; Markus 1994; Parks & Floyd 1996; Ngwenyama & Lee 1997). Pauleen and Yoong (2001) suggest that some electronic communication channels are more effective than others in building online relationships (including trust) and that the team *facilitator* plays a key role in strategic use of communication technologies.

2.3 Assessment – Teams & Problem Based Learning

The literature contains a plethora of assessment methods employed in contemporary higher education, but traditional written assessment still appears to be the dominant method of assessing students in engineering courses. The appropriateness of this method, however, may be questionable for a number of reasons:

1. Assessment methods should be compatible with learning objectives and with the general course pedagogy. Whilst many institutions and individual

academics have implemented innovative pedagogies, their assessment methods still often fall into a tradition individual written examination to be completed in a set time frame.

2. Students are largely assessment focused. Their work and subsequent learning is determined by what is assessed and what weighting is placed on the assessment item. Academics subscribe to this practice with a philosophy of "if you want students to learn it, assess it". This may have resulted in over assessment on the part of academics and learning *for* assessment on the part of the student (Brodie 2008a).
3. It may not be a suitable method as a means of assessing students' ability to apply technical skills and knowledge to real–life situations that engineering graduates are expected to perform in their professional work (Wellington et al. 2002) and even less valid for assessing the real–world skills or `soft skills' (Briedis 2002).

'Soft skills' including teamwork, communication (oral and written, formal and informal), creativity and lifelong learning, have been identified as neglected skills in engineering education (Thoben & Schwesig 2002; Ribeiro & Mizukami 2005b; Jamieson 2007b). Many institutions are now attempting to address these deficiencies in their curricula but to accurately and validly assess these skills is recognised as difficult and teamwork, particularly so.

2.3.1 Assessment of Teamwork

A frequent criticism of the assessment of team projects is that individual students in the teams often receive the same group mark irrespective of their contributions (Gibbings & Brodie 2008a). Peer assessment has been successfully used as a means of discriminating individual performance within groups by multiplying the team mark by an individual multiplier. The individual multiplier is arrived at by peer evaluation of the individuals' contribution to the team's performance (Wellington et al. 2002).

In team based projects, particular care must be taken with assessment. Students will quickly identify which team member has particular skills and knowledge, work ethic and motivation and use these characteristics accordingly. The result can be a report or artefact of a professional standard, but can we be sure that students have learnt any new skills and knowledge, or taken on new roles outside their normal comfort zone? (Gibbings & Brodie 2008a)

It is also recognised that peer–assisted learning (mentoring within teams), which can have a motivating effect on the teams (Frank & Barzilai 2004), and that mentoring between teams, must be encouraged and rewarded (Gibbings & Brodie 2008a). Brodie (2006) reported the development of an assessment strategy for the first of the PBL courses offered in the Faculty of Engineering and Surveying (FoES) at the University of Southern Queensland (USQ) to overcome identified shortcomings, and to effectively assess achievement and advancement of skills and competence, in a way that recognises diversity, prior skill and learning, and that does this in an equitable manner. This is achieved through a mixture of peer assessment and individual tasks including reflective portfolios.

The use of 'portfolios' and reflective writing has been employed in assessment sporadically, but again not without difficulty (Williams 2002; Brodie 2007b). Brodie (2007b) reports on the effective use of reflection and reflective portfolios but not without significant development of supporting resources and scaffolding for students and professional development for staff. However, once these resources and support mechanisms were in place, and when sufficient emphasis was placed on the reflective tasks, these assessment items became a useful insight into individual and team behaviours for the academics (facilitators) and also a significant learning tool for students.

Reflective reports or portfolios are used to encourage students to reflect on their learning and the group's processes (Brodie 2007b; Brodie 2008a). The addition of a reflective component to the assessment scheme can ask students to think about and document this area, but sharing of skills and knowledge, particularly in a diverse student cohort, needs to be explicit to engage the students in peer assisted learning and the gaining of new knowledge and skills (Brodie 2008a).

2.3.2 Assessment in Problem Based Learning

Assessment in PBL needs to establish the individual's knowledge, skill and competence rather than testing for factual knowledge (de Graaff & Kolmos 2002) and for the assessment to be authentic it must embody a range of non–traditional assessment techniques. It must also be an integral part of the actual course work. If the assessment is to be consistent with the pedagogy, this philosophy applies to any course that employs a constructivist paradigm (Wellington et al. 2002; Biggs 2003).

Leifer (1995) identifies five key pedagogies or themes which influence assessment in PBL:

1. Real world problems motivating the students and engaging students in *their own* learning;
2. A synthesis of theory and professional practice;
3. Problems lend themselves to a multidisciplinary approach;
4. Solving and documenting the problems needs significant project management skills which include problem formulation, teamwork, conflict resolution, negotiation, oral and written communication skills;
5. Larger problems or projects can include additional components to be presented or documented e.g. research methodologies, proposals, test results.

Whilst educators emphasise the impact of student assessment on learning, there is little agreement on methodologies for assessment in PBL (Swanson et al. 1997, p. 269). The literature shows that PBL courses and programs use a variety of assessment procedures. These include a mixture of written reports, oral presentations, written examinations, peer and facilitator assessment (of contributions and behaviour) and portfolios (of both reflections and/or own work) (Brodeur et al. 2002; Acar 2004; Brodie 2007b) and can focus on process, outcomes or a mixture of both.

Process variables for assessment included self–directedness, effort, motivation, attitudes and general problem solving steps. Assessment of learning outcomes, especially with a more ‘guided discovery’ approach to PBL is easier and more traditional approaches may be employed but may still be viewed as inadequate due to the fundamental pedagogy of PBL.

PBL strives for the student to take control over their own learning. Students decide what they know, and what they need to discover in order to solve the problem. Assessment can take this control of learning away from the student forcing them to think about and concentrate on what the instructor wants them to learn, or at least what they *think* the instructor wants them to learn. (Bridges & Hallinger 1995).

In summary assessments of *process* are closely linked to authentic PBL and, if structured correctly have a beneficial effect on student learning (Swanson et al. 1997) but these alone are not sufficient for a valid measure of student learning. Assessment of *outcomes* has many well developed and well validated procedures, but the assessment items must focus on the *application* of knowledge in a *problem solving situation*. These assessment items whilst mainly used for traditional grading purposes can also provide an effective and efficient way for student self assessment of their strengths and weaknesses which in turn assists their self directed learning. This ultimately is the goal of PBL.

2.4 Learning Community – Community of Practice

The concept of a Community of Practice (CoP) was first introduced by Lave and Wenger (1991) and has been extended to include concepts such as communities of learners. A learning community can be described as a cohesive community that "…embodies a culture of learning in which everyone is involved in a collective effort of understanding" (Rogers 2000). An essential characteristic of a learning community is that responsibility for learning is shared among group members including the facilitator or teacher. Each member can contribute existing skills and knowledge to the group to further the final outcome. It is argued that this type of learning leads to a deeper understanding of content and processes for group members (diSessa & Minstrell 1998; as cited by Rogers 2000). If these collaborative activities are applied to authentic, real life scenarios then the similarity to PBL emerges.

Most examples of situated learning involve communities of practice that share space and time i.e. proximate (Robey et al. 2000). *Virtual* communities of practice are most often referred to in the literature relating to business environments (Hildreth & Kimble 2000; Kimble et al. 2000; Neus 2001). The research in this area has been driven by globalisation and organisations increasingly working in distributed environments. These trends are directly responsible for the increasing impetus for engineering graduates to be confident and skilled in working in virtual teams (Brodie 2007a).

Similar trends for universities to move to distance, online and flexible education have resulted in research in virtual communities of practice to support the often isolated distance student or flexible ways of interaction between academics and students (Gibbings & Brodie 2008b; Brodie & Gibbings in press).

Discussions in these communities of enquiry are beneficial to learning. The communication encourages learners to develop and clarify their own thought processes. The communities of enquiry also provide an opportunity for exposure to *cognitive dissonance* which is critical to intellectual growth (Anderson 2004a). Even students who do not possess advanced knowledge benefit from communication with more knowledgeable peers (Misanchuk & Anderson 2001a; Rovai 2002; Brook & Oliver 2003; Wallace 2003). The nature of these discussions, and their role in facilitating student understanding, is central to the development of lasting knowledge that then can be used by students in future problem solving (Innes 2007).

2.5 Staff Training

Chapter 2.2.2 Virtual Teams in Education, clearly established the role of the facilitator in the success of virtual teams. The skills of the facilitator are crucial in the management and leading of global virtual teams and in clarifying all aspects of communication including the unspoken, interpersonal issues (Pauleen & Yoong, 2005). This role is even more critical when the outcomes of the team are focused on attaining individual learning goal rather than an artefact or reports as required by an organisation.

In a team formed for *learning*, the role of the facilitator is both changed and expanded. The facilitator does not lead the team, but guide it. The facilitator does not clarify communication, but helps team members to gain this skill for themselves.

The facilitator does not set the direction or goal of the team, but again helps the team set these directions for themselves whilst still ensuring that the team will meet all required objectives. In short the facilitator guides the processes followed by the team and the learning that ensues.

There are many definitions of facilitation in the education literature and the following is a small sample of definitions which have application to PBL (as cited by Brodie et al. 2006):

- "…coordinating rather than leading an exercise so that all group members are encouraged to participate in the discussion or activity"
- "…helping others think through what they want and organising themselves to achieve it"
- "Facilitation is a collaborative process in which a neutral seeks to assist a group of individuals or other parties to discuss constructively a number of complex and potentially controversial issues."
- "…in education it is to help the learner forward, to manage a learner focused education process in an outcome based education model"

Engineering academics often feel uncomfortable in this new role citing a lack of formal training in the necessary skills and a lack of appropriate resources (Seat & Lord 1998).

2.5.1 From Supervisory Role to Facilitator Role

Making the transitioning from a traditional didactic educational model to a learner-centred model is recognised as critical to the long-term success of educational institutions (Spender & Stewart 2002). This is a significant and radical change. A major barrier is staff attitude and uneasiness with the change (McNamara 1999). The PBL educational paradigm means that the roles of academic staff will change with a greater emphasis on designing and preparation, guidance and support, managing and delegating, rather than lecturing and tutoring.

Many universities are implementing (or have already implemented) PBL in some form in at least single courses. In particular cases, newer overseas university programs such as Aalborg University (AAU), Denmark, have been designed from the beginning to use the PBL paradigm in all courses. USQ, like many Australian universities, has partially undergone this transition by using PBL in parts of its programs. Despite the differences in the implementation of PBL similar levels or types of supervising roles exist. The challenge at institutions is to encourage staff to continuously rethink their roles as educators and redefine the traditional concepts of teaching. These supervisory roles, regardless of the implementation strategy, could be defined in terms of didactic, technological and pedagogical (Brodie & Borch 2004). However the focus should be on moving from a supervisory role which has responsibility for the end product, to that of a facilitatory role which helps the team process to reach the desired goal achieving individual learning goals along the way (Kolmos et al. 2001; Bartier et al. 2003; Brodie et al. 2006).

Didactic instruction traditionally has been conceptualised as the transmission of facts to students, who are seen as passive receptors. Knowledge in this situation is symbolic and isolated; learning does not typically motivate students or provide them with problem–solving skills they can apply to other situations (Dewey, 1902). Academics typically use a lecture format, writing notes on a board and presenting knowledge as facts. It is the lecturers who are active and the students passive; lecturers are the distant authoritive figure showing the ‘right’ way to solve problems and which ‘facts’ to learn (Smerdon et al 1999). Most literature hints that the old didactic model of learning is out of date and educators are challenged to transform the educational experience so that it is meaningful to the information–age learner (Spender & Stewart 2002; Helbo et al. 2003; Hlapanis & Dimitracopoulou 2007). The role of the educator/lecturer in PBL does however still need some didactic supervising, but in a modified form. Active participation from the lecturer (facilitator) in the learning process, guidance on problem solving and the presentation of ‘facts’ and information still form a vital part of the PBL learning experience. In PBL these elements of didactic teaching are preserved and are necessary for perhaps one of the most vital aspects of education in this paradigm; the structuring of the problem or project (Brodie & Borch 2004).

Gijselaers & Schmidt (1990) have shown that the problem design itself has the greatest overall effect on student learning outcomes. A good PBL problem or project is engaging and orientated to the real world, is ill structured and has multiple outcomes or hypotheses, requires team effort, builds upon previous knowledge and experiences, is consistent with desired learning outcomes and curriculum objectives and promotes the development of higher order cognitive skills (Kolmos 2002). In the facilitator mode the skill of the academic is not in the presentation of facts but the weaving of specific learning objectives into an ill–structured real world complex problem. The academic is active and preparation of the project/problem requires significantly more technical skill, knowledge and time than the traditional lecturer. The didactic teaching still takes place, in PBL it happens behind the scenes (Brodie & Borch 2004).

Experience from Aalborg University, Denmark (AAU) shows when transforming on–campus education into distance education that the didactic supervision used is the same. Project support courses (P–courses) are offered in the beginning of the semester. Students find the project work more enjoyable and often do not engage in the subject matter by attending the available lectures (Knudsen et al. 2003, Helbo et al. 2003). Thus the facilitator must be more active in the so called 'course focus' period. The facilitator must process email and reflective sessions within 24 hours and also comment on the problem solutions submitted by the students in an appropriate time frame. If students are not active, the facilitator must take action to prevent the student dropping out (Brodie & Borch 2004).

USQ has similar evidence to support the need for didactic supervision with both on campus and distance cohorts. Facilitators must constantly monitor student emails, posting weekly reports and team activities to ensure active participation by all team members (Brodie & Borch 2004).

Closely tied to the project/problem design and formation is the consideration of the technological aspects of supervision. In this technological age, supervising a team in PBL also requires significant academic input. Facilitators must ensure appropriate levels of technology are available and appropriately integrated into projects. At lower levels of a program, technology is a "cognitive tool" where the incorporation of computer hardware and software extend student capabilities allowing access to data and information; expanding interaction and collaboration with others via networks (Krajcik et al 1994). Technology can make the knowledge construction process explicit, thereby helping learners to become aware of the process (Brown & Campione 1996). At higher levels of a course, technology can be integral to the project and its inclusion is a core element in the knowledge acquisition and it emulates tools experts use to produce artefacts (Krajcik et al 1994). Competence development of facilitators in managing new technology is very difficult due to established staff autonomy in using Information Technology (IT) in the teaching and learning process. In on–campus and classroom driven sessions we see a great variety of IT in–use, which presents no great risk since the lecturer and other students are ‘right here’ to help if things goes wrong. However, in distance education, the students are typically on their own, and the use of IT must be carefully considered, chosen and adapted by the facilitator/lecturer and thoroughly tested, so autonomy is only allowed within strict limits with respect to a chosen common denominator.

Pedagogical aspects of PBL supervision relate to the mechanics of team supervision. This includes the motivational aspects of PBL, encouraging participation and self learning; team dynamics, effective communication and conflict resolution; and the annotation and review of team work. This is the area where most staff feel the most apprehensive and traditional engineering faculty have the least experience (Hansen and Jensen, 2003). Hansen (2000) and Langeland (2000) documented that by adequately addressing group dynamics, the team is more effective both in team and individual outcomes from the process. For distance learning and courses in particular, the transformation from well known class room teaching to a virtual class room learning environment is difficult. The developer must turn the class teaching process into a self–learning process. This can be done by guiding and motivating the student along with self tests, team reflections and peer problem solving (Borch et. al., 2003).

Overall, facilitators must be able to manage the whole spectrum of communication strategies via new technologies as well as the human and social processes, and often do this across cultures (Pauleen & Yoong 2001; Pauleen 2005).

3 Education Requirement and Context

3.1 Introduction

This chapter outlines the factors impacting on higher education in Australia in the early 21st century. These include:

- Changing student demographics (DEST 2004; Australian Government 2008);
- Changing student, government and industry expectations and requirements;
- Information and technology revolution.

These factors suggest the need for changes to curricula, course delivery and assessment, and set the background to the Faculty course changes described in this dissertation.

USQ is uniquely placed in the Australian engineering education market. The majority of USQ students study by distance education in an innovative range of three articulated programs in nine majors. This gives the Faculty a diverse student cohort and a distinctive role to play in engineering education in Australia.

All courses in the Faculty of Engineering and surveying are designed and delivered with our unique constraints and advantages in mind. The chapter firstly explains the factors contributing to change in engineering education generally, before outlining these changes in terms of pedagogy, curriculum development and delivery strategies unique to USQ.

3.2 Student Demographics and Diversity

Major changes in the higher education sector have occurred in Australia in the first decade of the 21st century. The Australian Government's focus on meeting predicted skill shortages, coupled with consumer desire for higher education by mature age students, have forced an increase in overall undergraduate commencements (DEST 2004). This growth in student enrolments have also been influenced by 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 less than half of commencing student admissions (Figure 2-1 Mechanisms for entry to undergraduate programs in Australia).

These recent changes in student demographics will continue into the future. The Bradley Review of Australian Higher Education, released in December 2008, made recommendations for reforms that will increase total enrolments in tertiary education in Australia and allow for increased numbers of international, full-fee paying student places. The Government's target is to increase participation of 25-34 year old domestic students from 29% at the time of the report to 40% in 2020, which will represent 284,000 additional students participating in higher education in Australia (Australian Government 2008).

New admission pathways and the changing demographics have resulted in an increasingly diverse student population. This diversity has implications for the nature of student engagement and also the nature of their expectations. It requires that the pedagogy employed by universities meets the learning needs of a greater diversity of learners (Ireson et al. 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, 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 (McCombs 2000; Howell et al. 2003; Patel & Sobh 2006).

3.3 Information Revolution

The proliferation of new information is having a further dramatic impact on higher education. "In the past, information doubled every 10 years; now it doubles every four years" (Aslanian 2001, p. 6). This information explosion has a flow on effect to higher education causing an increase in the content and breadth of courses and programs (Howell et al. 2003). The very nature of higher education is changing not only with respect to delivery methodology and technology, but also the very content, process and output. Alvin Toffler acknowledges this when he writes, "The illiterate of the 21st century will not be those who can't read and write. They will be those who can't learn, unlearn, and relearn" (Pond 2003).

There is a growing demand for **lifelong learning** and consequentially for instructional approaches to be more 'learner-centred'. Transitioning from a traditional didactic educational model of education to a learner-centred model is critical to the long-term success of educational institutions (Spender & Stewart 2002). This includes delivery and content that is "recursive and non-linear, engaging, self-directed, and meaningful from the learner's perspective" (McCombs 2000; Patel & Sobh 2006). Responses include not only appropriate programs which cover the required 'fundamentals' but also an increased focus on finding, applying and validating information and solutions. There are impacts on curricula and on delivery methods and assessment.

A pedagogical shift is occurring within distance education, with a move away from the transmission model to constructivist, socio-cultural and meta-cognitive models. In these models there is an emphasis on students' responsibility for their own learning and use of computer-mediated communication (Miller 2001; Rumble 2001). Bates (2000) suggests, "...perhaps the biggest challenge [in higher education] is the lack of vision and the failure to use technology strategically." The interaction between changing program requirements, technology, student demographics and enrolment patterns suggests the need for profound changes in the university system.

3.4 Student, Government and Industry Requirements

Government and university funding policies have focused attention on improving learning and teaching practices, the "student experience", retention and progression, and meeting generic graduate attributes (Scott et al. 2008; Department Education Employment and Workplace Relations 2009; Department Education Science and Training 2009). These practices, university policy and improvement are monitored though such processes and the Learning and Teaching Performance Fund, the Graduate Skills Assessment Test, the Australian Quality Assurance Agency (AQUA) and the TEQSA to be created in 2010-2011.

Market forces, student awareness and consumerism are also impacting on university approaches to curricula, pedagogy and teaching practices. In the increasingly competitive world of higher education, universities are now marketing themselves as 'meeting employer requirements', 'the university for the real world' and 'producing graduates for the future'. Thus their focus, at least in the marketing and promotion, if not in policy, is focusing on the generic attributes of their graduates. Universities now explicitly list their required graduate attributes to include teamwork, communication skills and problem solving (MUni 2004; USyd 2006; MelbUni 2007; USQ 2007). These changes and new directions are confirmed by de Alva (2000 p 38) who states that the future, higher education will be dictated more "…by what learners need, [than] by what has been traditionally done". This is particularly true of engineering education which is under increasing pressure for change (Felder et al. 2000; Engineering Council UK (EC UK) 2003; ABET 2007).

Traditionally, taught by lectures, supplemented by tutorial (theoretical numerical problem solving) and practical (laboratory) classes, engineering education has always been content driven with staff enforcing rigid course objectives. Both academic staff and students consider that the main objective of a subject is students' abilities to pass the final examination. These courses have, in the past, ensured technically competent graduates who have successfully met the responsibilities of the profession to provide goods and services to society. The subsequent development of other professional attributes relevant to communication and teamwork was then accepted as a responsibility of employers, and dependent on the developing maturity of the individual.

The needs of employers for immediately productive professionals, and the need of professional registration bodies for globally comparable graduates, are forcing engineering educators to increasingly focus on generic graduate attributes. In Australia, the national accreditation body (Engineers Australia) has focused heavily on the development of graduate attributes required in the engineering profession in addition to (but not at the expense of) discipline-specific technical knowledge. It now nominates a range of attributes and requires 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 (Engineering Council UK (EC UK) 2003; Engineers Australia 2004; ABET 2007). In short, the main focus of engineering higher education now is on outcomes and not the process.

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 29 out of 38 nominated success factors. Thoben and Schwesig (2002) and National Academy of Engineering (2004) extend the generic skill of teamwork, 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 major challenge especially given the current economic climate in higher education in Australia and the resistance to educational cultural change in the conservative world of engineering academics.

Engineering education and curriculum is particularly vulnerable to changing requirements of society and the profession. Its curricula and teaching philosophies are steeped in tradition and it is generally recognised that there is a propensity for academics to be focused on a narrow research area, often very theoretical in nature. There is a widening gap between academia and professional practice particularly in Australia where there is no requirement for academics to have relevant or current industry experience or qualifications in higher or adult education.

A strong, perhaps universal, trend in universities is to employ staff who are solely focused on research and have not worked in industry (Gottlieb & Keith 1997). Without evolution of engineering curricula and teaching practices universities will become decoupled from industry requirements and lose out to educational providers who can produce graduates who are technologically competent and intellectually confident about their place in the global economy. Related to this is a requirement for a shift from theoretical content to “outcomes” or “employer based” competency (Howell et al. 2003).

Engineering education reviews have mirrored these developments but it is debatable as to the extent the relevant recommendations have been implemented and evaluated in Australian universities. The gap between academic and engineering practice is even greater for distance education students. The majority of these students are already employed, at some level, in the engineering industry. Every day they see the real application, and practice of the theory taught, and are increasingly disillusioned with the differences. Whilst there is an argument for inclusion of some content on the basis of ‘*education versus training*’, the need for more relevancy and recognition of prior learning is becoming critical. This is particularly true for those universities with a diverse student cohort that is not solely focused on full time on-campus school leavers.

In general, education change in universities and in particular, change in engineering education is generated by:

- A changing cohort of students with diverse backgrounds, educational and work experiences, personal requirements and commitments;
- A more ‘consumerist’ approach to higher education by students who are demanding courses and content to meet their professional needs;
- Professional bodies and employers requiring new and different attributes from students to meet increasing competitive and global markets;
- An explosion of information technology to source data and information instantaneously;
- A predicted shortfall in engineering graduates (Bachelor of Engineering) and a growth in Engineering Technologists (Simcock 2008).

The follow section details the particular context and factors influencing change at USQ and the corresponding responses to such stimulus.

3.5 USQ Context and Responses

University of Southern Queensland (USQ) like other universities and engineering faculties has been impacted by these changing needs and the rapidity of that change. However, as previously noted, USQ is differentiated from other Australian universities by the extent of its distance education program and by the variation in background of its students. Over 2,500 students are currently studying engineering programs at USQ, with approximately 80% studying off campus by distance education and via online offerings and the remainder attending classes at one of the three campuses. The off-campus (distance) students are located across Australia and around the world (University of Southern Queensland 2009).

Error! Reference source not found. shows the long term average age distribution of commencing students in engineering degree programs. While about 80% of on-campus students are under age 24 at commencement, the external students' ages are much more widely spread. A total of 70% of external students are aged between 20 and 34 at commencement. As would be expected, the background of these students reflects the spread in age, with many bringing experience from a range of different jobs to their studies. All courses in the Faculty of Engineering and Surveying (FOES) are developed with an emphasis on the distance (off-campus) offering. This mode of offering requires more organisation and planning, with study packages for traditional courses containing all the course material, assignments and even sample examinations being prepared about six months before the semester starts. On-campus students can purchase most of these packages from the University bookshop.

The Faculty offers engineering degrees at three levels (Associate Degree, Bachelor of Technology and Bachelor of Engineering) requiring two, three and four years of full time study respectively. It also offers a number of double degree programs (e.g. Bachelor of Engineering and Business) which are of five years duration. The programs include major studies in Agricultural, Civil, Computer Systems, Electrical and Electronic, Environmental, Instrumentation and Control, Mechanical, Mechatronic and Software Engineering as well as Surveying (Spatial Science) and Geographic Information Systems. Programs, majors and duration are summarised in

Table 3-1. All these programs share the same core courses, particularly at first year (but there is no specific common first year). This results in a very wide diversity of student backgrounds and abilities in the foundational units.

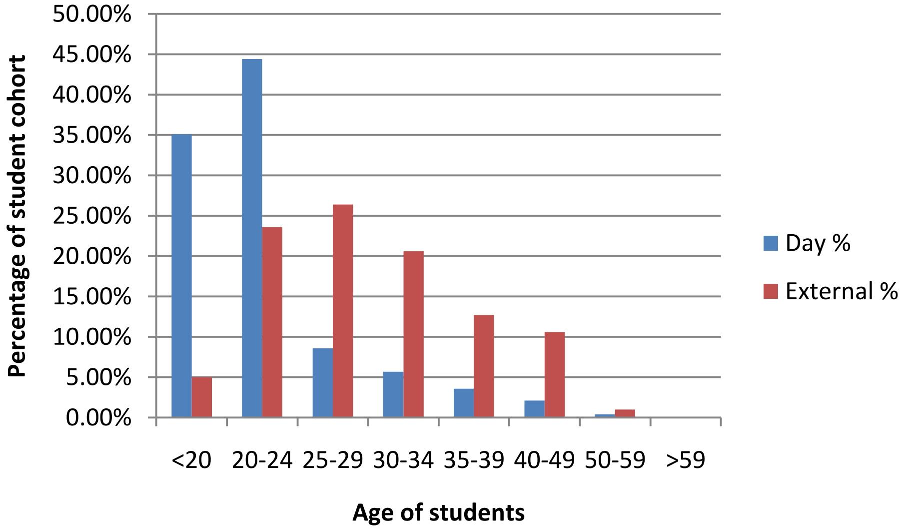

Figure 3-1 Commencing student age profiles at USQ in the engineering programs

Table 3-1 Undergraduate programs in Engineering and Surveying

Field of Study	Five Year Programs	Four Year Programs	Three Year Programs	Two Year Programs
Agricultural Engineering	✓	✓		
Building & Construction Management			✓	
Civil Engineering	✓	✓	✓	✓
Computer Systems Engineering	✓	✓	✓	✓
Electrical & Electronic Engineering	✓	✓	✓	✓
Environmental Engineering	✓	✓	✓	✓
Geographic Information Systems			✓	✓
Instrumentation & Control Engineering		✓		
Mechanical Engineering	✓	✓	✓	✓
Mechatronic Engineering	✓	✓		
Software Engineering	✓	✓		
Surveying/ Spatial Science		✓	✓	✓

It is very easy to lecture and/or assess these students at a level that is either too high for the Associate Degree students or too low for the Bachelor of Engineering students. This contributed to a high failure rate, in excess of 50% of the class, in 13 of the 28 foundational courses offered by the faculty. A review of student progression undertaken in 1998, found that 15 of the high failure rates were associated with on-campus course offerings while ten were associated with the distance offering.

Of more serious concern was the clear indication that students in the Associate Degree program were faring significantly worse than those in the Bachelor of Engineering program. Of the thirteen courses with high failure rates, nine had Bachelor of Engineering students who did not feature in the failing cohort. The Bachelor of Engineering Technology students performed better than the Associate Degree students, but not as well as the Bachelor of Engineering students. When the analysis was extended to cover all eleven foundational courses that were shared by the two student cohorts, it was found that the on-campus Associate Degree students had failure rates two and a half to three times as high as the Bachelor of Engineering (or Surveying) students undertaking the same material. The corresponding trend was noticeable in the award of higher grades for these courses.

Given the need to maintain articulation pathways between the program levels, it was not viable to improve student progression by offering the shorter Associate Degree and Bachelor of Engineering Technology program students easier (or different) courses. After contemplating these results, the Faculty concluded that a more comprehensive pedagogical approach was required. Hence the Faculty re-structured part of its program core to:

- Address poor progress and retention rates;
- Use to advantage of the range of students' prior knowledge;
- Better equip graduates with the range of attributes required by Engineers Australia, society and the university;
- Ensure that graduates have additional attributes now required by society, the profession and the university itself. These attributes include analytical and critical-thinking skills, problem-solving skills, independent learning skills,

communication skills, information acquisition, organization and presentation skills and decision-making skills.

There are many possible solutions to meeting such requirements. The main constraints for USQ, in identifying, selecting and adopting a solution, were the diverse student cohort and the distance education component to all programs and courses. Secondary issues included resource implications and the sustainability of changes to the curricula, pedagogy and delivery. The decision to adopt PBL followed from these considerations.

3.6 The Case for PBL

The increasing pressure for change has demanded responses from engineering education. Traditionally taught by lectures, supplemented by tutorial (numerical problem solving) and practical (laboratory) classes, has always been content driven with staff enforcing rigid course objectives. This is further formalized at USQ with staff and students working to a strictly enforced set of Course Specifications which detail, not only course objectives and specific topics, but the percentage of the course and hence assessment allocated to each topic. Both academic staff and students have believed that the main objective of a subject to be able to pass the final examination. These courses produce technically competent graduates who have successfully met the responsibilities of the profession to provide goods and services to society. Subsequent development of other professional attributes relevant to communication and teamwork has been accepted as a responsibility of employers, and depended on the developing maturity of the individual.

Engineering students are generally criticized as having inadequate cross-disciplinary integration, insufficient exposure to “real” problems and situations and insufficient retention of basic knowledge. This is similar to the criticisms of medical students in traditionally taught courses as reported by Koshmann et al (1994). Whilst these perceived shortcomings are very much a matter of judgement and opinion, it is generally accepted that the amount of knowledge to assimilate and the level of analytical skills to be developed in four years is very challenging, even in specialized branches of engineering. Furthermore, the previous paradigm in which graduates are recognized as learning on-the-job during the first two to four years of employment is no longer generally available; and to compound the problem much of the technical content given to students becomes redundant within the first decade of their working life.

These constraints are forcing the re-consideration of the approach to engineering education. There is general recognition that the solution lies in laying a foundation of abilities in engineering analysis and synthesis, complemented by lifelong learning (Felder & Brent 2003). Many are now recognizing the additional benefits available from such an approach. McLoughlin and Hollingworth (2000) point to the need to achieve higher order thinking outcomes and curricula in science, but their argument applies equally well to engineering. They argue that curricula must be organised so that learners gain exposure to different problem types, are given opportunities to encounter and analyse real life problems, generate, test and refine solutions. The traditional methods of learning engineering science as facts, figures and formulae, result in learning that encompasses no more than recall of facts, rote learning and memorisation. Many universities are starting to re-structure their courses to meet these new expectations and Problem-Based Learning becomes an attractive vehicle for such changes.

However, this argument is not yet accepted by all engineering educators. They worry that the graduates they produce will be ill-prepared to meet the range of problems that they will be confronted with on graduation. This answer is not unexpected: Pereira et al (1993) noted the same tendency in medical education, and identified a common failing with PBL programs due to entrenched non-constructivist models of learning and learner-teacher power relations.

The change to PBL presents a disruption to existing assumptions and has resulted in resistance to the PBL programs. Camp (1996) referred to the introduction of PBL courses as a “paradigm shift”, and this remains the case in engineering education. While more and more examples of PBL are being reported in engineering education in some form, the discussion of PBL in distance or online mode is still rare. However, such an implementation was required for USQ if it was to implement the necessary curriculum change. In addition, limited resources and equity concerns dictated that on-campus and distance students had the same opportunities and educational experiences.

3.7 Summary

This chapter has established the need for a new response to engineering education and sets out the rationale and methodology for change, particularly within the constraints imposed by USQ's market and student demographics. However, the wider implications for reform in engineering education are clear. Global economics, technology and student demands are challenging the traditional didactic approach to higher education. Carefully designed courses utilising communication and educational technology will not only meet the student requirements for increased flexibility in, and access to, higher education, but will also meet future requirements of the profession.

The new objectives of engineering education could be met by adopting a PBL approach to a strand of the core courses dealing with engineering projects, problems and design. Whilst PBL was seen to be relatively easily incorporated into traditional on-campus offerings, the move to distance education was not easily justified or implemented and literature to support and guide the design and implementation was very limited.

The following chapters of this dissertation document the innovative implementation of PBL to engineering education through distance education and virtual teams. The evaluation, validation and continuous improvement of the strategy, covering assessment, team and student communication, curriculum, staff training and facilitation of student learning has been governed by an overarching action research methodology supplemented by appropriate detailed investigations in particular areas as required. There are details in the following chapters.

4 Methodology

4.1 Introduction

The research underpinning this dissertation spanned a decade and utilises both qualitative and quantitative methods. The research was driven by the need to answer specific research questions at specific points in time. For example can the diversity of the student cohort be successfully used in supporting student learning through peer mentoring? Background content knowledge was gained through analysis and synthesis of published literature in a wide range of fields and over time various research methodologies were investigated and used to effectively investigate specific questions and clarify observations and results. The research not only contributes to the body of knowledge on several areas of interest but ultimately contributed to the author’s knowledge of the content and an increase in expertise in educational research methods.

Research involves three main aspects. First, the identification of some content that is of interest; second, some ideas, background and theory that give meaning to the content and third, some methodologies with which the ideas and content can be investigated. Research is extensive and complex and does not involve simply collecting and analysing data (Bringberg & McGrath 1985). Ultimately, regardless of choice of methodology, rigor of the methodology, validity of the data or the associated theoretical framework, the research outcomes will be influenced to some extent by the researcher, their prior background, experience and education.

This chapter presents discussions of two critical components:

1. The research process. This underpins not only specific investigations, but an overarching methodology. This has contributed to the growth of the author as a researcher, a growth of the content knowledge and contributions to the published body of knowledge in the relevant fields.
2. The research methodology and methods. The research which contributes, either directly or indirectly, to this dissertation spans a decade of work by the author. Areas of investigation, ideas about investigation and the methodology for investigation varied according to time, knowledge and phase

of the research. They span both quantitative and qualitative methods to give higher quality of inferences and validity of results.

4.2 The Research Process – a learning journey

Faulconbridge (2009) discusses the continuum of education, moving from 'novice to expert' by unique educational experiences as shown in Figure 4-1. The educational experience can result in a positive change as shown in Figure 4-1, no change, or even a negative change. He argues that the journey each learner takes is different because of variables such as learning styles, approaches and prior experiences.

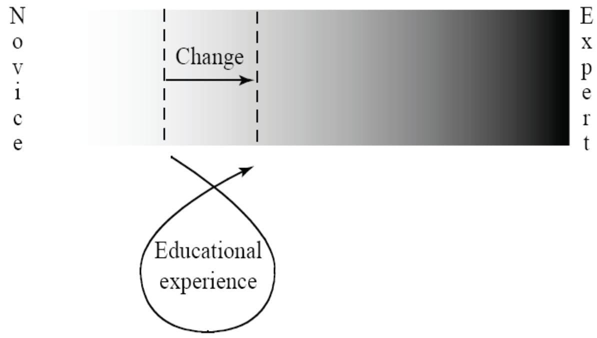

Figure 4-1 Educational experience resulting in change
(Faulconbridge 2009, p. 17)

The process of research can be conceived as a similar development to the learning process more generally. The researcher begins the journey along the continuum of a body of knowledge with a unique starting point depending on prior knowledge and experiences. For the purposes of this dissertation the 'educational experience' as noted in Figure 4-1 is replaced with a 'research experience', which is generated by the research question or the 'need'. The researcher may begin as a 'novice' new to research, move into a new area of research where prior research methods and experience may not apply to the new area, or begin at any point along the continuum. The move into a new area of research is the experience of most engineering education researchers who have expertise in a discipline or technical research area but begin as novices, to some degree, in 'education research'. It is this process, a personal learning journey, through the fields of educational research methodologies, as applied to a practical engineering education research perspective, which forms part of this methodology discussion.

Kirchner and VanVilstern (1997) propose that novice researchers need experiences composed of a knowledge component which includes the theories and facts, concepts and procedures and a skill development component. Pietersen (2002) claims that "…competence in conducting research can only be gained through experiencing the research process as a problem-solving event". Research is more than a mechanistic use of a given set of principles and techniques in a particular context (Burgess 1981). Consequently, researchers move along the continuum from novice to expert as they gain techniques and background knowledge both in *research* and in the *context*; a research and *learning* experience.

A 'research experience', as a whole experience, can be seen as analogous to action research. Steps in an educational research process are: identifying a need, question or research problem, reviewing the literature, specifying a purpose, collecting data, analysing and interpreting the data, reporting and evaluating the research (Creswell 1994, p. 51). All steps can use both quantitative and qualitative processes, but do not necessarily follow a linear process. For example, the initial research need or question directs the literature review but the literature may, in turn, modify or change either the initial research question or the initial hypothesis which may in turn alter the research method. This iterative process is similar to the action research process.

Action research is a well recognised research methodology in its own right, but it may not be the actual research methodology employed by the researcher. In the context of this dissertation it is used to explain the growth of a researcher, her understanding and her contribution to a body of knowledge as shown in Figure 4-2

Action research is known by many different names but at its core is "learning by doing". A problem is identified, a solution and evaluation strategy is planned and undertaken and results analysed to determine effect. Numerous iterations or cycles of this process may be undertaken.

The literature details four phases of action research to be conducted within each cycle. These are:

- Problem is identified and initial data set collected
- Numerous possible solutions identified leading to single plan of action which is implemented
- Data collection and analysis
- Interpretation and reflection.

The similarities between this process and a common *engineering* problem solving process are clear. However, the differentiating factor is that action research "…stresses the importance of learning [to the researcher] as a primary aspect of the research process" (Gilmore et al. 1986).

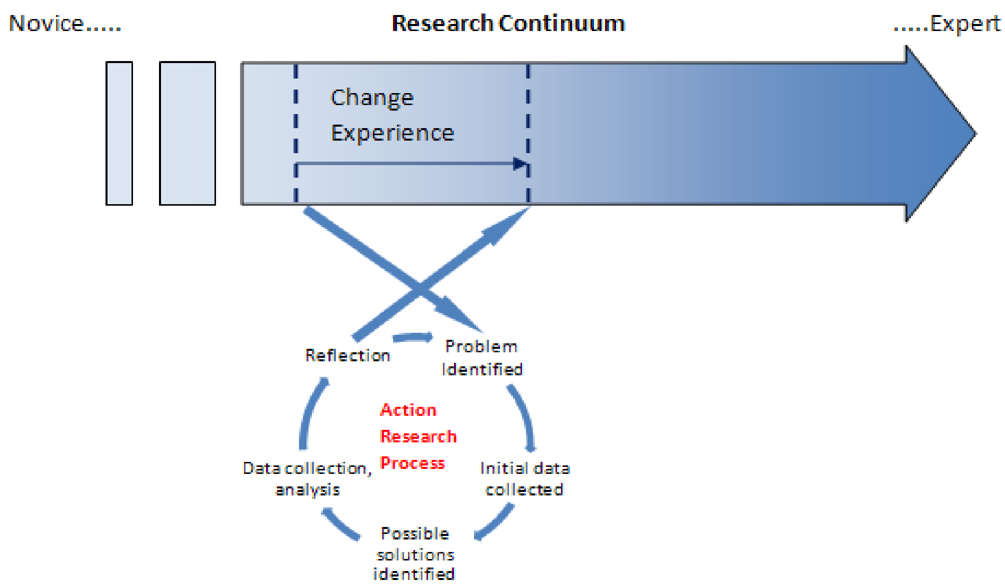

Figure 4-2 Research experience

Exploring the current literature (Figure 4-3), is critical to both Phase 1 of an action research process and the 'research experience'. The literature adds to the knowledge of the researcher and may form, or reform, the research question. Even after the research project has been completed, the investigator may return to the literature and see the theory in a new, or at least, different light. New interactions and relationships in the context are discovered. The researcher is learning both about the context and the research experience and methodology. Therefore, by ‘researching’ a problem the researcher is moving along the continuum from novice to expert.

At key points, however, the researcher can have innovative ideas which, when tested, add to the body of knowledge (BOK), as illustrated in Figure 4-3.

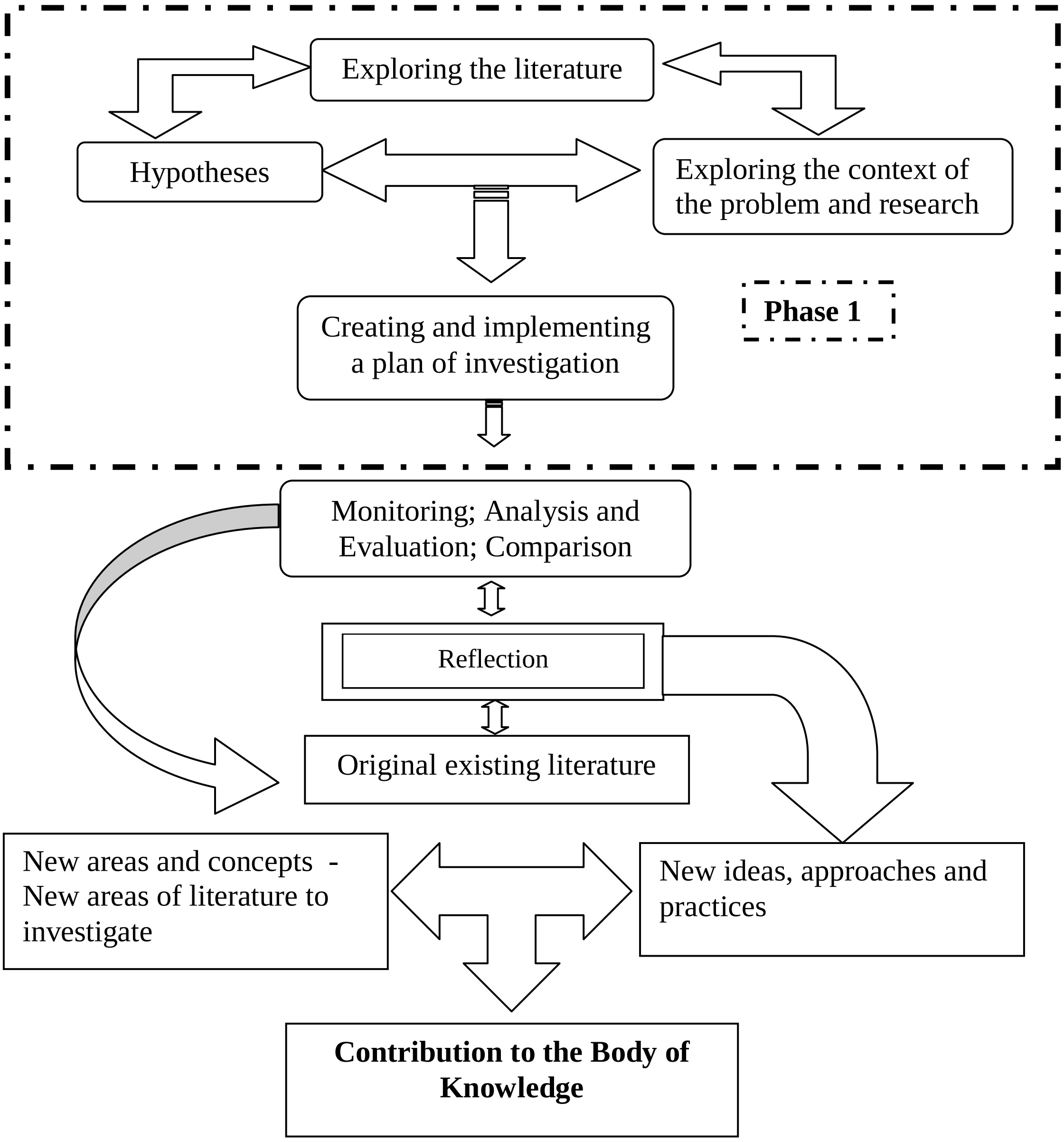

Figure 4-3 Research contributing to the body of knowledge – a personal synthesis

This change experience occurs not only in the ‘big picture’ context as an overarching approach to research and development of experience, expertise and knowledge, but also within each specific area of research. In the context of this dissertation, this means that a research experience has changed the author's knowledge in a number of fields including PBL, virtual teams and teamwork and assessment, all underpinned by the theories of distance education and the recognised need for academic staff professional development. This is shown in Figure 4-4.

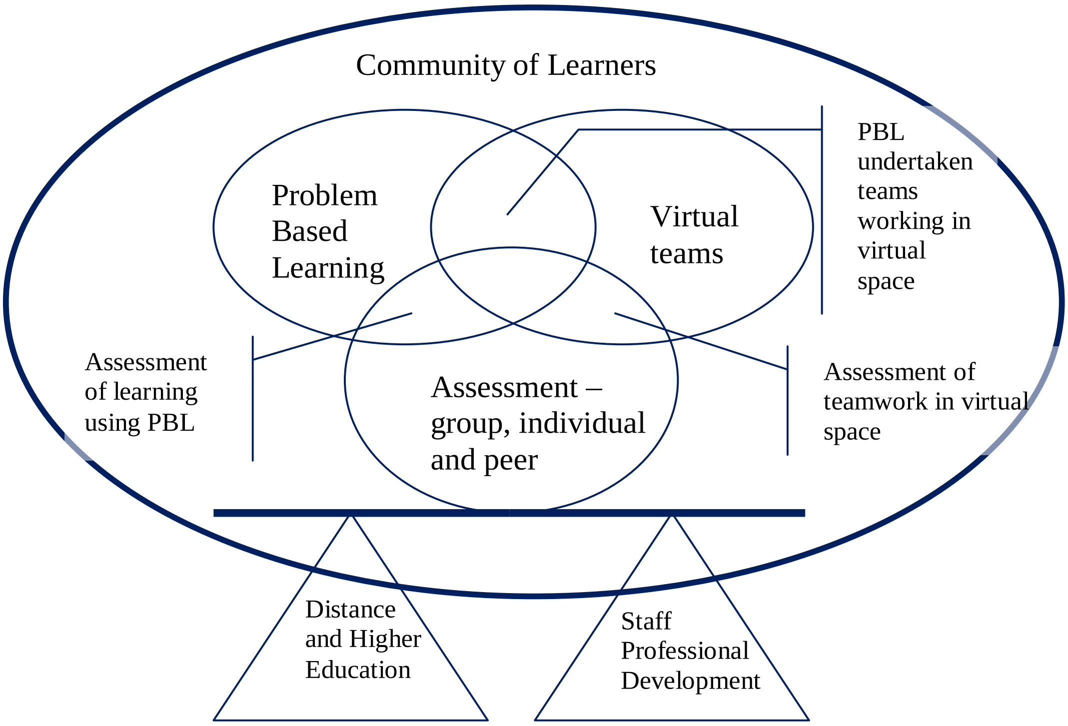

Figure 4-4 Areas and interactions of investigation

Table 4-1 shows the list of publications directly supporting the work of this dissertation, the research 'experience' and the contributions to the body of knowledge. Each grouping of publications supports the work of chapters 5 to 9.

Table 4-2 lists supporting publications which have supported development, contributed to the research experience by literature review, initial data collection and familiarisation with different research methodologies as detailed in the following sections of this chapter. They are the background or initial work for the main publications.

The total package of publications show a synthesis of research in different areas into a unique and novel package which delivers key graduate attributes to all students regardless of their mode of study; on-campus or distance.

Table 4-1 Publications showing the work of author and contributions to BOK

Challenging the Boundaries – The Application of PBL to Distance and Online Education

Brodie, L. 2009, 'eProblem Based Learning – Problem Based Learning using virtual teams', *European Journal of Engineering Education*, vol. 34, no. 6, pp. 497-509. [4]

Brodie, L. 2009, 'Transitions To First Year Engineering – Diversity As An Asset', *Studies in Learning, Evaluation, Innovation and Development* vol. 6, no. 2. pp 1-15

Brodie, L. & Porter, M[5]. 2008, 'Engaging distance and on-campus students in Problem Based Learning', *European Journal of Engineering Education*, vol. 33, no. 4, pp. 433-443.

Cochrane, S., Brodie, L. & Pendlebury, G. 2008, 'Successful use of a wiki to facilitate virtual team work in a problem-based learning environment', *AAEE*, Yeppoon, QLD.

Brodie, L. 2007, 'Problem Based Learning for Distance Education Students of Engineering and Surveying.', *Connected - International Conference on Design Education*, Sydney.

Brodie, L. 2007, 'Reflective Writing By Distance Education Students In An Engineering Problem Based Learning Course', *Australasian Journal of Engineering Education*, vol. 13, no. 1, pp. 31-40.

Brodie, L. & Porter M. 2006, 'Problem based learning for on-campus and distance education students in engineering and surveying', *EE2006 International Conference on Innovation, Good Practice and Research in Engineering Education*, vol. 1, eds Doyle S & Mannis A, The Higher Education Academy, Liverpool, England, pp. 244-255.

Non – refereed publications:

Brodie, L. 2008, ‘Problem Based Learning, Virtual Teams and Future Graduate Attributes’, *Keynote presentation delivered to MIT Symposium on Project and Problem Based Learning in Higher Education*, MIT, Boston. (Multimedia presentation)

[4] Sections of this publication are also used in Chapter 6 – Forming and supporting virtual teams
[5] Assoc Professor Mark Porter was Moderator of the strand of PBL courses at the time of publication

Forming and Supporting Virtual Teams in Higher Education Using a Learning Management System

Brodie, L. & Gibbings, P. in press, 'Connecting learners in Virtual Space – forming learning communities', in L. Abawi, J. Conway & R. Henderson (eds), *Creating Connections in Teaching and Learning*, Information Age Publishing.[6]

Brodie, L. 2009, 'eProblem Based Learning – Problem Based Learning using virtual teams', *European Journal of Engineering Education*, vol. 34, no. 6, pp. 497-509.

Brodie, L. 2009, 'Virtual Teamwork and PBL - Barriers to Participation and Learning', paper presented to the *Research in Engineering Education Symposium (REES)* , 20–23 Jul 2009, Cairns, QLD, Australia.

Brodie, L. 2007, 'Problem Based Learning for Distance Education Students of Engineering and Surveying.', *Connected - International Conference on Design Education*, Sydney.

Brodie, L. 2006, 'Problem Based Learning In The Online Environment – Successfully Using Student Diversity and e-Education', *Internet Research 7.0: Internet Convergences*, Hilton Hotel, Brisbane, Qld, Australia,

Assessment

Brodie, L & Gibbings, P. 2009 ‘Comparison of PBL assessment rubrics’, *In: 2009 Research in Engineering Education Symposium*, 20–23 Jul 2009, Cairns, Australia.

Brodie, L & Gibbings, P. 2008, 'Assessment Strategy for an Engineering Problem Solving Course', *International Journal of Engineering Education*, vol. 24, no. 1, Part II, pp. 153–161.

Brodie, L. 2008, 'Assessment strategy for virtual teams undertaking the EWB Challenge'. *In: AaeE 2008: 19th Annual Conference of the Australasian Association for Engineering Education*, 07–10 Dec 2008, Yeppoon, Queensland, Australia.

Brodie, L. 2007, 'Reflective Writing By Distance Education Students In An Engineering Problem Based Learning Course', *Australasian Journal of Engineering Education*, vol. 13, no. 1, pp. 31–40.[7]

Brodie, L. & Gibbings, P 2006, 'Skills audit and competency assessment for engineering problem solving courses', *Proceedings of The Internal Conference on Innovation, Good Practice and Research in Engineering Education*, vol. 1, eds Doyle S & Mannis A, The Higher Education Academy, Liverpool, England, pp. 266–273.

Gibbings, P & Brodie, L. 2006 ‘An Assessment Strategy for a First Year Engineering Problem Solving Course’, *17th Annual Conference of the Australasian Association for Engineering Education*, Auckland, New Zealand, 10–13 December. p 33

[6] This publication is also referred to in Chapter 8 Developing a learning community
[7] Sections of this publication are also used in Chapter 9 – Staff Training and Professional Development

Developing a Learning Community

Brodie, L.M. & Gibbings, P. in press, 'Connecting learners in Virtual Space – forming learning communities', in L. Abawi, J. Conway & R. Henderson (eds), *Creating Connections in Teaching and Learning*, Information Age Publishing.

Gibbings, P.D. & Brodie, L.M. 2008, 'Team–Based Learning Communities in Virtual Space', *International Journal of Engineering Education*. Vol. 24, no. 6, pp. 1119–1129

Brodie, L.M. & Gibbings, P.D. 2007, 'Developing Problem Based Learning Communities in Virtual Space', *Connected 2007 International Conference on Design Education*, University of New South Wales, Sydney, Australia.

Staff Training and Professional Development

Brodie, L., Aravinthan, T., Worden, J. & Porter, M. 2006, 'Re-skilling Staff for Teaching in a Team Context.', *EE 2006 International Conference on Innovation, Good Practice and Research in Engineering Education*, Liverpool, England, pp. 226-231.

Table 4-2 Supporting publications

Brodie, L & Loch, B. 2009, 'Annotations with a Tablet PC or typed feedback: does it make a difference?' In: *AaeE 2009: 20th Annual Conference for the Australasian Association for Engineering Education: Engineering the Curriculum*, 6–9 Dec 2009, Adelaide, Australia.

Brodie, L., Zhou, H. & Gibbons, A. 2008, 'Developing a Software Engineering Course using Problem Based Learning', *Engineering Education*, vol. 3, no. 1, pp. 2-12.

Sabburg J., Fahey P., Brodie L. 2006 'Physics Concepts: Engineering PBL at USQ. Australian Institute of Physics' *17th National Congress 2006*, Brisbane, Australia, 3–8 December 2006 p 1–4 (paper no 105) http://www.aip.org.au/Congress2006/136.pdf

Brodie, L.M. & Porter, M.A. 2005 ,'Responding To Changing Demands In Engineering Education – PBL For Distance And On–campus Students'. *The Higher Education Academy – Engineering Subject Centre* online at http://www.engsc.ac.uk/downloads/pbl_aus.pdf

Brodie, L. & Porter, M. 2004, 'Design, Implementation and Evaluation: an entry level Engineering Problem Solving course for on-campus and distance education students'. *5th Asia Pacific Conference on Problem Based Learning – Pursuit of Excellence in Education*, Petaling Jaya, Malaysia, 15–17 March, 2004

Wood, D. & Brodie, L. 2004, 'Student Perspectives on Engineering Problem Based Learning – The Portfolios'. *5th Asia Pacific Conference on Problem Based Learning – Pursuit of Excellence in Education*, Petaling Jaya, Malaysia, 15–17 March, 2004

Brodie, L. & Borch, O. 2004, 'Choosing PBL paradigms: Experience and methods of two universities', *Australasian Association of Engineering Educators Conference*, eds Snook C & Thorpe D, Faculty of Engineering and Surveying, USQ, Toowoomba, QLD, University of Southern Queensland, Toowoomba, Australia, pp. 213-223.

Brodie, L. & Porter, M. 2004, 'Experience in Engineering Problem Solving for On-campus and Distance Education Students', *Australasian Association of Engineering Educators Conference*, eds Snook C & Thorpe D, Faculty of Engineering and Surveying, USQ, Toowoomba, QLD, University of Southern Queensland, Toowoomba, Australia, pp. 318-323.

Brodie, L. & Porter, M. 2001, 'Delivering Problem Based Learning courses to engineers in on–campus and distance education modes'. *3rd Asia Pacific Conference on Problem Based Learning.* Yeppoon, 9–12 Dec.

Porter, M.A. & Brodie, L. 2001, 'Challenging tradition: Incorporating PBL in Engineering Courses at USQ'. *3rd Asia Pacific Conference on Problem Based Learning*, Yeppoon, 9–12 Dec.

4.3 Research Methods

A range of research methods have been employed to determine, investigate and validate the main areas and themes associated with this dissertation. The research has been carried out in a field or combination of fields over time. The research methods are not driven by publication, but by the need to answer a research question. For each publication methods varied according to area of research and the time, phase and range of each investigation and the knowledge and experience of the author (researcher). The overarching investigation adheres to an action research model, but the model is repeatedly applied at a number of levels

Largely, the extensive research and corresponding publications follow an explanatory mixed methods design (Creswell 1994). Initial and early publications used mainly quantitative data collected from surveys, analysis of learning management system (LMS) and student grades. These results provided a general picture of PBL in virtual teams in engineering education and its corresponding issues. Later publications used quantitative data corroborated by qualitative data to refine, extend and explain results. The mixing of quantitative and qualitative methods results in higher quality of inferences and validity of results (Teddlie & Tashakkori 2003). The linking of qualitative and quantitative data is supported by the literature which cites three board reasons for doing so: to enable confirmation or corroboration of each other via triangulation, to elaborate or develop analysis thus providing richer detail and to initiate new lines of thinking by providing fresh insight (Miles & Huberman 1994). Green et al (1989) propose that this list be extended as mixed method studies can help sequential research as the results of the first method can inform the second's sampling and instrumentation and can expand the scope and breadth of a study by using different methods in different components. The use of reflection (new lines of thinking by providing fresh insight) and results informing subsequent investigations and methodologies is in line with the overarching action research proposed by the work of this dissertation.

In the initial implementation of PBL in engineering education using virtual teams, student and staff perceptions and views were investigated following an action research paradigm as shown in Figure 4-5 and used both qualitative and qualitative methods.

The investigation over several offers of the course to both on-campus and external students used a range of surveys. The data collection and subsequent analysis allowed a fine tuning of implementation and assessment strategies and resource development as indicated by the stakeholders in each semester of offer. For example, staff and students indicated a very high workload associated within first year course, ENG1101 *Engineering Problem Solving 1*. Analysis indicated a change in assessment would contribute greatly to reducing workload and subsequently, over several offers, the assessment was modified until the workload for all was more appropriate (Refer to Chapter 5).

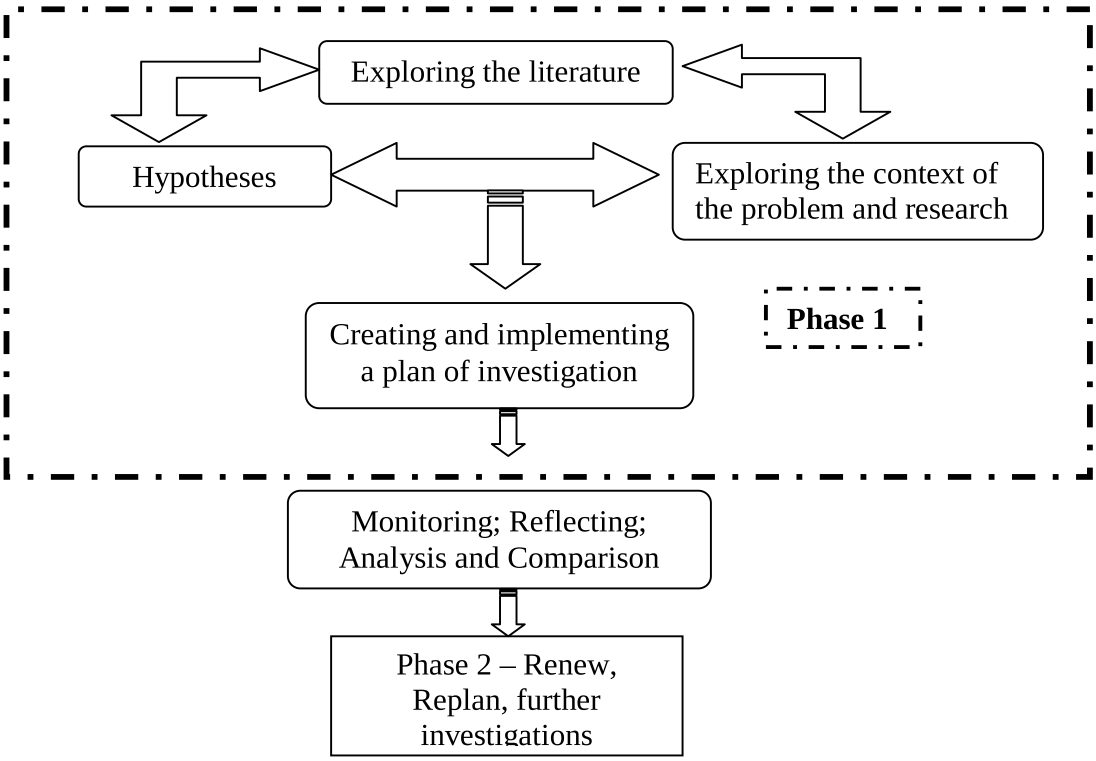

Figure 4-5 Action Research Strategy

As the implementation strategy was bedded down, more refined investigations and analysis of student learning and behaviour was undertaken. This required a variety of methodologies for data collection to provide validation and included:

- Self perception surveys

- Student and staff interviews
- Analysis of student usage of the resources and interaction through the learning management system
- Analysis of student grades
- Thematic analysis of student reflective portfolios
- Investigation of student interaction (meetings and discussions through the LMS) using a grounded theory approach

Exploration and research of a number of areas is continuing but is beyond the scope of this dissertation and is outlined the chapter on Further Work.

4.3.1 Surveys

Three main surveys were used from the inception of the course and these surveys have continued to current offers of the course and form the basis for a longitudinal study on student perceptions of learning. Two of the surveys, Facilitator and Course, are modified from the standard university evaluation questionnaires (SET). The modifications to the questions reflect the different teaching strategy and are more applicable to the pedagogy and philosophy of the course. The third survey was developed to investigate student perceptions of their learning in the course. It covered the main objectives of the course e.g. teamwork, communication, problem solving. Answers were multiple choice (five point Likert scale) and short written responses. Analysis of reflective portfolios was used to validate survey responses. Collated data has been published in numerous peer reviewed publications and is presented in the following chapters.

4.3.2 Interviews

Semi-structured interviews were used to investigate the effect of:

- The use of technology, barriers to participation and equity
- Issues relating to flexibility (or loss of) of study
- Time and workload allocations for staff and students
- Structured teamwork and study and its implication for individual participation and motivation.

Staff

Interviews and semi formal discussions have taken place with facilitators, full time and sessional staff. Feedback from staff was obtained during staff training sessions, staff team meetings and more formal focus group settings. Areas for investigation were:

- Requirements for training and professional development and the evaluation of facilitator training sessions
- Workload: in terms of marking and feedback requirements, facilitation of teams including technical requirements and team issues such as communication issues, conflict resolution and general teamwork and project management issues
- Requirements for support resources (for both staff and students)
- Barriers to student learning and participation; dealing with conflict in team
- Efficient and effective use of the Learning Management System including communication with student teams, assessment submission and monitoring team and individual processes and learning
- Evaluation of assessment strategies, marking rubrics and technologies (for example use of tablet PCs, electronic submission of assessment items).

Data and information collected was summarised and distributed to staff for validation and confirmation.

Students

Face-to-face sessions and interviews via telephone for external students were used to investigate and validate a variety of perceptions and implementation problems. Participation was voluntary but very few students chose not to participate. Students were chosen randomly from two main groups: those students who dropped the course prior to the commencement of the semester and those students who dropped the course within the first three weeks of the course. The main use of interviews was to determine reasons and possible solutions for student lack of participation in the course and hence dropping the course before the official census date.

Interviews investigated:

- Reasons for dropping the course
- Additional support or resources needed
- Perceptions towards studying teamwork in an online environment
- Self perceptions of student's current team work and communication skills

Data collected was validated by two methods. Interviews were transcribed and ten percent of randomly chosen transcriptions were emailed to students for checking and five percent of students were re-interviewed approximately 12 weeks after their initial interview to check for similarity in responses.

4.3.3 Use of Learning Management System

A learning management system (LMS) is a generic term for commercial software to aid delivering, tracking and managing education. It is a platform for the lecturer to provide course material and supporting resources to students. The software allows interactions and communication between lecturer and students, as well as between students. It also provides other functionality including assignment submission and usage statistics. In 2009, five learning management systems, Blackboard[8] (including WebCT), Moodle[9], Desire2learn[10], Sakai[11] and eCollege[12], dominate the Internet communication systems for eLearning activities. Moodle and Sakai are open source and the remaining three are proprietary. Blackboard is the dominant firm and enjoys approximately 75% of the market share. Moodle, as the next competitor, recently attained double digits at 10% (Essa 2009).

In 2008, USQ moved from WebCT (now part of the Blackboard group) to the open source software Moodle as the LMS for the University. All students can access the LMS via the USQ portal, USQConnect (recently changed to UConnect). This is linked to the student 'StudyDesk' which provides links to courses on the LMS and is individualised according to the students enrolment. All courses at USQ have a

[8] Copyright © 1997-2010. Blackboard Inc.
[9] Moodle™ is a registered trademark of the Moodle Trust
[10] Copyright © 1999-2010 Desire2Learn Incorporated.
[11] licensed by the Sakai Foundation
[12] Copyright 1999-2008 eCollege.com®

presence on StudyDesk. Whilst the way statistics are displayed varied between the two LMS platforms, similar data can be extracted from each system. Statistics where gathered from the learning management system for:

- Number and frequency of postings per student and per team
- Student time spent on StudyDesk
- Use of resources
- Communication systems used by student teams and their effectiveness

4.3.4 Thematic Analysis of Student Portfolios

Another data collection method used as part of the research for papers contributing to this dissertation was the analysis of student reflections in portfolios. There is an increasing emphasis for educating students to be ‘reflective practitioners’. This is linked to lifelong learning, and in engineering education and engineering practice it is increasingly used for professional development by Engineers Australia for accreditation procedures (Engineers Australia 2004).

Reflective learning has its roots in philosophy and was emphasised by the work of John Dewey (Orland-Barak 2004). In the educational literature reflective learning approaches focus on portfolio and journal writing. Reflective Learning has the potential to be conducive to making implicit or tacit knowledge (Schon 1987). A useful tool for expanding and facilitating reflective practice is individual portfolios.

Reflective portfolios are used to encourage and support learners to become independent learners. Students can anticipate their own learning needs and monitor their progress and their development (Heartel 1990; Wiggins 1993 as cited by; Orland-Barak 2004). Portfolios can also be used as alternative assessment instruments (Wolf et al. 1991; Wade & Yarbrough 1996; Tillema 2001).

Portfolio entries can fall into two main categories – product and process. Product entries respond to a specific stimulus or task whilst process entries are more reflective in nature and are not necessarily in response to a particular or specific prompt. In ENG1101 both types of artefacts are used and analysed by examining two hundred portfolios (one hundred from distance students and one hundred oncampus).

Within this analysis emergent patterns within the data of both the product and process are identified and analysed. Details are further discussed in chapters 5 and 6.

Emergent patterns or themes where identified, coded and classified. The thematic analysis yielded recurrent themes across the two portfolio types: teamwork, communication, technical skills and knowledge, conflicts, self knowledge and learning and professional development. Each of the thematic categories was divided into sub-categories pertaining to specific dimensions of the broader thematic category. This thematic analysis gave validation of results from surveys and is detailed in the relevant publications as required.

4.4 Summary

The extensive research and corresponding publications follow an overarching, explanatory mixed methods design. Initial and early publications used mainly quantitative data and later publications used quantitative data validated and expanded by qualitative data collection to refine, extend and explain results. Collated data has been published in numerous peer reviewed publications. Research methods for each publication varied according to area of research and the time, phase and range of each investigation along with the knowledge and experience of the author (researcher).

The extensive research covered by this dissertation spans a decade. The research not only contributes to the body of knowledge in several areas but also documents the growth of the research, both in research methodology, but also in content in the areas of interest. The publications show a significant contribution to the body of knowledge by linking existing areas of research in PBL, distance and engineering education, teamwork in virtual space (virtual teamwork) along with the supporting needs of assessment and staff training. This provides a unique and novel package of delivering key graduate attributes to engineering and spatial science students who study in either an on-campus mode but utilising educational and communication technology or true distance education mode where team members have no opportunity for face-to-face communication.

5 Challenging the Boundaries – The Application of PBL to Distance and Online Education

5.1 Introduction

This chapter outlines the integration of Problem Based Learning into the curriculum at USQ through the spectrum of initial investigation, evaluation of effectiveness and subsequent changes to seek improvement. The discussion includes development and refining of the course objectives, resources provided to students and staff, student team formation strategies and assessment.

Investigation followed an action research methodology in two phases. Firstly the initial planning and implementation are described and data from the Phase 1 investigations are given. Refer to Figure 5-1.

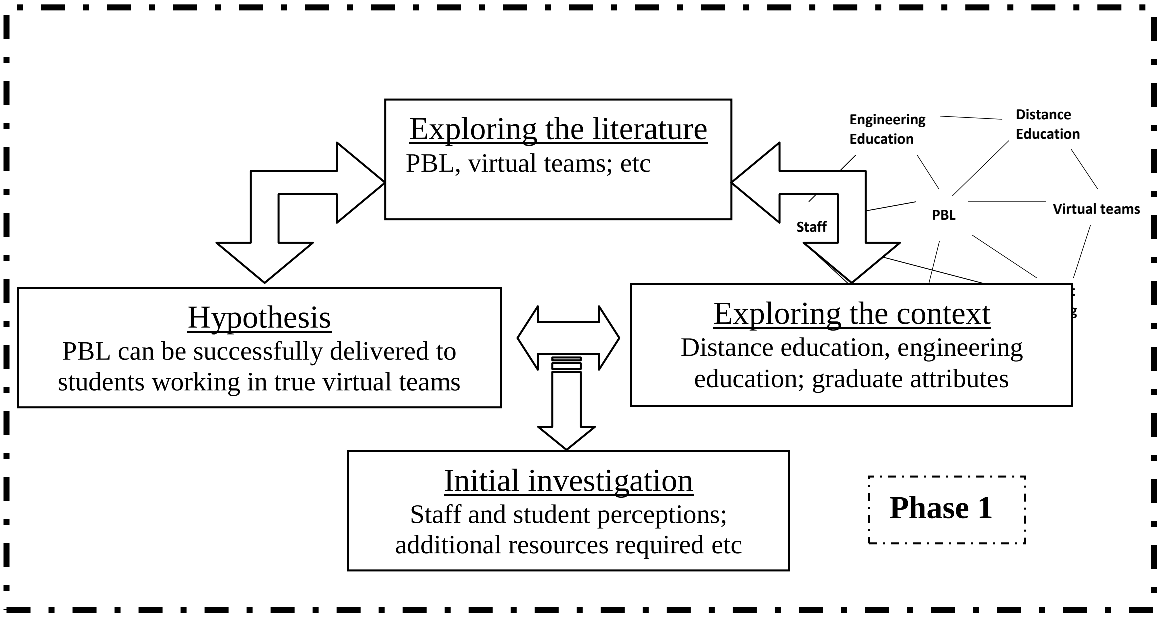

Figure 5-1 Implementation and initial investigation

Following initial data collection and analysis, subsequent changes to the course and resources are detailed, and finally, data from Phase 2 (Figure 4-5 Action Research Strategy) of the research is presented.

Data included surveys of staff and students with Likert scale and open ended responses with analysis of portfolios for validation. Sections of this chapter have also been summarised in the following peer reviewed publications:

Brodie, L. 2009, 'eProblem Based Learning – Problem Based Learning using virtual teams', *European Journal of Engineering Education*, vol. 34, no. 6, pp. 497-509. [13]

Brodie, L. 2009, 'Transitions To First Year Engineering – Diversity As An Asset', *Studies in Learning, Evaluation, Innovation and Development* vol. 6, no. 2. pp 1-15

Brodie, L. & Porter, M[14]. 2008, 'Engaging distance and on-campus students in Problem Based Learning', *European Journal of Engineering Education*, vol. 33, no. 4, pp. 433-443.

Cochrane, S., Brodie, L. & Pendlebury, G. 2008, 'Successful use of a wiki to facilitate virtual team work in a problem-based learning environment', *AAEE*, Yeppoon, QLD.

Brodie, L. 2007, 'Problem Based Learning for Distance Education Students of Engineering and Surveying.', *Connected - International Conference on Design Education*, Sydney.

Brodie, L. 2007, 'Reflective Writing By Distance Education Students In An Engineering Problem Based Learning Course', *Australasian Journal of Engineering Education*, vol. 13, no. 1, pp. 31-40.

Brodie, L. & Porter M. 2006, 'Problem based learning for on-campus and distance education students in engineering and surveying', *EE2006 International Conference on Innovation, Good Practice and Research in Engineering Education*, vol. 1, eds Doyle S & Mannis A, The Higher Education Academy, Liverpool, England, pp. 244-255.

Non – refereed publications:

Brodie, L. 2008, 'Problem Based Learning, Virtual Teams and Future Graduate Attributes', *Keynote presentation delivered to MIT Symposium on Project and Problem Based Learning in Higher Education*, MIT, Boston. (Multimedia presentation)

[13] Sections of this publication are also used in Chapter 6 – Forming and supporting virtual teams
[14] Assoc Professor Mark Porter was Moderator of the strand of PBL courses at the time of publication

5.2 PBL in Virtual Teams for Distance Education

The Faculty concluded from a review in 2000 that the new graduate attributes, recommended by Engineers Australia for engineering graduates, could be met through the introduction of Problem Based Learning (PBL) courses. More importantly it was proposed that PBL could be implemented for distance education students (Brodie 2000). The review also concluded that the didactic teaching of a number of foundational courses was not meeting the needs of the Faculty's diverse cohort of students and its unique articulated program structures (Porter 1999). Many courses (including those listed below) could not challenge the better students if they were structured to help 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, or content that could not be gained from other teaching and delivery methods. As a result the Faculty acted to undertake strategies to refocus the content and teaching methodology of over ten percent of the four year degree program.

Four engineering science content based courses (Physics and Instrumentation, Numerical Computing, Computers in Engineering and Statistics) were removed and replaced by a strand of four new courses to be delivered using PBL, with our existing final year research project as a capstone course for our four and five year programs. The new courses were designed to cumulatively develop five key attributes, summarised as:

- An ability to be flexible, to adapt to changing circumstances and to master new techniques;
- An understanding of, and ability to apply, knowledge of engineering fundamentals and basic science including computing and mathematics;
- An ability to gather and utilize information from the range of sources relevant to their field, and an ability to be discriminating in the way it is used;
- An ability to apply problem solving techniques. This encompasses:
    - problem identification, formulation and solution;
    - a capacity for analysis, evaluation and synthesis;
    - innovation and creativity;

- An ability to utilize a systems approach to design and operational performance.

The new courses had underlying objectives of introducing students to ‘real engineering’ (such as open ended, un-structured problems) at an early stage of the program and inspiring them to continue with their studies, developing teamwork and communication skills (written and electronic), the professional use of computers and technology and the habits and skills of lifelong and reflective learning.

The four courses in the strand were named Engineering Problem Solving 1, 2, 3 and 4 and integrated into the Faculty’s suite of programs shown in Table 5-1. The curriculum and specific course objectives for the four courses were completed and formal specifications written so that courses became the integrated Project and Design Strand.

Table 5-1 PBL Strand of Courses and team sizes

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

As students progress through their program, the strand was constructed such that the problem complexity and technical difficulty of each problem solving course increases as does the need for student independence and application of research (Refer to Figure 5-2). Teamwork skills are developed in the early courses such that the teams provide peer support to team members.

Many students find it a revelation that they have significant knowledge and skills from their life experience to help their teams achieve its overall task performance.

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 their research skills grow (as they progress up the strand) the team support is reduced until the student is ready to demonstrate professional level engineering work in his or her final year research project (thesis).

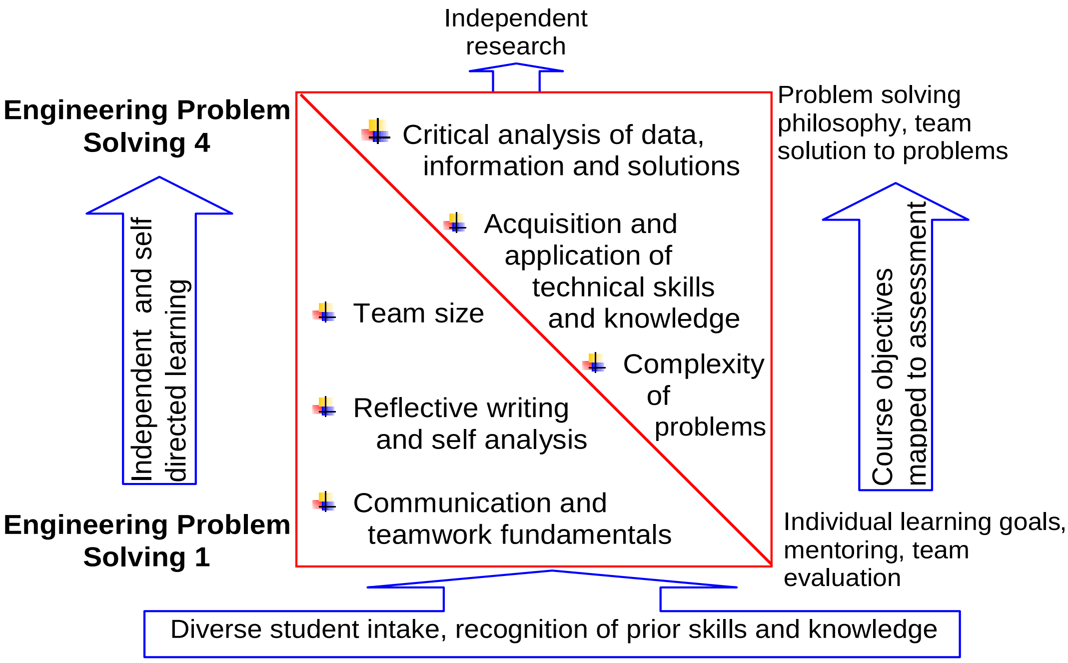

Figure 5-2 Scaffolding in the problem solving strand

The data and research presented in the dissertation is directly related to the first of the courses, ENG1101 Engineering Problem Solving 1 (EPS1). However the philosophy, curriculum foundations, staff training, assessment strategies and communication protocols laid down in EPS1 course became the foundation of the strand. Examiners (course leaders) and academic teams of the subsequent courses used the model and supporting material and made only minor changes to suit differing course objectives such as in assessment, where in higher courses there is less emphasis on team process and reflection.

Previous chapters described the required curriculum change to implement PBL within the Faculty in a meaningful way by simultaneously delivering significant technical content and the Engineers Australia required graduate attributes. Anticipated problems and challenges with the curriculum change included:

entrenched staff attitudes to what constitutes appropriate engineering 'content' and traditional delivery methods; workload implications; the diversity of the student cohort; lack of literature to guide the design and implementation of PBL for distance students and developing a suitable skill in academic staff for implementation of PBL and effective facilitation of teams.

To begin the process it was necessary to develop the following specific objectives for the new EPS1 course:

- Contribute as part of a professional team working on engineering problems;
- Understand the requirement for leadership in a successful engineering team;
- Demonstrate an understanding of group dynamics by negotiating roles and timelines for a given task;
- Seek and evaluate the input of other team members;
- Employ prior knowledge and experience to assist in solving a problem, recognizing the value of such prior knowledge from people with diverse backgrounds;
- Identify and use appropriate scientific and mathematical techniques to explain phenomena encountered in the set range of problems;
- Present results in an acceptable engineering manner;
- Understand the requirements for measuring physical properties;
- Use basic statistics to analyse measurements and explain the variation that occurs in properties;
- Explain the difference between "data" and "information";
- Use a computer for general communication and the production of technical reports;
- Understand computer terminology;
- Describe the concepts of Systems Analysis;
- Begin to apply systems analysis to defined engineering systems, problems or projects;
- Demonstrate a basic skill level in engineering problem solving.

These objectives were the starting point for course development and for planning a suitable delivery and assessment strategy in line with a PBL methodology. They also became the initial reference point for review and evaluation of the course.

EPS1 focuses on 'setting the scene'. It introduces students to PBL and has a significant emphasis on teamwork, conflict resolution, problem solving skills and strategies, application and sharing of prior knowledge (peer assistance and mentoring), self directed learning and reflection, communication skills (both as individuals and as a team), task allocation and finding and applying appropriate resources to the problem.

Students are allocated to a team of six to eight members, as indicated in Table 5-1 and assigned a staff member to act as team *facilitator*. Resources provided for the teams in the course include:

- A course resource web page where problems are released and specific resources are provided or indicated to help address the problem or improve the team operation. Initially this web page included a Frequently Asked Question (FAQ) section, regular tips and hints from the Examiner and extra resources particular to each problem. However with the implementation of a different Learning Management System (LMS) most of these have been replaced by information provided on 'USQStudyDesk[15]'. The web page has been retained as a 'backup' in case the University LMS should be down for an extended period and as a general file archive.
- Communication facilities through a university wide commercial LMS (WebCt, recently changed to Moodle). This provides email, discussion boards (or forums) 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/projects.

[15] USQStudyDesk – "*access to Start–up materials (i.e the introductory materials and the first two modules of the study book) and any of the following: discussion forums, recorded lectures, past exam papers and assessment items, including any CMA tests, for each course*" (http://www.usq.edu.au/currentstudents/offcampus/usqconnect/default.htm accessed 20/8/08)

The technical information is taken, not from traditional engineering or technical texts, but other sources so that students must 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.

A recent innovation has been the use of Web2.0 technology, specifically a Wiki, to encourage a team *collaborative* approach to the problem or project solution (Cochrane et al. 2008).

While delivery of PBL to an on–campus cohort is widely used around the world, there was scant data related to distance delivery. Moving to a fully virtual environment the author realised considerable effort would need to be spent by the teaching team to establish a learning community in virtual space for the students to remotely engage with their team, their facilitator and other students in the course. However, even with this forewarning, the effort required in establishing a true ‘team’ for the students was underestimated for the distance students who have no opportunity for face–to–face communication or contact. In addition the distance student typically has no history of sourcing their own study material and resources. Study materials are usually, if not always, printed material and the entire course study resource – content, tutorial problems, assessment items and sample examinations, are provided to the student.

In the first course of the strand, students are allocated to a team of eight. Whilst this is at the upper limit that the current literature advises, the larger initial team size was able to cater for students who drop the course and not affect the viability of the team. This meant that teams did not have to spend extra time and effort reforming during semester. Initially the allocation of team members was such to simply ensure that each team had a mixture of AD, BTech and BEng students of all majors, as numbers allowed thus giving the widest chance at diversity a mix of prior knowledge and skills.

5.3 Phase 1– An Initial Investigation of the First Offers

In the initial semester 1 offering, 176 on–campus and 169 distance students completed the course and the initial semester 2 offering 206 distance students completed the course.

Students were graded by the marks obtained in the four team projects (85% of total) and the individual portfolio of reflections submitted at the end of the semester (15%). The team reports provided an overall mark for each project, and this mark was then moderated by the results of peer assessment forms submitted by each student and nominating the level of contribution provided by every member of that student team. The facilitator's observations were used as a quality check on the peer assessment forms. Typical problems are shown in Table 5-2.

Table 5-2 Sample Problem outlines and learning objectives

Problem scenario	Main learning objectives
A baby is found dead in a stolen car (in Australian summer). Teams are asked to provide technical advice to a legal team working on the case	Heat, temperature, experimental methodology, statistics, errors and uncertainties, ethics and the role of engineers in society
Predicting the life span of an old timber bridge with decaying wooden pylons	Force, pressure, basic statistics and dynamics, statistics, errors and uncertainties, Australian standards
Redesigning a failed winery to become a boutique brewery and orange juice factory (to use as much existing equipment as possible)	Fluid flow (laminar, turbulent, in pipes, viscosity etc), design principles including costing
Maintenance of an unsealed road on a sand island	Force, pressure (with a view to limiting types of vehicles and tyre pressures to minimise damage), investigation of surfacing options, installation and ongoing maintenance costs

After the initial offers of the course, to both on–campus and distance students working in virtual teams, a review and evaluation process was undertaken to determine student perceptions of the course and their learning and staff perceptions of the new delivery method and pedagogy.

These investigations were 'big picture' and whilst determining if the course was meeting the learning objectives, in terms of graduate attributes and technical content was of interest, the main focus of the initial investigations was larger issues such as workload, missing or required refinement of resources, student perceptions of the course and directions for further development.

This data was gathered using student reflections and anonymous surveys with Likert scale responses and short open ended questions. A small number of telephone interviews (25) were conducted for validation. The response rate from the survey was 63.7% and 86% of students submitted reflective portfolios which also gave valuable data for validation.

5.3.1 Student Profile and Perceptions

The age profile of the students in the first offer was consistent with the data presented in **Error! Reference source not found.**. Of the on–campus and distance cohorts, there were 8% and 5% female students respectively. Students were distributed in the programs and majors as shown in Figure 5-3 and Figure 5-4 and indicated work experience as in Figure 5-5.

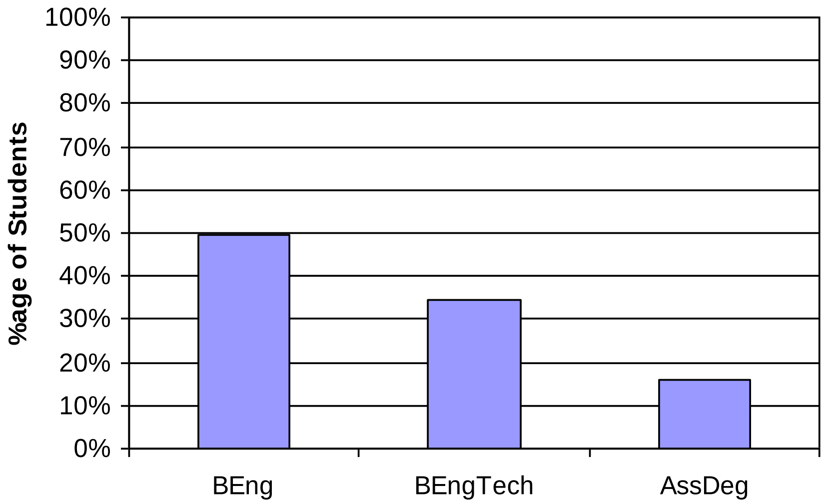

Figure 5-3 Program distribution for the first offers

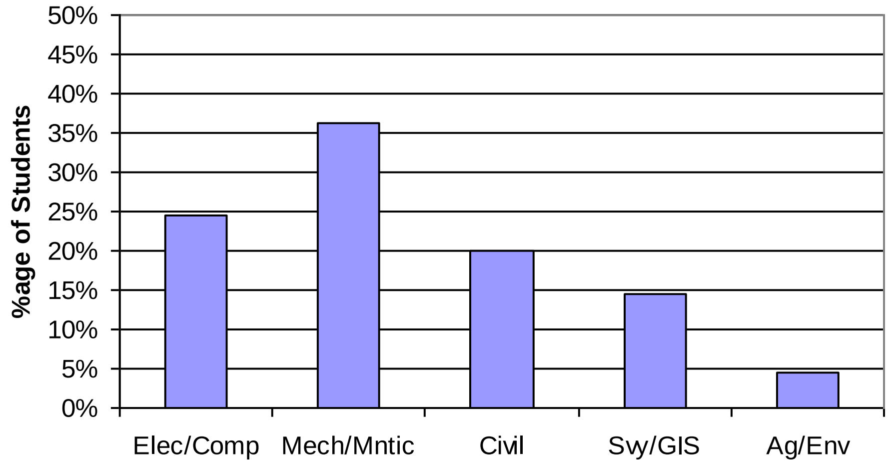

Figure 5-4 Students enrolled in each major

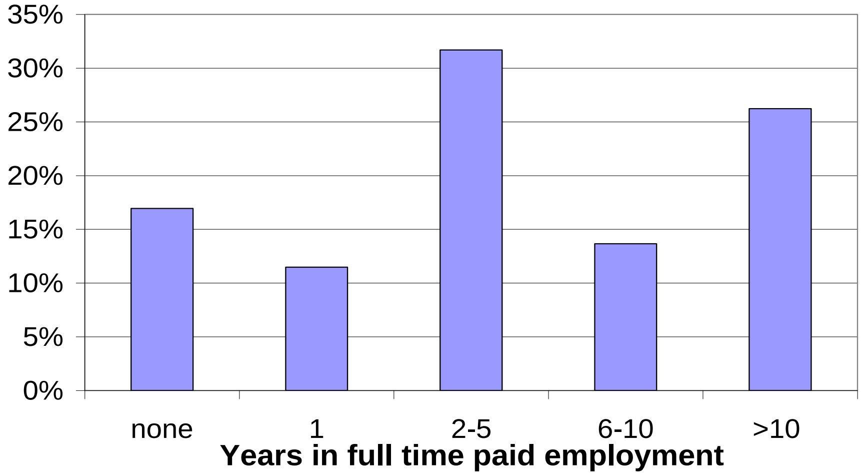

Figure 5-5 Experience in the work force

Analysis of the portfolios submitted by the students in 2002 indicated that approximately 92% of the students viewed aspects of the course favourably (although noted constructive criticism) and 5% offered no definite opinion. This positive response was not reflected in the standard teaching evaluation process carried out by the University. To some extent, this could reflect the inappropriateness of the formal evaluation items for this type of course. The university questionnaire requested information regarding ‘delivery of lectures’, ‘delivery of tutorials’, and ‘course content’. It was not suitable for a team based course which used PBL. (In 2004 application was made to the University to have these standard questions replaced with more appropriate questions suited to the delivery and pedagogy.)

Figures 5-6 to 5-11 detail collated responses to the learning survey. There was no significant difference in responses between on–campus and distance students ($p \leq 0.05$, n= 351).

Figure 5-6 shows that 43% of the on–campus students retain a preference for lecturing as the main mechanism for presenting course material (this question was not relevant to distance students who do not have access to lectures for any course). Another 21% have no opinion on this matter, leaving only 36% of engineering students who indicated a preference for PBL. It is likely that a dislike of teamwork is also influencing this result, but the two aspects were not adequately separated in the survey. Facilitators in the course suggest that the increased workload is a significant factor in the student responses, and less motivated students, who would normally not start studying in earnest until several weeks into the semester, are particularly against this form of learning where peer pressure forces them to contribute continuously and from the start of the semester.

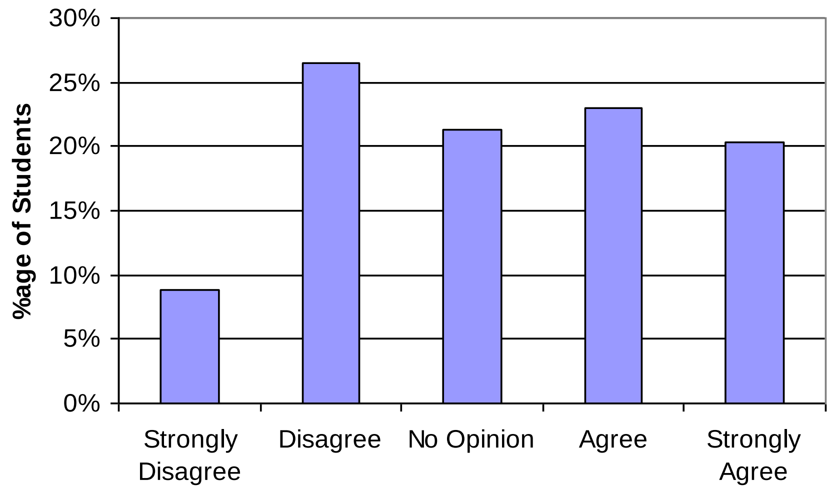

Figure 5-6 Student response on preference of lectures for course delivery

Figure 5-7 shows a more general response from all students to the statement that their knowledge learnt in the course was not retained as well as that learnt in traditional courses. The results are 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. It would seem that the learning of basic facts involving engineering science was no more effective in EPS1 than in other didactic courses from the student's point of view. The advantages of the PBL course lie in the other learning that occurs in the course.

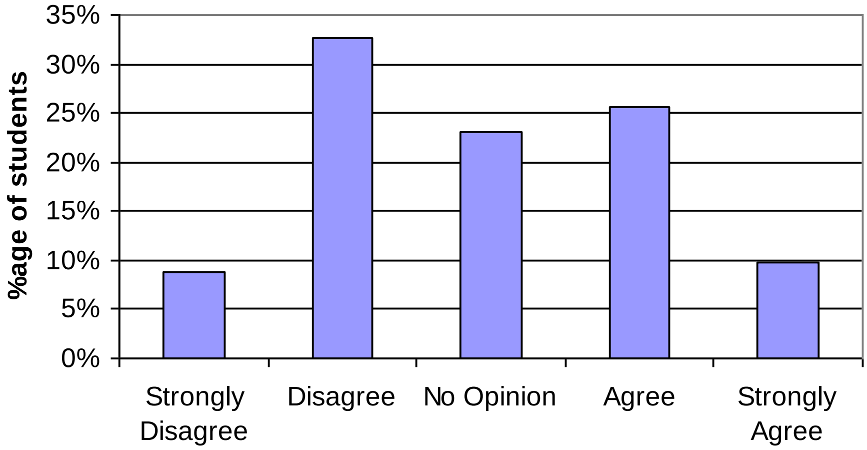

Figure 5-7 Student response to retention of knowledge being *less* than in traditional subjects.

Figures 5-8, 5-9 and 5-10 mitigate the negative responses shown in Figure 5-6 and 5-7. Figure 5-8 shows that 54% of students thought that the PBL course had increased their ability to learn, with only 14% unsure of this effect. Figure 5-9 further indicates that their confidence in their ability to independently learn new concepts was also increased. 52% of respondents either agreed or strongly agreed with this question and 22% were undecided.

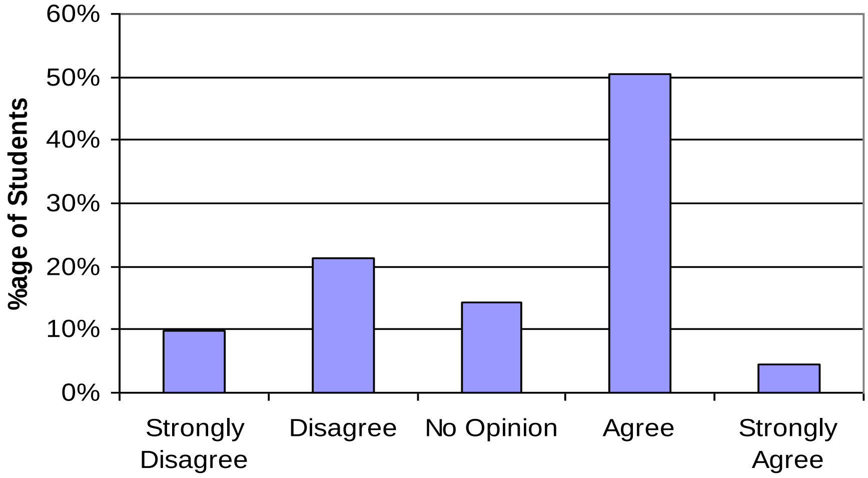

Figure 5-8 Student response to the courses increasing learning ability

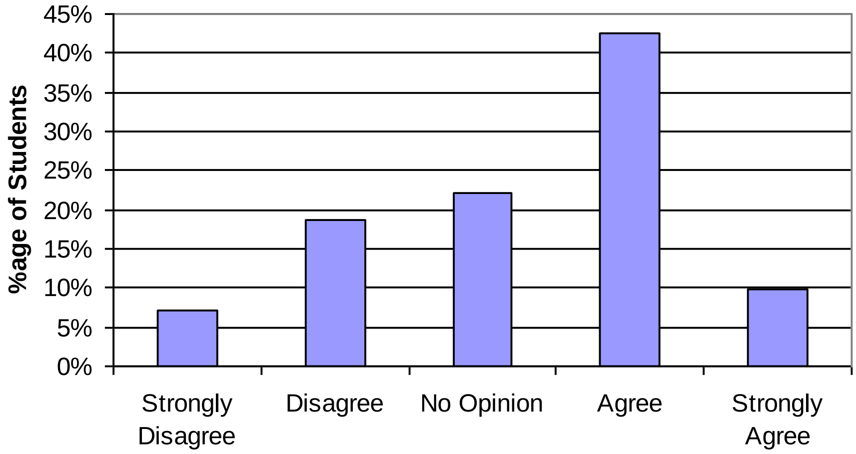

Figure 5-9 Student responses to the courses increasing their ability to undertake independent learning

Of even more interest was the survey response to questions relating to key course objectives of enhanced problem solving skills and the effective use of prior knowledge. Figure 5-10 shows that the vast majority of students thought this objective had been achieved. 70% of respondents either agreed or strongly agreed with this proposition. Only 15% were unsure of the effect. A similarly large majority (83% of respondents) thought that the courses had enhanced their appreciation of the prior knowledge and skills of their fellow team members, as shown in Figure 5-11. Only 8% had no opinion on this issue and 10% disagreed.

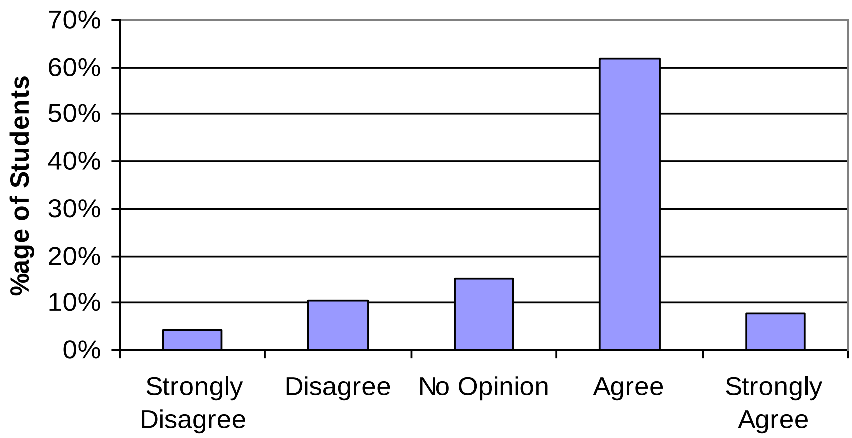

Figure 5-10 Student response to PBL course enhancing their problem solving skills

The student portfolios qualitatively affirmed the results of this survey. Unprompted portfolio entries were categorized into several themes of interest and examples of entries are shown in Table 5-3.

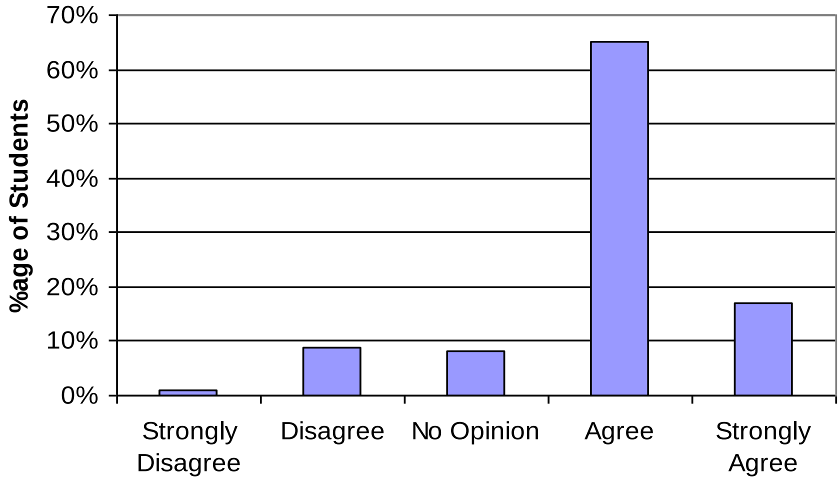

Figure 5-11 Student response to PBL course increasing their appreciation of prior knowledge in problem solving.

Table 5-3 Themes from portfolios and surveys

Theme	Example from portfolios and short answer survey questions
Problem solving skills	• *I believe…I am now more capable to give solutions to problems which I had not come across to this point in my life. I have seen this in my day to day work.* • *It has shown me that there are a lot of different ways people solve problems and sometimes their ideas are better than yours are.* • *I believe I am a better problem solver now than I was before and I can work better in a team environment because….*
Independent learning and learning ability	• *This course has taught me different ways to tackle problems and answer them in an accurate technical nature.* • *I have learned how to use problem based Learning to my advantage and I believe it is an excellent way to learn.* • *This subject has taught me so much I believe I will use these skills with my other assignments. I can find and apply information on my own….* • *I have confidence in my ability to find the correct information and present it in a format that is suitable for the intended audience.* • *I am keen to accept the challenge of learning or improving on skills such as PowerPoint presentation…* • *This subject has had a positive effect on how I performed in assessment in my other subjects…* • *As I reviewed my circled responses to the questionnaire…I discovered that my abilities had been dramatically strengthened. I found that not only had I been able to improve my own skills, but also to assist and improve that of my teammates.*
Retention of knowledge	• *The course has been a learning curve for myself, and I know that the experience and knowledge gained in this course will be to great benefit in my future.* • *I believe I will remember each and every one of the four problem solving projects for a significantly longer time than the traditional reading a textbook and sitting the exam type subject, which often results in the information being lost as soon as you walk out of the exam room.* • *In regards to learning how to learn, I think this project has had a positive influence on me. It has taught me more… to be aware and tackle problems with a more open mind.*
Prefer lectures	• *This course has been useful to me in terms of increasing my computer skills, but I think that PBL may not have been the best way to do this. What it has left me with is a very patchy and incomplete competence in these areas. I can get an acceptable result, but I'm sure there are better and faster ways of achieving it. With the time pressure applied by this unit there seems little opportunity to fill the gaps in my skills beyond what is directly required for each assignment. A more formalized approach to these matters would have resulted in more rounded knowledge.* • *I am looking forward to the next Problem Solving unit. I can see my effectiveness as a team player can be improved, and that this will be of advantage to me in the future. For technical skills and knowledge, I hope that anything vital will be covered elsewhere.*
Prior knowledge	• *As we all possessed different skills and knowledge, we were able to come up with a vast range of ideas and solutions to complete the projects.* • *I have come to the realization that every person has a different point of view and knowledge [to share] when solving problems…*

In line with course objectives, other student perceptions and comments were noted. Main areas featured were teamwork, specific technical skills, communication skills and self awareness and are shown in Table 5-4.

Table 5-4 Student unsolicited reflections on main objects of the course

Theme from unprompted reflective portfolio entries	Example of student entries
Teamwork	• *I have learned how to work better as a team and the importance of completing your given task by a certain deadline.* • *The human dimension can mean that no matter how hard certain members try to help the group succeed it can take only one member in certain cases to pull the team down.* • *It seems some members want to do the least amount of work possible.*
Specific skill learnt	• *I have learned how to reference correctly.* • *I have learned to be open minded when tackling complex problems and to look for a greater variety of information sources….there is a difference between data and information and I have learnt to think about what I am using and its validity.* • *This subject has taught me so much I believe I will use these skills with my other assignments. These include….* • *I am a lot more proficient using my computer as an engineering tool. I feel a lot more comfortable using MS Excel and Word, and working between programs.* • *If we had concentrated on the engineering aspects of the particular projects and the lecturers taught us about fluid flow pressure etc, I feel that most students would have learnt a lot more from this subject.*
Communication skills	• *I have personally found that I can now explain myself and justify my decisions to other people a lot better than in the past, a result of this being frequently necessary throughout the course, due to the eight different viewpoints my team had on nearly everything!*
Self awareness	• *Seeing myself to be rather introverted, I was pleased to find myself contributing my theories, ideas and constructive criticism in our group situation. Overall I think this type of course with a team environment and reflective writing is a very positive and informing way of learning.* • *I tended not to participate much in the conversation, this may have been because there were several dominant members in our team…however now that I have recognized the problem I intend to voice my opinions more.* • *This course has taught me how to learn in a different way and research new resources.*

5.3.2 Student Issues

Concerns and issues raised by students in portfolios and the survey included: the high workload for the course, difficulty in communication (with both facilitators and other students), non–participating team members, poor support from facilitators and slow turnaround time on assessments. Student concerns were largely mechanistic in nature but still valid and needed further investigation.

In student interviews and survey questions, workload for the course was prominent issue:

> *With the extreme workload of this subject, I found I couldn't do two subjects, work full time and have a life at the same time. It has made me prioritise my life a bit more.* – **student interview response**.

> *Large workloads for this subject meant that some other studies have been neglected.* – **student survey response**

Courses at USQ require a nominal student effort of 150 hours. This generally covers all work in the course: lectures and tutorials/directed study; private study; assessment (assignments and examinations) etc. Staff and students reported significantly higher workloads in this course as illustrated by the above comments. However this was not supported by survey data. The workload for the course equates to approximately 10 to 12 hours of student effort per week. For traditional on–campus lecture based courses this is based on two hours of lectures; two hours of tutorials and the remainder to be used in private study. For distance students, the expectation is that individual students work through the study material provided following a study schedule set out in the course material. As similar level of work i.e. 10 hours per week is expected.

The survey indicated that 89% of students believed they were spending 6 to 8 hours per week in total on this course – checking discussion forums, communicating with team members, undertaking individual tasks, completing reflections and general course work. There was no significant difference ($p \leq 0.05$) between on–campus and distance student responses. This is less than the recommended study time, but student's perceptions were that this was still excessive. Telephone interviews with 25 randomly selected distance students indicated that they spent, on average, only two to four hours per week per (traditional) course and thus believed the workload for ENG1101 was high.

Whilst the survey and interviews did not support the student claims of excessive workload, other issues were validated. Lack of facilitator support underpinned by a poor understanding of the role of the facilitator; poor recognition of the concept of PBL and self directed learning and insufficient recognition and follow up by facilitators on low participation and contribution by team members are all issues for further investigation and consideration.

Given the innovative nature of delivering a core engineering course to a diverse student cohort working in a PBL virtual team, the initial offers were successful but further improvements could be gained by addressing some key areas:

> *The positive aspects of the course were overshadowed by the negatives, but are still worthy of mention. These were the team learning environment meant being able to draw on and learn from other students' abilities; the approachability of the lecturers and the ability to network and communicate amongst other students.* – **student survey response**

One unexpected advantage of the course was the social aspect. It provided the students with a mechanism for meeting people and establishing friendships, an important aspect of first year university life and one often unavailable to distance students. Many distance students noted that this was one of the best aspects of the course and it was thus prioritised for further investigation in subsequent offers.

5.3.3 Staff (Facilitator) Perceptions

The removal of four traditionally taught, core courses and replacement with four PBL courses was not without discussion within the Faculty and in some cases significant controversy. Staff were understandably nervous about such a venture especially as the lack of literature for delivering PBL with no face–to–face communication forum for the majority of the students.

The workload policy of the Faculty dictates that the large core courses, of which ENG1101 is one, are taught by a multidisciplinary team of staff as individual workloads allow. The staff team was not appointed until close to the beginning of semester and there was little opportunity for comprehensive staff training or professional development in PBL or facilitation. Many staff were hesitant in their new role and did not understand the expectations of them.

Staff were briefed on assessment (individual and team), general implementation of the course and discussed (through several meetings) general concerns, implementation issues and expectations. Staff were asked to keep a log of reflections, including student problems, proposed solutions and final outcomes. Regular staff team meetings were held and an informal community of practice established.

After the initial offering of the course staff logs and meeting minutes were reviewed and key themes collated. These were circulated to the staff team for validation. Issues of workload, individual student participation and communication difficulties echoed the concerns of students and several other areas of team process where raised:

- **Student team code of conduct:** Each team, as part of the first team assessment was asked to write a team code of conduct and responsibilities. Resources and guidelines were provided. Analysis of assessment items indicate that teams, on average did very well, as marked according to the assessment scheme, with this particular section of the assessment. The codes were well thought out but lacked adequate discussion and follow up in the team. There was little or no thought to *roles*, corresponding responsibilities and most importantly, consequences of breaching responsibilities and expectations. Facilitators reported that teams had a code of conduct but rarely was it applied or referred to by the teams. It was seen by the students as a trite exercise of little or no value.
- **Task allocation with in student teams.** Task allocation within the teams was done based on prior experience, but not with *learning* in mind, only expediency in achieving the goal of submission. Student teams focused on submission deadlines and achieving the best mark possible. Tasks were

allocated on the basis of prior knowledge and skill but working with existing skills rather than improving or learning new skills. This was evidenced by student postings as exampled below:

- *I write reports all the time at work, so I will do the final report. Everyone just send it all to me* – s**tudent posting to discussion forum**
- *…who has done physics and knows about Bernoulli's equation?* and followed by *That's great mate! Can you take care of the calcs [sic] I can't make head nor tale [sic] of them* – s**tudent posting to discussion forum**
- *… there is no surveying in the problem so I don't know what I can do to help* – s**tudent posting to discussion forum**

- **Project management of the problem.** Teams usually gave little thought to planning, even with prompting from the facilitators:
  - *I asked team [team number] to think about timelines many times, but each suggestion was ignored. In the end they struggled to meet the deadline and only by the extraordinary effort of [student name] did the team make the submission.* – **from minutes of staff meeting**
  - *Come on guys! We only have 2 days left and we have done .... [nothing]* – **posting from team discussion forum**
- **Student portfolios –** Students were asked to complete reflective portfolios throughout the semester with a final submission at the end. Three main problems were discovered: timely completion of the portfolio, assessment of the portfolio and level of reflective writing achieved by the students.

Facilitators reported that most students were leaving the portfolio until the last minute. It is unknown if students were keeping records or draft entries but evidence suggests that most students were completing the portfolio at the last possible moment, purely from memory.

This was supported by results from the 25 telephone interviews where 19 of the students indicated they began their portfolio a maximum of one week (majority of students (14), answered 2 days) prior to submission at the end of the semester. The portfolio was not consistently completed over the course of the semester as intended and no notes were kept throughout the semester.

Other problems with the portfolio were reported by facilitators. These included time taken to assess, uncertainty with assessment criteria, difficulty in providing students with guidance in writing the portfolios and uncertainty with the role of reflective writing in engineering education and PBL. This was verified by reviewing the average mark of each facilitator for portfolios. Figure 5-12 shows that there were significant differences between markers and their interpretation of the marking criteria despite a discussion at a markers' meeting and subsequent moderation.

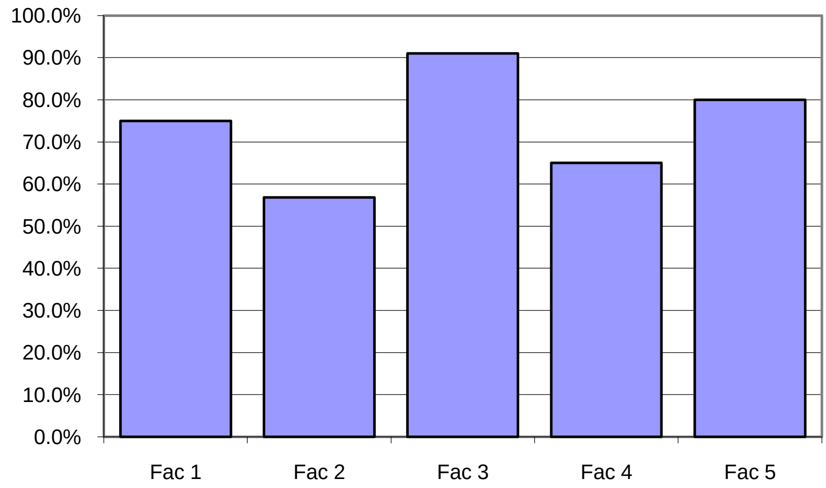

Figure 5-12 Individual facilitator marks for portfolio (semester 1 2002)

- **Differing views within the student cohort on the role of facilitator:** Whilst facilitators themselves struggled with the changing role and its differing requirements, students also had misconceptions as to exactly what the facilitator would do. Students and teams saw the role of the facilitator differently ranging from a project manager, normal academic tutoring role to team leader:
    - *…our facilitator was useless, all he ever did was ask* ***us*** *questions* – **student feedback form**
    - *…my teams think I am the tutor and will tell them exactly what to do* – **facilitator comment**

   - *We request an extension on the submission of Assignment 1 as our facilitator gave us no guidance on tasks and timelines* – **team communication to Examiner**
   - *The most ineffective member of the team was our facilitator* – **comment from student portfolio**
   - *I don't feel like I am doing anything. All I can ever think of is to ask the students 'What do* **you** *think?', what else am I supposed to do and more importantly how do I do it?* **– facilitator comment from staff meeting**
   - *We were often delayed as we would post a question to the facilitator and then have to wait days until he replied... often answering our question with a question* – **comment from student feedback form**.
   - *I thought that our facilitator was helpful, but was unclear on a number of issues where he would answer our question with another question, i [sic] understand that is supposed to make us think about it more, but it got to a point where it was a little annoying.* – **comment from student feedback form**

- **Workload –** Facilitators, like students, reported a high workload in the course. Facilitators found guiding the student teams through four team assessment items, monitoring participation and marking substantial submissions difficult in a short semester. However, like students, these perceptions were not substantiated by evidence. Data from the Learning Management System (LMS) showed that facilitators of distance teams spent little time online monitoring discussions and interacting with students. In some cases, this was as little as 30 minutes per week for four teams.

  In traditional courses many academics would have little to no communication with distance students. Whilst the official workload for the PBL courses was substantially greater than lecture based courses (one and a half times), it was sometimes difficult to encourage or enforce staff engagement with student teams.

- *I haven't got time to be reading every student post. I've got lectures to give* – **comment from staff meeting**
- *I won't be able to check on teams for the next week. I am preparing a grant application* – **comment from staff meeting**
- *Can I just do marking?* – **comment from staff meeting**

5.3.4 Summary of Initial Investigations

Whilst the initial offers of the course were deemed to be successful, there was evidence to suggest that improvements could be made. This was to be expected given the innovative nature of the development. In line with the action research process and its contribution to the 'change experience' of the researcher, initial data was collected, problems and possible solutions identified. The review occurred through personal reflection and a further review of existing literature, covering new areas e.g. peer assistance and assessment as shown in Figure 5-13.

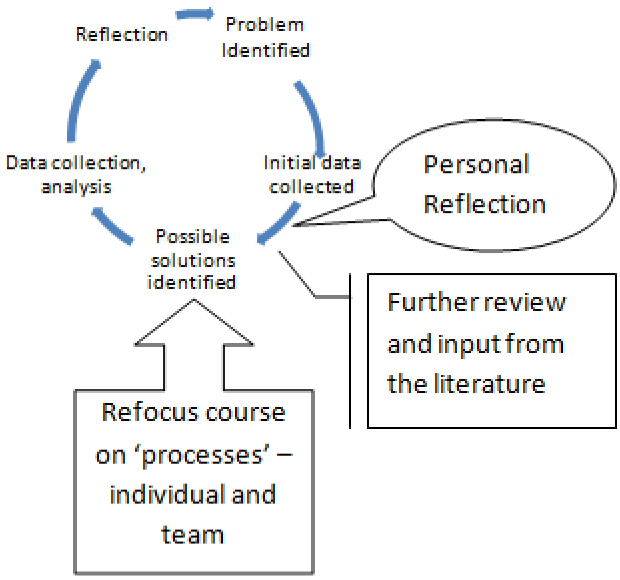

Figure 5-13 Personal research process

This resulted in incremental changes to the course, assessment strategies and resources provided; however the fundamental philosophy and delivery of the course remained unchanged. Changes to the course are detailed in the following section.

5.4 *Changes to the Course*

The main change in the course was moving from an outcome or product objective to that of a process both at the individual and team level. The aim was to have students focus on building and understanding key strategies such as problem solving, communicating in a virtual environment, planning etc. To support and encourage this change, assessment was modified and extra resources produced. Changes were incremental and each modification was evaluated. This enabled each modification to be investigated for effect. The majority of changes occurred in the assessment strategies and can be summarised as rewarding team and individual effort and supporting with resources, process and progress and minimising the focus on the final product or outcome.

Changes where not done in a linear or sequential fashion. Rather, one change dictated a change in another area or the need for an additional resource. There were flow on effects for each modification. In broard terms, modifications fell into two main categories – team strategies and processes and individual reflection.

5.4.1 Foundations for a Successful Team

Developing a successful team strategy was addressed by modifying team assessments and criteria. The main issues identified include:

- Workload,
- Building a *team* and students working collaboratively,
- Developing meeting strategies to support the individual team requirements and environment,
- Developing an awareness of ‘problem solving’. This includes defining the problem, finding resources and evaluating and validating solutions,
- Meeting deadlines and including all team members in task allocation,
- Task allocation: encourage students to take on unfamiliar and unknown tasks to extend skills and knowledge based on their prior expereince and to assist other members by sharing their experise.

To address issues of workload and tight timelines over the semester, one team submission was removed. This allowed teams more time to plan and reflect on the team process. More emphasis on process and improvement was placed in all team submissions, and as the first team assessment laid the foundations for building the team and individual learning, more student and staff time and resources were directed into this area. Initial evaluations showed that while the team developed a code of conduct, it did not sufficiently address all areas, was not revisitied or updated as the team matured or encountered new problems and was seen as a trivial exercise by the students. More emphasis, through resources and assessment, changed this from an 'ice breaking' activity to a core part of the the team process, revisited throughout the semester.

Similarily student teams did not think sufficiently about the implications of working *as a team* and what strategies might be used to help the the team become efficient and effective. This includes team meeting strategies, a generic problem solving strategy and a project managment plan. Teams were so focued on meeting submission deadlines and achieving the best possible mark, basic foundations which could be taken forward and applied to future courses and work situations were being overlooked.

The revised first team report had four key elements as shown in Figure 5-14 to encourage teams to set in place a *process* and strategies which would lay the foundations for the semester and beyond.

Part A	Team Code of Conduct, Roles and Responsibilities
Part B	Team Meeting Strategy
Part C	Peer Assessment Strategy
Part D	Project management and mentoring plan

Figure 5-14 Overview of team report 1

Subsequent team reports included a *team reflection and evaluation category* as indicated by Table 5-5. This had the advantage of forcing teams to use and review their codes and strategies and for team which encounted problems, it allowed them to still obtain a good grade in the assesment piece by identifying and working towards a solution.

Table 5-5 Assessment criteria for Team Report 2
(Brodie 2008a)

Criteria	**Percentage of report mark**
Team Reflection and evaluation • Problem solving *strategy* • Management plan • *Evidence* of mentoring and skill sharing to meet individual and team learning goals • Review and analysis of code of conduct • Demonstrate an understanding of team dynamics, use of COC when problems arise • Analysis and critique of performance with a view for improvement	50%

The mentoring plan linked the team project management plan to sections of the first individual portfolio (see following section for details). A key part of the portfolio was to have students identify their own strengths and weaknesses and set individual learning goals. These learning goals and prior experience set the basis for peer assistance within the team and to value the diversity each member brings to a team.

Some students had difficulty in appreciating the value of this multidisciplinary course. e.g. *"I am going to be a surveyor, none of the projects were about surveying…they were interesting, but of no use to me".* Sharing learning goals, prior knowledge and experience and planning to help other members of the team helps with self-directed learning and allows for all members to contribute meaningfully to the team, even if problems were not 'discipline specific'.

Initially team selection ensured a mix of all programs and disciplines. This approach however, was seen to ignore the range of prior skills and knowledge of the students and often left teams without appropriate peer mentors over the required range of skills, course objectives and projects. A 'skills audit' of student prior knowledge and abilities was implemented and this now forms the basis of team formation enabling teams to have a solid basis for mentoring and peer learning within each team.

5.4.2 Reflective Writing – Helping Students Understand Their Learning

Reflection is a very important part of the learning process and the theory on learning and reflection comes from a number of different sources. It begins with Kolb's (1984) work on learning cycles and Schon's (1987) ideas about reflection. Students must be given time to synthesize their new knowledge and reflect upon what they have discovered. This is particularly important in PBL where learning is sometimes covert – problems and projects are solved without the student being aware that skills and knowledge have been acquired and enhanced. Students must be allowed, and prompted if necessary, to reflect, individually and as a group. Reflection therefore became a key part of the assessment.

The intention of the reflective portfolio is to use the writing process as an effective means to facilitate students' critical thinking about the aspects of course content, issues, and group dynamics. Norris and Ennis (1989, p. 176) define critical thinking as "reasonable and reflective thinking that is focused upon deciding what to believe or do". Keefe (1992, p. 123) notes, "Reflective reasoning moves beyond simple rules, relationships, and principles to higher frameworks of meaning—analogy, extrapolation, evaluation, elaboration, invention". These skills and behaviours are the basis of Bloom's work where he catalogued six levels of learning: knowledge, comprehension, application, analysis, synthesis and evaluation. The last three of these skills (analysis, synthesis and evaluation) are indicative of critical and reflective thinking and writing.

Dr. L. Dee Fink of the University of Oklahoma carefully distinguishes between substantive writing and reflective writing. Substantive writing refers to writing that is focused on a topic and attempts to present information and ideas the writer has about that topic. Reflective writing focuses on the writers experience itself and attempts to identify the significance and meaning of a given learning experience. To guide students through this process a reflective writing guide was developed. A similar guide for staff was also developed to enable staff to guide and effectively assess the submissions.

5.5 Phase 2 – Effectiveness of Change

Implementations and changes were effected by semester 1 2005 and the second phase of data collection began. Data was collected until the end of the first semester 2008, covering 11 offers of the course. Data for semester 2, 2008 was not used in the analysis as problems with the learning management system prevented the surveys being available to all students and hence there was a very small response, well below the average of previous semesters.

Survey responses from 820 of the 1377 students (response rate = 59.5%) enrolled over the time frame were collected. Responses were on a five point Likert scale with responses of Strong Agree (SA), Agree (A), Neutral (N), Disagree (D) and Strongly Disagree (SD), NA (not answered). The student perception data were validated by analysis of open ended responses to survey questions, discussion forums and student postings and student reflective portfolios. Portfolios were chosen randomly from the student cohort to match the profile of program of enrolment as in Figure 5-16.

The main aspects of the course of interest are independent learning, communication, team work and problem solving skills. Considering these four main areas, there was no significant difference between the on-campus and distance students for ability to learn independently and enhancing communication skills as shown in Table 5-6. Statistically, there was a small difference between on-campus and distance students in their responses for problem solving skills and teamwork questions. However, the trends in the data are clear as evidence by the data shown in Table 5-7. The slight increase in distance students who do not believe their teamwork skills were enhanced by the course could be due to many reasons including their perception that they already had significant teamwork skills prior to the course, their dislike of teamwork (in an academic context) and difficulties in managing virtual teamwork. The last of these factors is discussed in Chapter 6.

Figures 5-15, 5-16 and 5-17 detail the profile of the student cohort. From 2005 to 2008 there was a significant growth in enrolments into the Associate Degree program. Many of these students will in time articulate into either the Bachelor of Technology or the Bachelor of Engineering, but in beginning university they do not have the sufficient prerequisite studies especially mathematics to enrol in the four year Bachelor program. The majority of the AD enrolments are into the civil major (see Figure 5-16).

The age profile of the students is shown in Figure 5-17. The data from the survey shows the majority of students are in the 18 to 24 years age bracket. Further interrogation of enrolments shows that only 13% of the students come directly to university from school. Thus the vast majority of students have work experience of some form before they enter university.

Table 5-6 Significant difference in student responses between on-campus and distance students

Ranks

	study mode (Multiple Choice)	N	Mean Rank
ability to learn independently enhanced (Multiple Choice)	1	593	416.17
	2	224	390.03
	Total	817	
communication skills were enhanced (Multiple Choice)	1	594	401.23
	2	224	431.43
	Total	818	
problem solving skills were enhanced (Multiple Choice)	1	594	400.61
	2	224	433.07
	Total	818	
teamwork skills were enhanced (Multiple Choice)	1	594	400.45
	2	224	433.51
	Total	818	

Test Statistics[a,b]

	ability to learn independently enhanced (Multiple Choice)	communication skills were enhanced (Multiple Choice)	problem solving skills were enhanced (Multiple Choice)	teamwork skills were enhanced (Multiple Choice)
Chi-square	2.379	3.280	3.914	4.178
df	1	1	1	1
Asymp. Sig.	.123	.070	.048	.041

a. Kruskal Wallis Test

b. Grouping Variable: study mode (Multiple Choice)

Table 5-7 Data for on-campus and distance students relating to problem solving and teamwork skills

On-campus / Distance	Strongly agree	Agree	No Opinion	Disagree	Strongly Disagree	Not answered
Problem solving skills were enhanced (On-campus)	22 (10%)	144 (65%)	22 (10%)	16 (7%)	12 (7%)	7 (3%)
Problem solving skills were enhanced (Distance)	56 (9%)	337 (57%)	89 (15%)	70 (12%)	37 (6%)	4 (1%)
Teamwork skills were enhanced (On-campus)	37 (17%)	140 (63%)	21 (9%)	9 (4%)	11 (5%)	5 (2%)
Teamwork skills were enhanced (Distance)	79 (13%)	355 (60%)	41 (7%)	76 (13%)	33 (6%)	5 (1%)

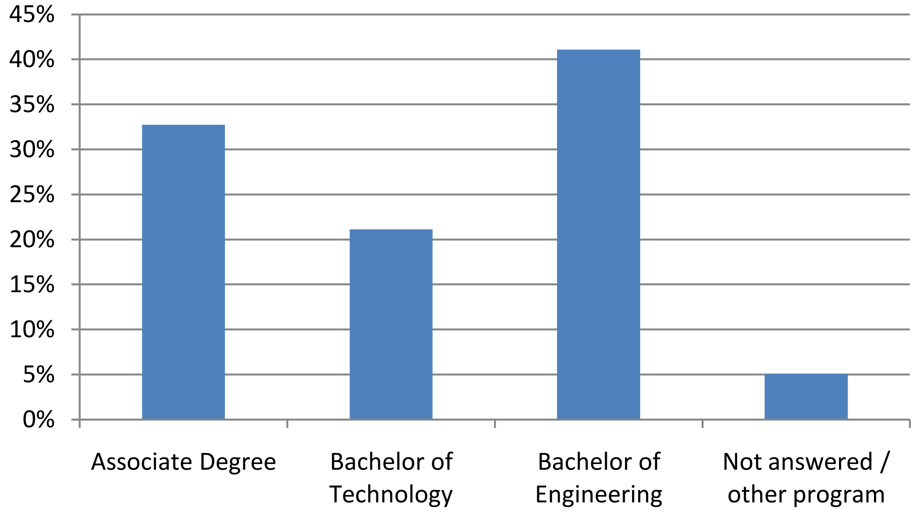

Figure 5-15 Program of enrolments

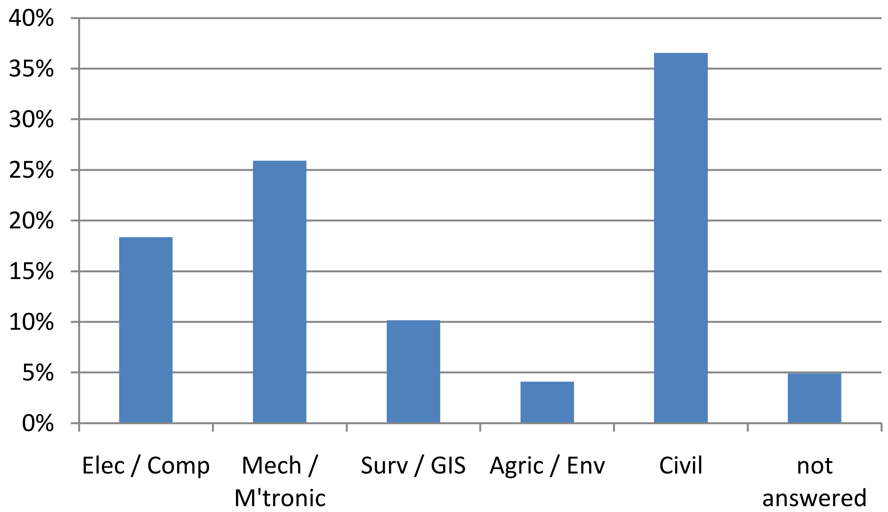

Figure 5-16 Distribution of discipline majors

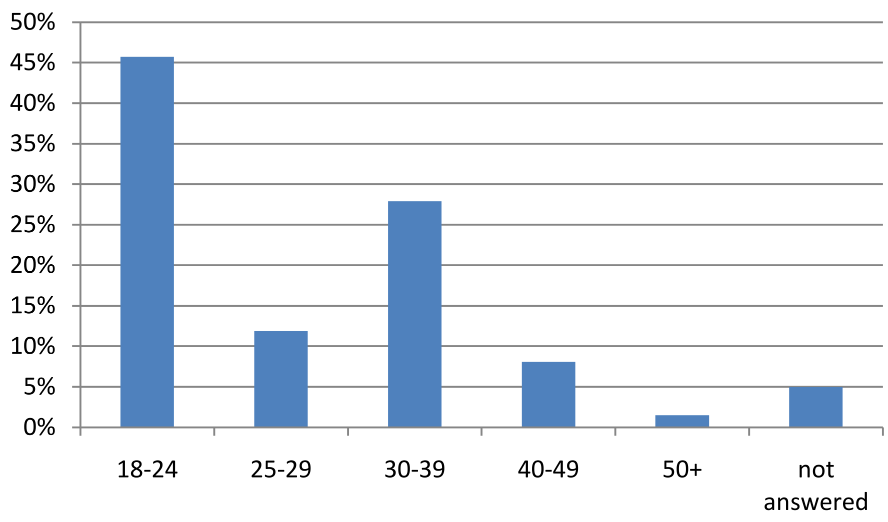

Figure 5-17 Age profile of students

The second phase of the investigation focussed on establishing whether the key graduate attributes of problem solving, teamwork, communication skills and lifelong and self directed learning could be successfully delivered using problem based learning with students working in virtual teams.

The first change in the course was to focus the teams on process by setting up strategies and procedures that can be carried into future problem solving courses and their future careers.

The first team report gives students guidance to set up these procedures whilst allowing students the flexibility to work within their team constraints. The establishment of a code of conduct is a critical step in forming the team. Survey responses to the question "Developing the team code of conduct was helpful to the team" indicated that the majority of students, both on–campus and distance supported this statement. Refer to Figure 5-18. There was a very strong correlation between these results and the results for the second question of "The code of conduct encouraged team development" (R^2 = 0.98 for on–campus and distance students).

The following quotes from student portfolios and surveys support this finding.

> *I thought the code of conduct was a waste of time. I really wanted to get into the problem. However by the end of semester I realised the coc [sic] was one of the most important things we did as a team. It helped us solve*

many nasty situations and by the end of the semester it looked like a formal legal document. It will certainly be the first thing I get the team to do in the following prob solve[sic] course – **comment from portfolio**

[one advantage of the course is]....having teams organise themselves before diving into the work: previous courses gave you a team and told you to get to work without formulating a successful method for working with others – **comment from student survey**

[The best aspect of the course was]... the exposure to Virtual team environments and the management tools available to assist the team... – **comment from student survey**

We were presented with a real life problem that needed a solution and this motivated me a lot. I loved the realness about this course. It was not just a bunch of theories that you needed to cram into your head. It was very practical and each team could take it to the level they wanted. Skies the limit!!!! – **comment from portfolio**

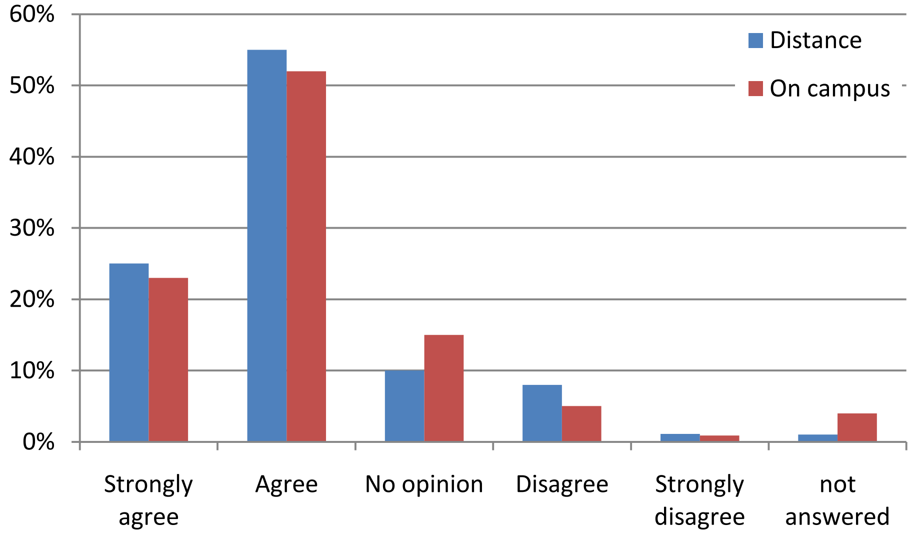

Figure 5-18 Student perceptions on the use of developing a team code of conduct

5.5.1 Teamwork

Students often begin the course with a strong self perception of having significant experience in teams and this therefore equates to practical teamwork skills. Most students believe that work, school, sport, and family are, in some respects *team* activities and it follows that necessary skills have already been gained. In initial postings to discussion forums a seeded thread asks students to post information about their prior teamwork experience and skills. Students' list sport and work predominately as exposure to teams and the overwhelming majority believe they already "know about teamwork". Sample postings from Team X discussion forum are shown below:

> *I work in a team already....* – **student X1 posting**
>
> *I already know about teamwork… the course will not teach me anything* – **student X3 posting**
>
> *I have significant experience in working in a team gained from 20 yrs of running my own business* – **student X4 posting**
>
> *You can't learn about teams from course work, it is something you learn from experience* – **student X5 posting**

Perceptions were tested at the end of the course using surveys, team reflections and comments from unprompted student reflections in the portfolio. For students, teamwork features as both the best and the worst aspect of the course, but there was a shift in awareness and understanding of their own skills and knowledge base. Figure 5-19 shows the collated response to the teamwork questions in the end of semester survey. The majority of the students believe that their teamwork skills have increased as a result of the course. There is a strong correlation between these two questions results. Using Spearman's technique, which is suitable for ordinal data (Siegel 1957), the correlations are given in Table 5-8.

Students often made very insightful comments in their portfolio on both their own ability and knowledge of teamwork. Team X, whose initial postings are given previously are indicative of responses[16]:

> *Our team discussed our responses to the teamwork questions. We are now faced with a dilemma. If we are so good at teamwork why can't we work [effectively] together in this course to get the work done [?]* – **Team X Reflection – report 2**

> *I have never worked in a 'team' where I had no power over the group. I have always been the boss and could tell everyone what to do and do it my way. When I had no power....it was totally different"* – **comment from portfolio (student X3)**

> *I realised now I don't work in a team but a group......I think I will reorganise things at work* – **comment from portfolio (student X1)**

> *I really don't trust my team members and this is vital in a team. This is more indicatative [sic] of me than of my team mates…* – **comment from portfolio (student X4)**

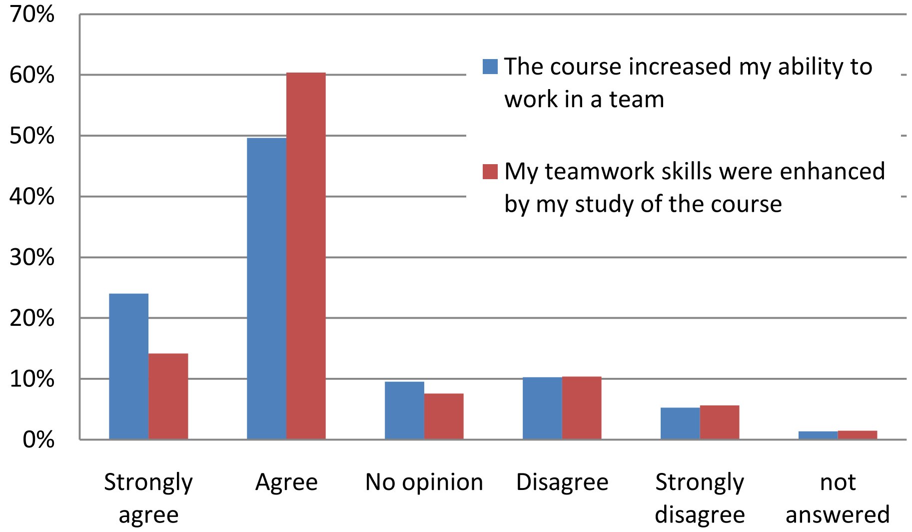

Figure 5-19 Student perceptions on teamwork
(n=820)

[16] Portfolios from Team X were used in addition to the randomly selected portfolios.

Table 5-8 Correlation statistics

Correlations

			ability to work in a team (Multiple Choice)	teamwork skills were enhanced (Multiple Choice)
Spearman's rho	ability to work in a team (Multiple Choice)	Correlation Coefficient	1.000	.683**
		Sig. (2-tailed)	.	.000
		N	820	820
	teamwork skills were enhanced (Multiple Choice)	Correlation Coefficient	.683**	1.000
		Sig. (2-tailed)	.000	.
		N	820	820

**. Correlation is significant at the 0.01 level (2-tailed).

In course evaluation surveys, teamwork featured predominantly as a response to the best aspect of the course but there were also comments citing teamwork as the worst aspect of the course. The number of comments in response to: "the most helpful aspect of the course" which mentions teamwork far outweighed those given in response to "the least helpful aspect of the course". This validates the survey data. Illustrative comments are given in Table 5-9.

Similar responses were noted in the portfolios:

> *....one of the assessments focused on the building of teams and how they move through different stages after being formed which i [sic] found was very interesting and something that could be applied within your team.* – **comment from portfolio**

> *The course is a lot different to what I had imagined it to be. It's not just textbooks and teachers, but learning from experience, which is what life is going to be all about. University is not only preparing me for my career but for the world I am going to be a part of in the future.* – **comment from portfolio**

Comparable results were seen with the other key course objectives: communication skills, problem solving skills and independent and self directed learning and are discussed in the following sections.

Table 5-9 Short answer response to the course evaluation survey – Teamwork

Most helpful aspect of the course	Least helpful aspect of the course
• *...learning how to work with people in a team. Gaining leadership skills by being given the chance to be one...* • *Team Work. This is a vital skill for everyone in everyday life and their working life. I believe the individual task could be reduced in order to maximise the learning of team work.* • *The most helpful aspect of this course is to make all the students work together with each other and even individual. makes a student to learn leadership quality.* • *...that we worked in a team.* • *The most effective part of this course is to work in team. The way the course had explain team ethics was really good. Seriously the points covered in this course will be really helpful for me in my future studies and in my professional career. The definition of team work and a better way of working in a team was learned ....* • *The most helpful parts of the course were the teamwork parts as they inspired and taught each member of the team to communicate effectively.* • *...Teamwork guides and problem solving as a team.* • *...having a team to work with and a facilitator to keep us on track.* • *My team mates were the most helpful aspects; they helped me to achieve my goals and I learned a lot about teamwork from them.* • *The focus on teamwork in problem solving, a skill that I had absolutely none of beforehand and is very relevant in the workplace.*	• *I found it extremely frustrating working with team members who lacked the same motivation and drive for results.* • *Other students did not fully participate in team projects, leaving other members to do extra work to cover shortfall* • *Having to work in teams* • *I dedicated a lot more than the suggested 10–13 hours per week during team assessment items to try to ensure a good team mark, to ensure a good personal mark. I often felt that I had to "lift" other team members to ensure this would happen, and put myself under considerable stress to try and achieve this.* • *The team aspect is an issue for people who work long hours. Although it is interesting interacting with others, I do this on a daily basis and having to commit to another team outside of work is an added workload that places pressure on families. I took the external study on so I could work at my own pace. I can understand the need to interact students just out of school with no professional experience, but experienced professional students I have to say the team commitment is a burden*

5.5.2 Independent and Self Directed Learning

The ground work for independent and self directed learning was set in the first portfolio where students set individual learning goals for the course. They must identify goals in line with prior knowledge and experience and listed course objectives: plan a strategy, including possible resources, to reach these goals and set in place an evaluation strategy to determine, with evidence, progress towards or attainment of the goals. Students are guided to set at least five goals and include a variety of goals:

- Technical/academic components e.g. knowledge of applied physics, statistics, use of excel including graphing;
- Social/group components e.g. teamwork, leadership;
- Individual/self components e.g. time management, motivation;

Table 5-10 provides an example of a Portfolio I submission for one individual learning goal.

Further evidence of the importance of setting goals is given in surveys and portfolios. Figure 5-20 indicates that 78% of students believed that setting their own learning goals was helpful. It gave them the opportunity to reflect on their current skills and knowledge, use these skills in the team and improve in others.

Table 5-10 Example of student entry for Portfolio 1

Goal	Plan and resources required	Evaluation strategy
Improve my leadership skills	Take on the leadership role [in the team] for TR2 [team report 2]. Research different leadership styles and running a team electronically [in virtual space] – make use of the library and the research tips provided	Ask the leader from TR1 [team report 1] to mentor and assist me. Study and modify the strategy put in place by the previous leader. Ask the team members and facilitator for feedback on my leadership style. If our team achieves a good mark in TR2 with everyone participating I will have achieved my goal

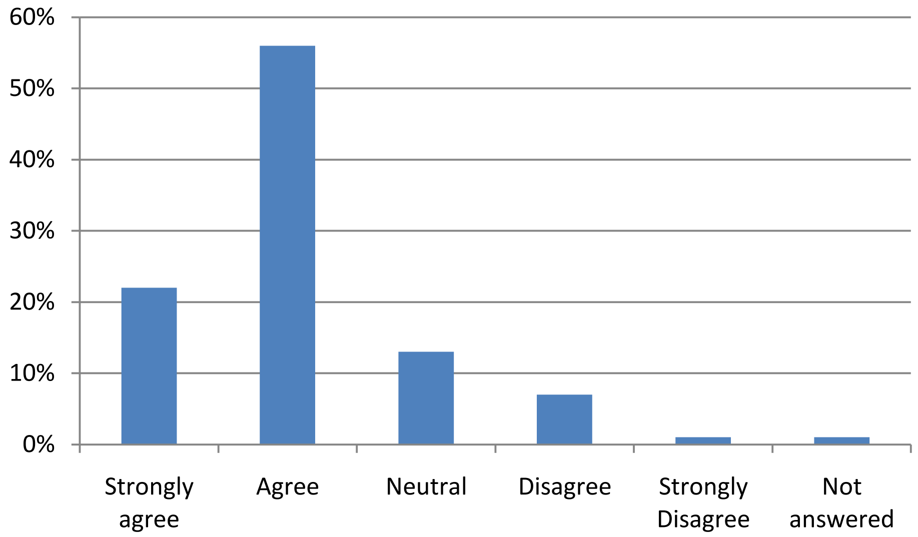

Figure 5-20 Setting my own goals was helpful to my learning
(n=820)

> *Goal setting gave me a target to achieve and forced to put theory into practice helps to increase knowledge of a subject* — **comment from portfolio**

> *The personal learning goals we very helpful in identifying your own areas of weakness.... which I found was very interesting and something that could be applied within your team.* – **comment from portfolio**

> *The goals I have set for myself are more than just something to make the facilitators happy, they are not just to be seen to be making an effort. Instead I see them as ongoing and applicable outside the realm of this subject and extending even beyond the completion of it.....They have been designed to challenge me in areas I perceive as personal weaknesses or lacking in applied experience.* – **comment from portfolio**

Throughout the team process, teams are encouraged and rewarded through the assessment strategy to mentor and assist team members to meet their goals. Whilst sharing and using the diversity of the team is one aspect; both giving and receiving peer assistance helps the students achieve self directed and learning.

Independent learning was evidence by four questions in the student surveys:

- My self–directed learning skills were enhanced
- My ability to independently learn increased
- My confidence in my ability to learn independently improved
- My confidence in seeking out new knowledge and apply it to a problem was **reduced.**

Results are shown in Figure 5-21. There was no significant difference between responses from on–campus and distance students and a strong correlation with the three positive self learning questions; with results confirmed by the converse question (confidence was reduced).

Student portfolios also contained evidence to support perceptions:

> *This course has challenged my ideas of learning, and through the application of problem–based learning [The course] has taught me what no other subject has before…. As such, I feel confident in my basic knowledge of all the areas covered in this course, and I am confident in my ability to learn what I don't already understand* — **comment from portfolio**

> *…one thing I did learn from this course is that team–based problem solving is a much more enjoyable method of learning and I also believe that I learned a great deal more than usual* – **comment from portfolio**

> *[This was] a more active way of learning.... Enhances own self learning abilities....* – **comment from portfolio**

In 2002, in the initial investigation, student perceptions on PBL as a teaching methodology versus lectures showed that there was not a strong conviction amongst the students that their knowledge, and retention of that knowledge, had improved as a result of the course, refer to Figure 5-6 and Figure 5-7.

In the second phase of the investigation, this perception had changed significantly. The collated responses to "my retention of knowledge was not as good as with traditionally presented material (print or lectures)" is given in Figure 5-22. Whilst students with no opinion on this statement increased from 23% to 29.4%, there has a significant shift in opinion for Agree (2002 – 26%) to Disagree (2008 – 50%) indicating that changes to the implementation of the course had resulted in an improvement in student perceptions with respect to their learning and the format of material presentation.

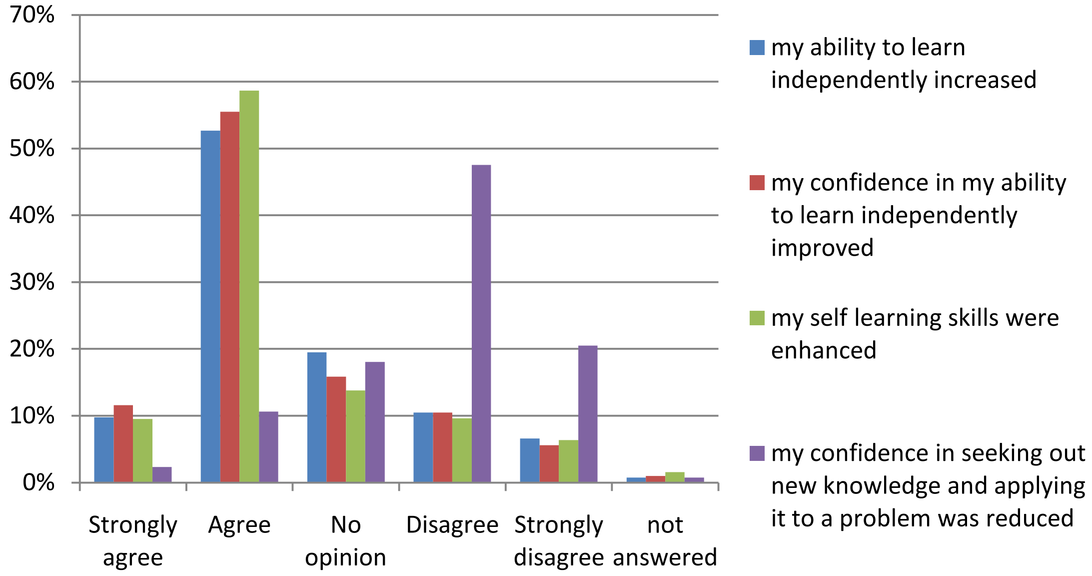

Figure 5-21 Survey responses to test student perceptions of independent and self learning skills

(n=820)

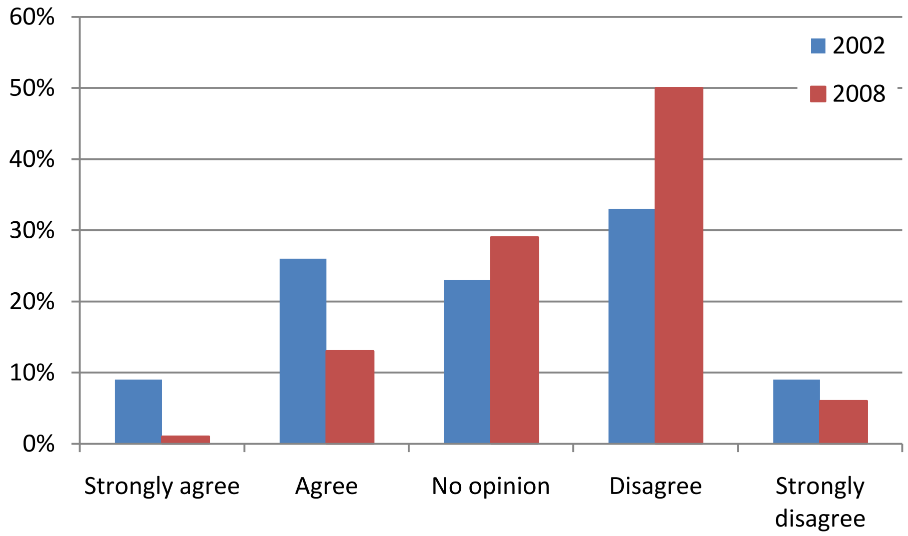

Figure 5-22 Retention of knowledge was less than in traditional courses

Retention of knowledge was not often specifically mentioned in either surveys or portfolios but there were many comments relating to ‘learning’:

> *I learned many new things...[including] technical concepts as they applied to a practical problem. My team mates and facilitator were terrific and I really enjoyed learning in a practical sense. I do not enjoy traditional learning methods as I do not believe retention and learning quality is as good. Life is not assessed or altered by studying [for] exams, but through experiencing situations and solving problems.* – **comment from portfolio**

> *[The best aspect of the course was:] The course structure, as it reinforced the required learning outcomes by challenging your understanding of the work, especially with the individual requirements. As the course progressed the puzzle opened up before you ....Overall [the course] is a great eye opener and good learning experience.* – **comment from survey**

Central to self directed and independent learning is reflection: “what did I learn?”; “how did I learn it?”; “how can I use the knowledge differently?” are indicative of critical thinking and represent the highest levels in Bloom’s taxonomy of learning (Bloom 1956). However, typically engineering students struggle with reflective writing, but structuring the reflective writing tasks and providing the resource of the reflective writing guide did assist and improve the level of reflective writing (Brodie 2007b).

> *Many of reflection tasks were time consuming. I personally prefer maths, physics, report writing etc. and I'm not a big fan of the reflection criteria etc. However I can clearly see how it relates to engineering in the real world.* – **comment from survey**

> *I could not quite grasp the reflective writing concept* – **comment from survey**

> *I found that the least helpful things were the reflections in the portfolio's, this doesn't mean that this was uneffective [sic] just the least effective.* – **comment from survey**

The Portfolios, were the most helpful aspects of the course as it facilities learning by reflection. The portfolios of this course were linked to each other and follow a natural progression from initial learning, development, and reflection. I found the very useful in facilitating individual learning..... **– comment from survey**

Reflective writing enhanced my self evaluation skills and my communication skills greatly improved as well. **– comment from survey**

[I learnt most from] the requirement for reflection which allows the team members to learn from previous knowledge and the completed tasks. **– comment from survey**

[The most helpful aspect of the course was...] Individual portfolios. They were excellent it [sic]better understanding how we learn.– **– comment from survey**

The idea of reflection has been one of the positives in my list of goals. I have never really reflected on my learning style, or about any of the past subjects that I have completed. I believe that this will definitely help me as I proceed with my degree. – **comment from student portfolio**

Nearly all comments on reflective writing and portfolios can from student surveys. Very few students thought to comment on reflective writing in the actual portfolios themselves, instead focusing on problem solving skills, teamwork and communication skills.

5.5.3 Communication Skills

The course presents many opportunities for development and improvement of communication skills. These span:

- Formal (formal technical reports, memos and presentations) and informal (discussion forums and synchronous chat);
- Individual (portfolios and in team meetings) and team (team reports and communication with facilitators and course examiner)

The skills largely focus on written communications. Very few teams have the opportunities for teleconferencing for example. Students begin to understand the complexities of communication, particularly without the normal cues from intonation and expression.

From the surveys, 78% of the students either agreed or strongly agreed that the course had increased their communication skills. See Figure 5-23.

> *……I feel that working externally and communicating solely via the internet, exacerbates the issues that can arise when working in a team. You have to put in extra effort to communicate effectively. i.e. correctly word your statements so that they cannot be misinterpreted. It's from this aspect of the subject that I feel I have learnt the most thus far. I am surprised at how I am actually using these communication skills in my day–to–day work now with success –* **comment from portfolio**

> *'Written communication is a skill that improves with practice, and this course has definitely given me a lot of practice. One of the reasons that this course teaches professional writing better than others, is the fact that it allows students to critique each other's work. Not only have I learned from having my own work critiqued, but also from critiquing the work of other students. –* **comment from portfolio**

> *I also found that it was easy to communicate within a group via email and the Internet. I enjoyed this part of the course, as it allowed members to join in discussions at different times of the day and this suited the group as we all work different hours and have a range of internet access times available to us* **– comment from portfolio**

To date there has been no thorough investigation of the improvement of communication skills in the students. Anecdotal evidence supports the assumption of improvement in writing skills in some students, but not in all. Similarly the examiners of following PBL courses indicate a difference in skill level between those students who have successfully completed the first course when compared to students who gained an exemption in the course. These students struggle not only with the concept of PBL but also communicating electronically. However this assumption has not yet been rigorously investigated.

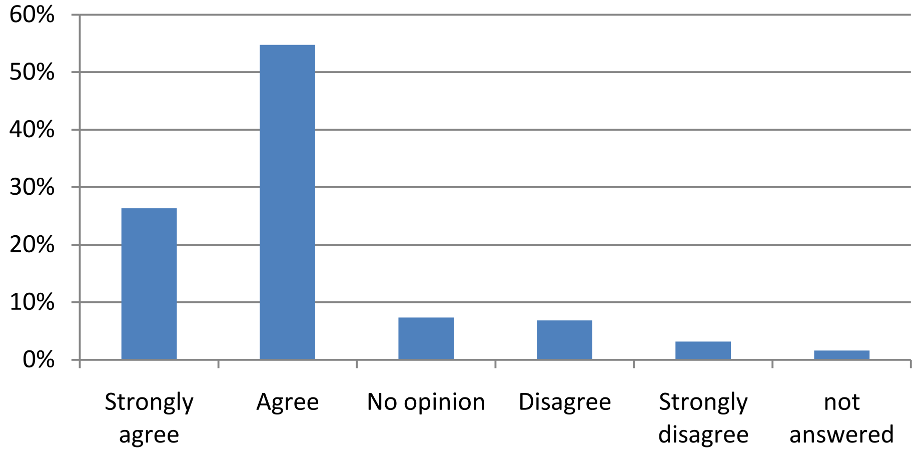

Figure 5-23 Student perceptions on the improvement of communication skills as a result of the course

(n= 820)

5.5.4 Problem Solving Skills

The course allowed students to apply their prior learning, skills and experience, to a variety of scenarios. Like teamwork, many students believe they already know about ‘problem solving’ and have sufficient and effective skills in this area. On–campus students, particularly those with no work experience (have come straight from school) equate problem solving to solving text book problems in mathematics or physics. Older students assume problem solving skills are a consequence of experience.

“I solve problems every day at work”, is a common response from students when asked about their skills.

Over the duration of the course, students believe that their problem solving skills have been enhanced. Their appreciation of how their own prior skills and knowledge, as well as those of their colleagues can be effectively utilised in problem solving has also increased. Refer to Figure 5-24. The assessment tasks encourage and support teams and individuals to reflect on and understand the steps undertaken in solving problems. Students utilise their prior knowledge and the knowledge of their colleagues not only in solving the problem, but also to meet their individual learning goals. There is a significant correlation between these three aspects (Table 5-11) and demonstrates that the wide range of entry paths, educational and work experience of the students in the course allows the sharing of knowledge and mentoring within the problem solving exercise.

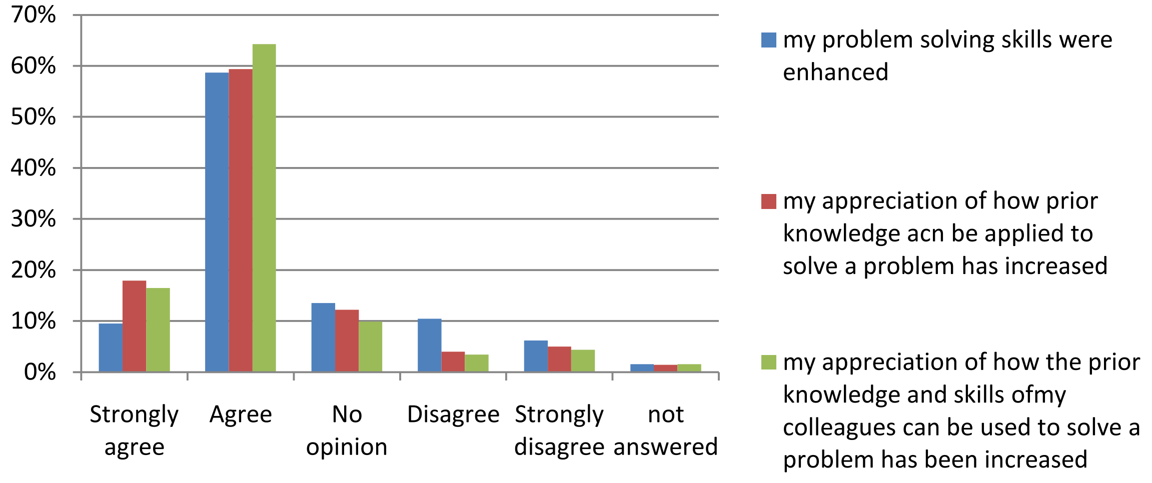

Figure 5-24 Student perceptions on problem solving skills

Team diversity and its effect on solving problems is a key theme which emerges from all data. Sharing skills, knowledge and experience clearly assists teams in understanding and solving the problems.

> *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…* – **comment from Team Reflection**

> *Diversity works for the team because we: Solve a problem using different viewpoints.; Use each others' skills to increase the team's output; Learn skills from one another* – **comment from portfolio**

> *[The course] ....allowed students to apply their prior learning, skills and experience, to a variety of scenarios that may vary to their normal exposure.* – **comment from portfolio**

Table 5-11 Correlation statistics for problem solving skills and application of prior knowledge

Correlations

			problem solving skills were enhanced (Multiple Choice)	appreciation of how the prior knowledge (Multiple Choice)	appreciation of prior knowledge of my colleagues (Multiple Choice)
Spearman's rho	problem solving skills were enhanced (Multiple Choice)	Correlation Coefficient	1.000	.583**	.552**
		Sig. (2-tailed)	.	.000	.000
		N	820	820	820
	appreciation of how the prior knowledge (Multiple Choice)	Correlation Coefficient	.583**	1.000	.813**
		Sig. (2-tailed)	.000	.	.000
		N	820	820	820
	appreciation of prior knowledge of my colleagues (Multiple Choice)	Correlation Coefficient	.552**	.813**	1.000
		Sig. (2-tailed)	.000	.000	.
		N	820	820	820

**. Correlation is significant at the 0.01 level (2-tailed).

The theory of problem solving and developing a 'strategy' which can be applied in other circumstances and problems has been emphasised in the delivery and assessment. As part of the team reflection, teams must address this aspect of their teamwork. The link between a problem solving cycle and assessment is clearly established and is becoming an overarching concept of the course which is applied at every level and for all assessments.

The 'problem solving cycle' shown in Figure 5-25 has been integrated to the wiki pages for students so the concept is continually visible. Effects of this innovation, on both students in this course and the learning which is carried into the following PBL course is an area of further investigation.

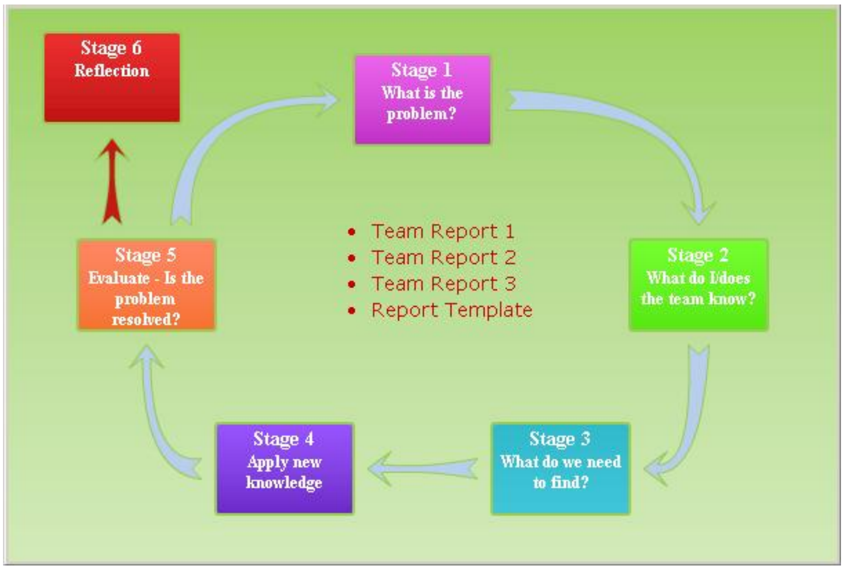

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Figure 5-25 Problem Solving cycle

5.6 Summary

This chapter summarises the continuous development and evaluation of the first PBL course, ENG1101 *Engineering Problem Solving 1*. An initial investigation proved the concept of PBL delivered to students working entirely in virtual space. Subsequent reflection (by the author), literature review and implementation of new ideas resulted in a significant improvement in the key areas of problem solving, communication, teamwork and self directed learning skills.

Some areas such as communication skills require further investigation to fully detail improvements, but current data supports the hypothesis that improvements are successful.

The majority of students believe that their problem solving, communication, teamwork and self learning skills have increased as a result of the course. Data sources include student surveys with five point Likert scale validated by short response answers and unprompted reflections in student portfolios.

Further, in depth investigation is indicated in some areas for future work but the data to date supports the hypothesis that the course is delivering on key graduate attributes. These attributes have been identified by industry and accreditation bodies as integral to the success of future engineering graduates in a global economy.

The course successfully uses the diversity and expertise of the student cohort, fostering mentoring and peer assistance for the transference of skills and attaining self nominated learning goals. Again, the literature suggests that these learner centred approaches to education are necessary for tertiary education.

The implementation of PBL in virtual space is dependent on a number of major issues: the support of suitably trained staff, student teams forming a learning community, and the incorporation of a suitable Learning Management System into the design and implementation of the PBL curriculum. These areas are investigated and detailed in the following chapters.

6 Forming and Supporting Virtual Teams in Higher Education Using a Learning Management System

6.1 Introduction

Universities have responded, to varying degrees, to the demands of the profession for teamwork, communication, problem solving and lifelong learning skills in their graduates. They have also responded to the demands imposed by changing technology with respect to discipline specific knowledge and skills and its application in professional engineering, but their response to the impact of technology on ‘soft skills’ has been less obvious.

Chapter 6 summarises the work on forming, supporting and evaluating virtual teams for student learning. Working in a global environment, and hence virtual teams, is a likely requirement for future graduates and is already discussed in the literature. The rapid development of technology does have significant impacts on engineering education and the profession in general.

The literature on true virtual teams, teams working entirely in virtual space, is minimal particularly when applied in the context of higher education and PBL. The work of the author to date, provided in this chapter and evidenced by the publications listed below, make a significant contribution to the body of knowledge in this area. It synthesises and summaries the use of, and data acquired from, the Learning Management System (LMS) which supports student communications and delivery of key resources. The LMS has been integral in forming a learning community for the engagement of all students and staff.

However, working a virtual environment and working in a virtual team, is not without difficulties. In addition, the requirement for *learning*, a key obligation for universities and higher education providers, is an additional complication to teamwork and one not usually discussed in the literature. Barriers to participation and learning, in a virtual environment, have also been investigated and a framework proposed as a basis for further work. The framework has implications not only for virtual teams, but for teams working and studying in traditional on-campus environments.

Sections of this chapter have been peer reviewed and published in the following papers:

Brodie, L. & Gibbings, P. in press, 'Connecting learners in Virtual Space – forming learning communities', in L. Abawi, J. Conway & R. Henderson (eds), *Creating Connections in Teaching and Learning*, Information Age Publishing.[17]

Brodie, L. 2009, 'eProblem Based Learning – Problem Based Learning using virtual teams', *European Journal of Engineering Education*, vol. 34, no. 6, pp. 497-509.

Brodie, L. 2009, 'Virtual Teamwork and PBL - Barriers to Participation and Learning', paper presented to the *Research in Engineering Education Symposium (REES)* , 20–23 Jul 2009, Cairns, QLD, Australia.

Brodie, L. 2007, 'Problem Based Learning for Distance Education Students of Engineering and Surveying.', *Connected - International Conference on Design Education*, Sydney.

Brodie, L. 2006, 'Problem Based Learning In The Online Environment – Successfully Using Student Diversity and e-Education', *Internet Research 7.0: Internet Convergences*, Hilton Hotel, Brisbane, Qld, Australia,

6.2 PBL and Distance Education – a framework

Several examples of PBL used in a quasi distance mode such as using the internet for part of the course delivery have been reported in the literature (Taplin 2000) but for the most part PBL has not been quickly absorbed into distance and online education pedagogies as discussed in Chapter 2. Zemsky and Massey (2004) reported on the failed uptake of general e–learning in America and suggested that the e–learning innovation cycle has stalled at the innovator and early adopter stages, rather than becoming mainstream. The report argues the online initiative has not been developed into a form that can transform learning and teaching in higher education.

Web–based teaching and the integration of communication technologies into the higher education curriculum in meaningful ways which result in *student learning* is still in its

[17] This publication is also referred to in Chapter 8 Developing a Learning Community

infancy and online educators are “blazing new trails in developing the essential elements and process that will lead to high–quality, active, online learning environments” (Caplan 2004, p. 176). McDonald (2007) believes:

> *When technology is introduced to education, it creates the opportunity to innovate, but also challenges and changes existing processes. Online teaching requires a significant shift in pedagogy and practice for many teachers.*

Thus there is recognition in the literature that online teaching requires a different approach and different skills to support student learning. This is, in some part, due to the mix of rapidly changing communication and web technologies which are available to teachers and academics but mostly discusses the need for a pedagogical shift for teachers to engage students in an online environment. When designing and incorporating a PBL methodology, particularly where learning is constructed in a true virtual team environment, there was little or no prior literature or research documented on student learning, patterns of communication, required staff training and changing educational requirements.

Desmond Keegan (Keegan 1980, 1986) identified six key elements of distance education:

- separation of teacher and learner,
- influence of an educational organization,
- use of media to link teacher and learner,
- two way exchange of communication,
- learners as individuals rather than grouped and
- educators as an industrialized form.

Many of these elements can easily be expanded or slightly modified and applied to PBL in the higher education sector. If media is used to link teacher and learner, then learner can link with learner and hence a separation not only of the teacher but of other students working in a team environment is possible. The two way exchange of communication could easily be a multiple exchange between many participants with learners as individuals bringing prior skills and knowledge to share in the information exchange and the influence of an education organisation becomes a facilitator of learning.

If the media link is the Internet and electronic communications, then Anderson's (2004b) model for online learning, as shown in Figure 6-1, can be adapted as a foundation for online Problem Based Learning (PBL) and team based PBL becomes not only possible but a way of overcoming the 'isolation' typically felt by traditional distance students. The model provides a framework for the interactions between multiple students and the academic facilitator via synchronous and asynchronous communication. Technologies can deliver resources and content required to support individual student learning in a learning community and teamwork in a virtual environment.

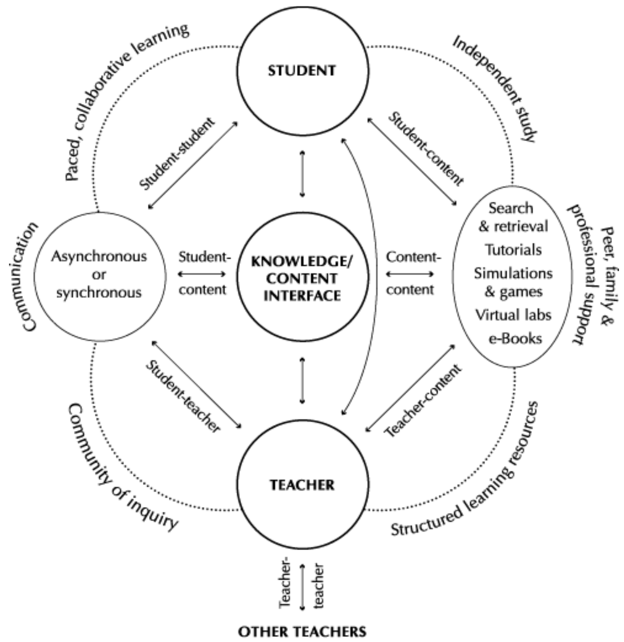


Figure 6-1 A model for online teaching and learning
(Anderson 2004)

However, despite these linkages and synergies there are only a limited number of references to PBL in *distance* higher education. Of available references to group based cooperative learning nearly all require at least some face–to–face meetings of the team members. This does not make full use of the available technology and means that students need to physically meet.

Brodie (2006) describes the implementation of an LMS to facilitate communication between team members undertaking a PBL course in engineering. Analysis of the data provided by the LMS on student usage was undertaken and linked to student engagement and learning.

6.3 Data from the LMS

As an example of results, consider Semester 1 2006 which can be viewed as typical for the course. In this semester there were a total of 309 students enrolled with 113 enrolled in on campus mode and 196 in distance mode. Students spent a total of almost 10000 hours in 155000 sessions on WebCT, the university Learning Management System (the university has since recently moved to Moodle ©). They posted a total of nearly 16000 messages to the discussion boards. This consumed the majority of time on the LMS accounting for 67.5% of student time or 6750 hours. Figure 6-2 shows the distribution of sessions and percentage of total sessions spent on all the functions offered by the LMS. It should be noted however that the email facility offered by WebCT was not available to students. For administration reasons the examiner uses email addresses provided by students on their enrolment forms.

The chat rooms within WebCT were also poorly utilized with many teams using other mechanisms for synchronous electronic chat such as MSN. This was due largely to the instability of the chat rooms on the USQ server.

The URL as shown in the figure is the Course Resource Page. This is heavily utilised by students accounting for over 10 % of all sessions and 1054 hours of student time. This time accounts only for students who visited the Course Resource Page by entering via WebCT. It does not account for students who went to the URL directly without logging into USQStudyDesk.

Figure 6-3 shows the total number of postings on team discussion boards for each of the two student cohorts – distance and on campus teams as well as the use of the general discussion board and the 'combined' boards. The general discussion board was used for administration questions and general overall guidance. The combined discussion boards were structured for interaction between teams and more significantly between on–campus and virtual (distance) teams.

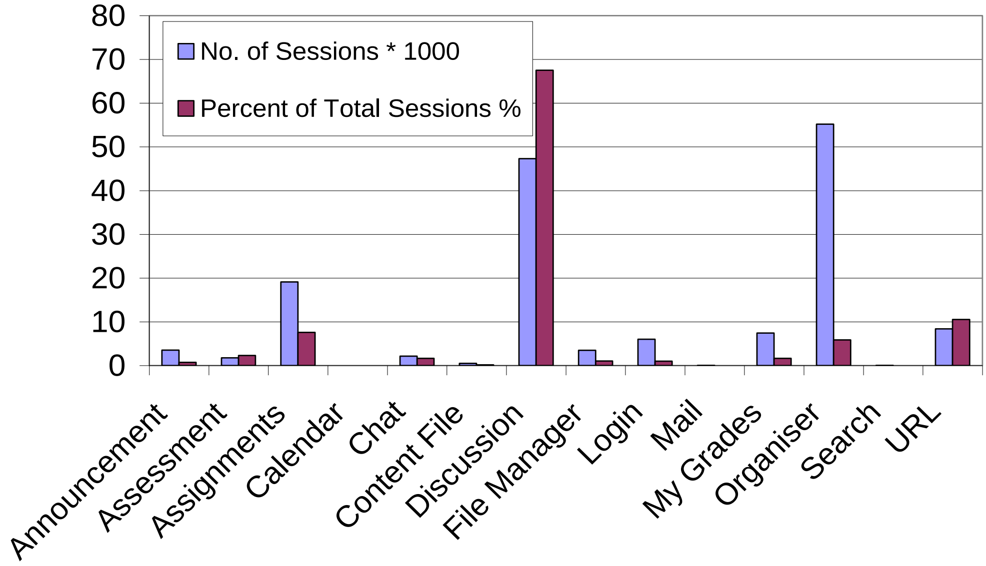


Figure 6-2 Usage of the LMS for a typical semester

At first glance the data shows significantly more postings for distance teams, who have no alternative communications, than for on–campus teams who can meet face–to–face. However, Figure 6-4 shows that the average number of postings per student per week was equally shared between on campus and distance students. This is an interesting result as it was assumed that on–campus students would make significantly less use of the 'virtual' communication methods. However they liked the flexibility offered by electronic communications and virtual teamwork.

> *Our team initially did not make good use of the team discussion board. We did not believe we needed such a gimmick. However over the last few weeks of the work we found it harder and harder to get everyone along to a meeting. [Student names] were never available and generally their motivation was not what it should have been but we all seem to have gotten different things to do and the time on the timetable to work on the course had been filled with other things. Then [our facilitator] started posting information on the discussion board and we realised this was what we needed…* – **comment from (on–campus) team reflection**

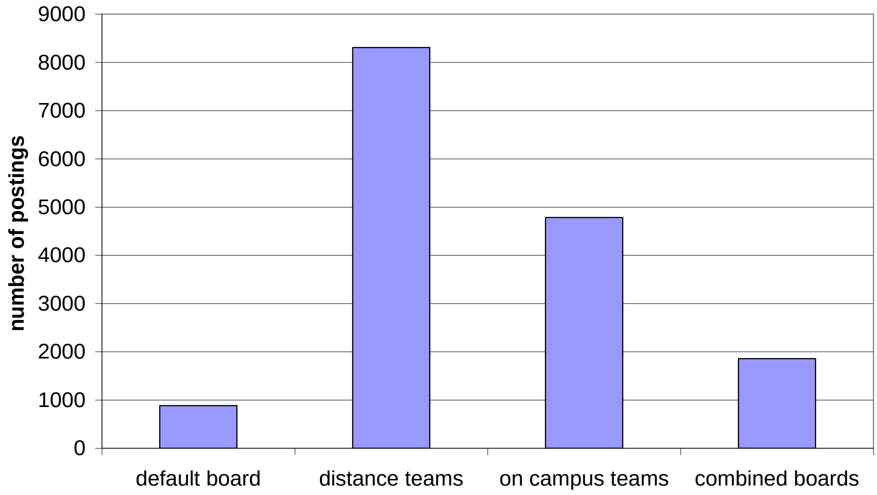


Figure 6-3 Use of discussion forums

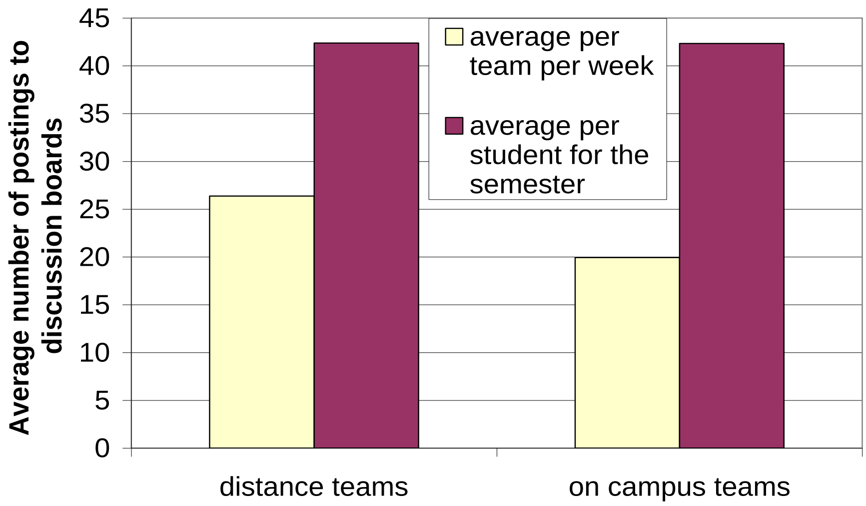


Figure 6-4 Average number of postings to discussion boards for a typical semester

Further analysis of postings is shown in Figure 6-5. In this analysis posting per student per week is compared to due dates of assessment items. In the beginning of the semester on–campus students mostly use a face–to–face meeting for discussions but over the course of the semester the on–campus teams take up the use of the forums over face–to–face meetings.

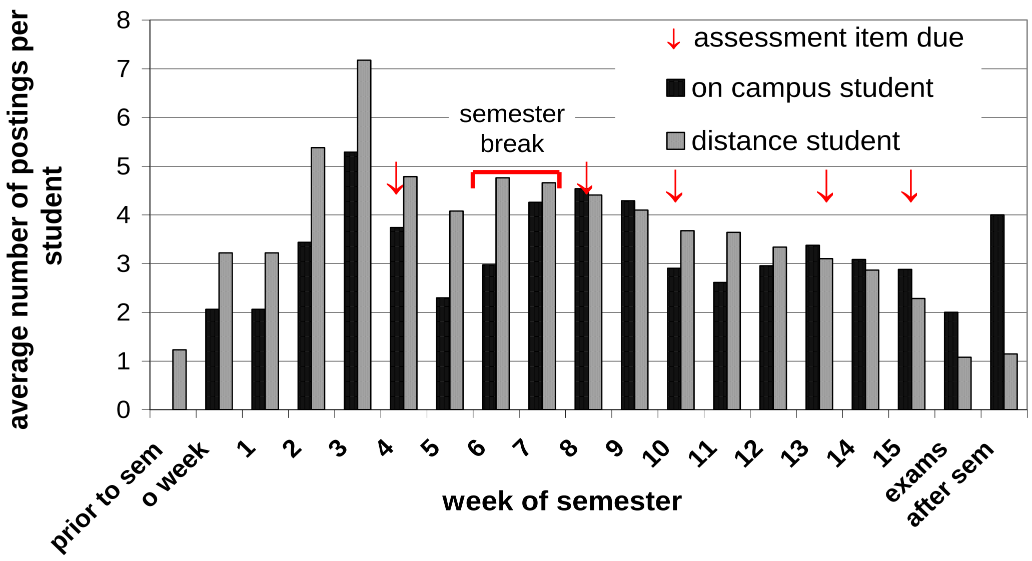


Figure 6-5 Average number of postings per student per week

There is a high use by distance teams especially prior to the due date of the first assessment, as would be expected. This is also confirmed by the average time per week students spend on the discussion forum as shown in Figure 6-6. Once the initial hurdle of getting to know members and working out a plan for interaction, as per the first team report, the distance students have a relatively constant number of postings per student per week and settle into a routine of meetings and team communications which is suited to their teams profile and communications plan.

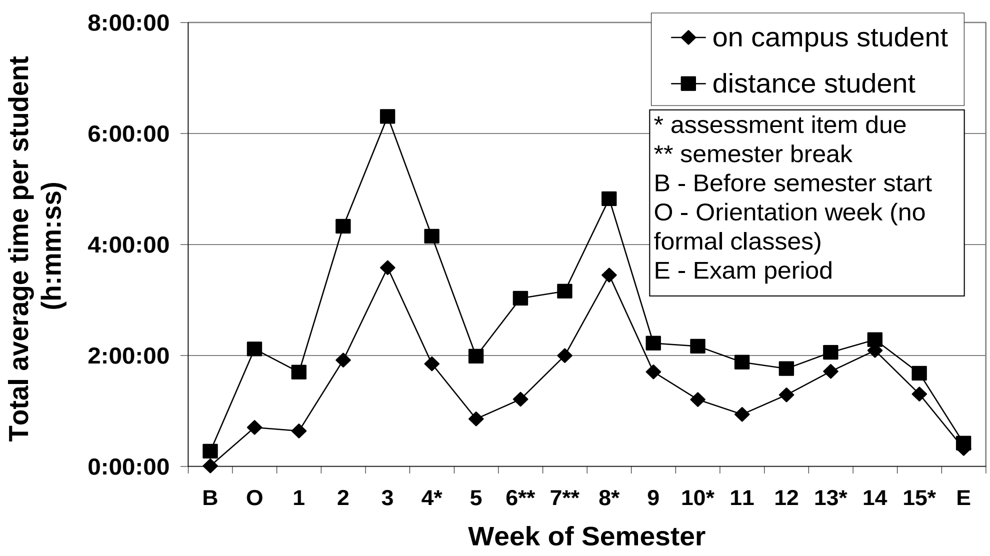


Figure 6-6 Total average time per student per week for semester 1 2007

6.4 Overview of Postings to Discussion Forums

On–campus students

Postings by on–campus students during the first two weeks of semester were task orientated and were largely in response to the outcomes of face–to–face meetings. They used the discussion postings to share email addresses and contributions to the first team report such as ideas for the code of conduct and available times for meetings. This was particularly evident in the week prior to the first assessment item where the discussion forum was used to share files and drafts of documents.

On–campus students worked more ‘virtually’ over the two week semester break. Many students leave the campus and the discussion forums were utilised to discuss and prepare the next assessment item, although having to study over the semester break caused much resentment among the on–campus students. Distance teams were much more aware that the semester break is an ideal time to catch up on study and is not a ‘holiday’.

During the second half of the semester on–campus students consistently used the forums and replaced face–to–face meetings with postings and virtual meetings using the chat forums.

At the end of semester there was a considerable increase in postings from on–campus students. These postings were related to several topics including:

- Farewelling team members e.g. *“Thanks everyone for a great effort over the semester…”;*
- Querying grades and sharing results e.g. *“Hi everyone, team results are in…here is the feedback”* and “*Does anyone know when portfolio will be marked?”;*
- Setting up a team for the following course e.g. *“…does anyone know if we can stay together for ps2 [the following team based course]?”*
- Discussing other courses e.g. *“…did anyone else find [maths examination] a killer….?”*.

Distance students

After the initial assessment item, distance teams quickly settled into a routine of postings and team operation. Over the course of the semester number of postings declined but the postings became longer and more task orientated. There were fewer postings related to off task or social interaction and when present, these discussions were incorporated into other postings.

Postings indicated that virtual teams were more consistent in their approach to tasks and developed better patterns and strategies of usage. Their forums were generally, by the end of semester, better organised with more threads to separate out various areas and topics for discussion.

6.4.1 Forming, Storming and Norming

Analysis of postings on discussion boards by categorising posts from both cohorts of students indicates that:

- During the beginning of the semester in weeks 1 and 2 virtual teams have more postings on ‘social’ interactions indicating the ‘forming’ of the team, but still largely related to the mechanics of teamwork and the tasks to be undertaken. They exchanged personal email addresses and phone numbers, listed available times and were largely work and task focused. There were also a large number of postings questioning the ‘whereabouts’ of listed members. For on–campus students this social interaction was usually done in the face–to–face sessions, some formalised and others organised by the student teams themselves. Their initial postings merely documented the face–to–face meetings and there were more ‘off task’ postings. They also were more accepting that team members were missing or non participatory.

  On–campus teams were more accepting of the ‘fluid’ nature of the team make up during the early weeks. They were not necessarily more accepting of new team additions when compared to virtual teams, but were more accepting, particularly in the early stages of the semester, of the fact that although students had enrolled in the course and had been allocated to the team they may not yet be active.

Virtual teams, particularly those that had a clear leader who took charge from the beginning, were more expectant that the allocated team members would be available and ready to participate from the beginning. However, both cohorts were welcoming and inclusive of new members during the first 3 to 4 weeks of the semester.

After these initial 'forming' weeks, virtual teams were usually more reluctant to accept new members, especially if these members had been allocated to the team from the beginning, but had only now become active.

- Both cohorts, on–campus and virtual teams, showed evidence of 'storming' in postings largely to do with non or poor participation. However the on–campus teams realised more quickly the differing levels of motivation and commitments of members whereas in the virtual teams these problems were hidden in 'work, family or other commitments'. Whilst virtual team members do have significantly more work commitments, usually working full time and in many cases shift work, it appeared easier for these students to cite 'difficulties or overtime needed' at their place of employment as an excuse for not meeting team deadlines. It was not possible to verify these reasons either by the examiner or other team members.
- During the 'norming stages' of team development both cohorts have established clear rules of operation and working strategies suitable to their particular circumstances. The postings were largely task orientated. Virtual teams had more postings relating to seeking clarification or assistance. On–campus teams merely posted completed tasks for critiquing or inclusion in the final report.
- There were no significant or consistent differences between on–campus and virtual teams in the time taken to reach, or the overall duration of, each of the team phases. Some teams reached the performing stages before others and some not at all; however it appears that this is not related to method of team meeting (face–to–face or virtual) and was more dependent on the personalities and motivation of team members.

6.4.2 Barriers to Participation and Learning

There is no significant difference in the overall performance (final grade) of virtual teams compared with on–campus teams. However, virtual team members do have to overcome significant barriers particularly with respect to *learning* in this medium. There are three main areas to be addressed if effective student learning is to be obtained. A proposed model for barriers to students participation is shown in Figure 6-7. The model proposes that the main categorises are Time, Technology and Learning.

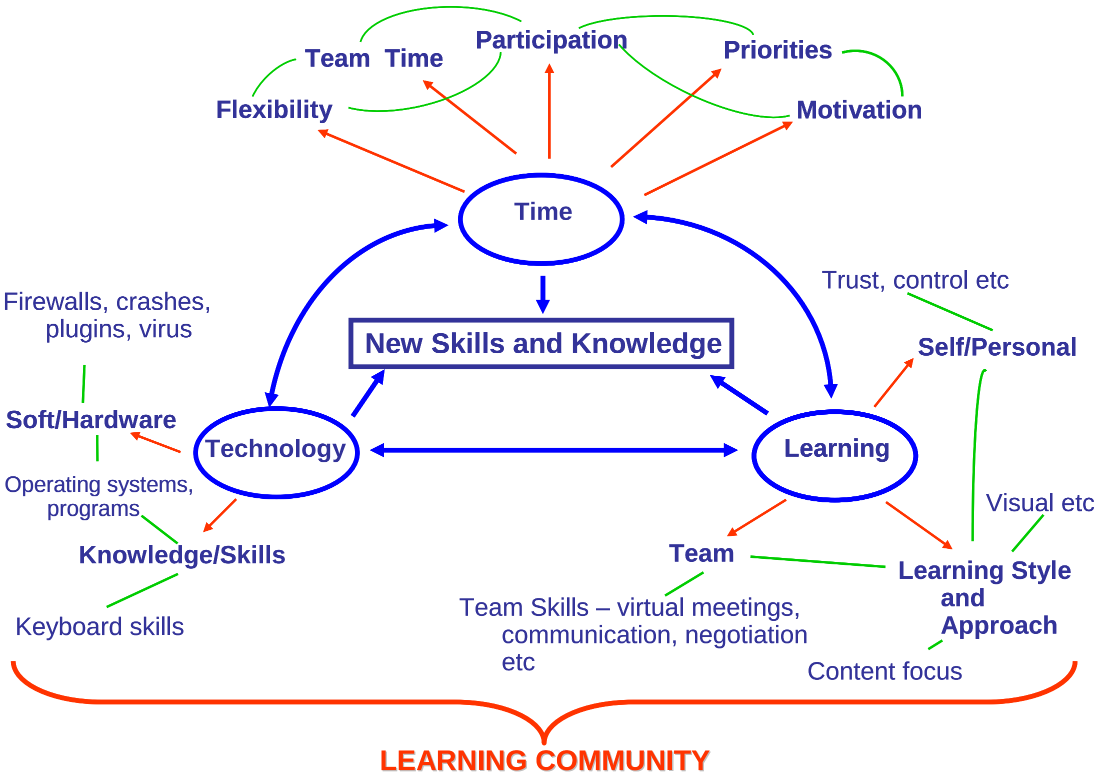


Figure 6-7 Barriers to student learning in virtual teams

Each of these categories has overlapping and interwoven aspects. For example Time can be broken down into the aspects of motivation, priorities, participation, team time, and flexibility which have related impacts. If a student has low motivation, this impacts on participation and on his/her flexibility to be available for team meetings and to meet team priorities. The converse is also true. If a student has low flexibility in their time and availability, it impacts on participation and motivation.

Technology has great impact on a student's learning and their ability to learn. If they do not have the skills and knowledge to readily interact with the team and access other resources, there are immediate and severe consequences for their engagement in the learning opportunities available through the virtual team interaction. Lack of general keyboard skills to efficiently make postings to discussion boards, reply to emails or contribute to a synchronous chat session can frustrate the student and in some cases marginalise the student from the team. Similarly, inability to navigate firewalls, virus and anti–virus software, recover from system crashes and the installation and use of operating systems can impact a students learning even before they have begun. They are sunk at the first hurdle.

Over a three year period all students who drop the course within a few weeks of the start of semester (prior to the census date) have been contacted to ascertain reasons and identify further support mechanisms required. A total of 128 students have been interviewed. Reasons for dropping the course can be categorised as follows:

- Insufficient time to devote to the course,
- Insufficient flexibility to attend or participate in team meetings and working to a team timetable,
- Poor access to a computer or internet access,
- Seeking exemptions from the course as they believe they have sufficient 'team work' experience,
- Unwillingness to work in a team environment,
- Unpreparedness for the commitment to study (in general),
- Change in personal and work circumstances.

From this survey the two main barriers to student learning are Time and Technology which account for 82% of reasons given for students who drop the course within a few weeks. Seven percent claim they are seeking exemptions on the basis of prior work experience; five percent state a change in personal circumstances; three percent state they are unwilling to study in a team environment; three percent were unwilling to give reasons or gave unclear reasons.

The last of the barriers to student learning and participation – Self Learning is more difficult to investigate and quantify and is a significant area of study in its own right.

The learning of a student in a tertiary environment is a complex area and is influenced by many factors – learning style, self efficacy, pedagogy and personality to name a few. An added layer of complexity of this is the 'team': the personalities, interaction of the team members and the requirement for the student to be an independent learner. Some students thrive in this sometimes new situation whilst others seek the normality of a standard classroom or course where the work is individual and directed by the 'teacher'. Examples of this are shown in the following student comments from a standard course evaluation form:

> *I prefer to be told what to learn and not have to figure it out for myself* – **student comment from survey**

> *If I wanted to be a self learner, I wouldn [sic] not have come to university*– **student comment from survey**

> *Setting my own learning goals was a liberation – I have never learnt so much about myself or the topic I set [for further investigation]* – **student comment from survey**

Analysis of the student reflective portfolios shows a surprising number of students give unprompted comments about their own learning style both as an independent learner and as a team player. A random sample of 200 (100 distance students and 100 traditional on–campus students) portfolios in 2009 showed that

- 53 distance students made comment about their ability, or inability, to trust members of their virtual team especially in the early part of the course. This compared to just 12 on campus students who meet face to face.
- 37 distance students made comments on the controlling aspect of a personality, either themselves or a team member e.g. He/she/I always takes control of the meeting; He/she/I tries to dominate the meeting/everyone etc. Only 24 on–campus students made similar statements.
- 47 distance students made specific comments relating to the differences in working in a virtual team compared to a face–to–face team. Their comments related to the different interactions between team members in the virtual environment, reflected on how the interactions would have been different in

the different environment, or reflected on what they had learnt about themselves or team members.

- Distance students appeared to bring more team skills to the course and were able to reflect on the use of these skills in a different (virtual) learning environment.
- On–campus students reported more difficulty or dislike with the self directed nature of the course, whilst the distance students made more comments relating to the technical aspects of the projects. On–campus students had more comments believing that the course was not a true representation of the profession of engineering with comments like “we spent lots of time in meetings which is not what happens in an engineering office” and “the project was not what engineers in industry would be doing”. This impacted on their motivation and learning tasks.

  Distance students were more ‘content’ focused and disliked the research aspect of the course. For example “I believe we should have learnt more discipline specific technical content. I did not learn much from researching [topic] as it was not in an area I am working in.” and “if I wanted to learn myself I would not have enrolled in an engineering degree” were typical comments.

- A different maturity in approach to study was also evident in the portfolios. Whilst the portfolios were not matched for student age, the distance students are, on average, older. More distance students commented on the reflective task itself with comments like:

  This reflection really started me thinking. It is helping me to examine not only what and how the course is teaching but how I am performing, my shortcomings and what I need to work on. **– (Student comment)**

  The idea of reflection has been one of the positives in my list of goals. I have never really reflected on my learning style, or about any of the past subjects that I have completed. I believe that this will definitely help me as I proceed with my degree. **– (Student comment)**

An understanding of the barriers of time, technology and self-directed learning and their interactions is vital if PBL in virtual teams or even learning in virtual communities is to be used in higher education. Understanding the implications and intricacies of the framework allows appropriate support mechanisms to be developed and implemented. This will assist students in vital areas so they can understand and reflect on their individual perspective and can then focus more on their own learning and performance in a virtual team environment.

6.5 Summary

Working effectively and efficiently in a virtual team is a likely requirement for future graduates. The global nature of engineering, and rapidly evolving technology, may significantly change the profession of engineering and engineering education must also evolve to meet these needs. Whilst universities have adopted key graduate attributes such as teamwork, communication, problem solving and lifelong learning into their curricula, the concept of a global profession and its implications have not been fully explored. The concept of virtual teamwork and its difference from face–to–face teamwork, especially from a student learning perspective, has potential and requires further investigation.

A preliminary framework representing three major barriers to student learning in virtual teams has been developed: time, technology and learning. The model successfully represents the interactions between these barriers and implications for student participation and learning in a virtual team environment. By understanding such hurdles, changes in assessment, resources, facilitation and support mechanisms can be designed and implemented to support students so that learning is the central focus of the course and is not unduly compromised by other influences such as technology and personal learning style.

The further work required to validate this model is discussed in chapter 10.

7 Assessment

7.1 Introduction

The assessment strategy developed for use in the course has evolved over time and continues to evolve. It is designed to support the objectives not only of this specific course but also to enhance the pivotal role the course plays in the strand of courses, in the program and in the overall professional development of the student.

The underpinning philosophy of the course assessment is to support and encourage an individual student, team progress and learning for team members. The focus is on individual and team *process and progress* rather than just a final outcome and production of an artefact. Engagement of the student in self-directed learning, a critical appraisal of progress of self and team and their role within the team progress are central to individual assessment.

In assessment of projects (or problems) it is usual, and easier, to assess the final outcome. In professional practice this is the bench-mark and the only important factor. However in student learning situations and in particular first year courses, whilst the outcome is a goal for students to work towards, the process and ensuring students learn from the experience is equally important.

Whilst minor details and weightings of assessment items may have changed over time, the main assessment components of the course have remained stable and are:

- Team project reports, modified by a peer and self assessment mark, to give an individual mark from the team report. Team reports have a *team reflection* component.
- Individual reflective portfolios which also include some set tasks.

Details and development of the assessment strategy have been published in the publications below. The development and validation of assessment rubrics, suitable for open ended problems and projects have also been documented.

The publications, in peer reviewed journals and conferences, span several years and demonstrate the active research nature of the assessment strategy development in the PBL course. Sections of these publications are included in this chapter:

Brodie, L & Gibbings, P. 2009 ‘Comparison of PBL assessment rubrics’, *In: 2009 Research in Engineering Education Symposium*, 20–23 Jul 2009, Cairns, Australia.

Brodie, L & Gibbings, P. 2008, 'Assessment Strategy for an Engineering Problem Solving Course', *International Journal of Engineering Education*, vol. 24, no. 1, Part II, pp. 153–161.

Brodie, L. 2008, 'Assessment strategy for virtual teams undertaking the EWB Challenge'. *In: AaeE 2008: 19th Annual Conference of the Australasian Association for Engineering Education*, 07–10 Dec 2008, Yeppoon, Queensland, Australia.

Brodie, L. 2007, 'Reflective Writing By Distance Education Students In An Engineering Problem Based Learning Course', *Australasian Journal of Engineering Education*, vol. 13, no. 1, pp. 31–40.[18]

Brodie, L. & Gibbings, P 2006, 'Skills audit and competency assessment for engineering problem solving courses', *Proceedings of The Internal Conference on Innovation, Good Practice and Research in Engineering Education*, vol. 1, eds Doyle S & Mannis A, The Higher Education Academy, Liverpool, England, pp. 266–273.

Gibbings, P & Brodie, L. 2006 ‘An Assessment Strategy for a First Year Engineering Problem Solving Course’, *17th Annual Conference of the Australasian Association for Engineering Education*, Auckland, New Zealand, 10–13 December. p 33

7.2 Overview of Assessment

Students are seen to be largely assessment focused. It is often assumed that their study and subsequent learning is determined by what is assessed and what weighting is placed on the assessment piece. Academics subscribe to this practice with a

[18] Sections of this publication are also used in Chapter 9 – Staff Training and Professional Development

philosophy of “if you want students to learn it, assess it”. This may have resulted in over assessment in many courses and students learning *for* assessment (Cochrane et al. 2008).

In team based projects and courses, this is particularly true with the team looking to optimise outcomes. Practically, students will quickly devise who in the team has particular skills, knowledge, work ethic and motivation and apply these characteristics accordingly. Although the result can be a report of a professional standard, is there any guarantee that students have learnt any new skills and knowledge or taken on new roles outside their normal comfort zone? The addition of a reflective component to the assessment scheme can ask students to think about and document this area, but sharing of skills and knowledge particularly in a diverse student cohort needs to be explicit to engage the students in peer assisted learning and the gaining of new knowledge and skills.

The difference in skills, knowledge and prior experience should be captured and used by the assessment system. The strategy adopted for use in ENG1101 specifically rewards students for mentoring (peer assistance) and proactively addressing team problems. This ensures students gain transferable skills and knowledge beyond producing one technical report. This will support them not only in subsequent courses but also in their professional life.

As outlined in earlier chapters, the PBL strand consists of a series of four consecutive courses, with an additional final year research project seen as the capstone. The main objectives of the first two PBL courses, which are compulsory for all students in the faculty, are to develop the fundamental skills needed for participating effectively in multidisciplinary teams and to expose students to a wide range of problem–solving tools. Subsequent problem–solving courses are designed to expand and improve these skills, and to impart fundamental technical content in several discipline areas.

Because of different disciplines, different study modes and programmes, existing knowledge, expectations, level of interest and other cultural and personal differences, the difference in learning objectives of each individual student can be profound, and this can complicate the assessment process. Indeed, most of these elements have been identified by others as core principles that need to be considered when designing education for adult learners (Knowles et al. 1998).

Most students studying in distance mode do so because they are already employed in some capacity in industry. Because they are already in the workforce, many have different skill levels and personal competency attributes compared with internal students, and their `learner context' (Savin-Baden 2004) will be quite different. There is also a possibility of students, particularly school leavers, not yet possessing the skill set, to truly be independent learners. It is clear that during the setting of course objectives and assessments, there needs to be some recognition of prior learning or skill, particularly for those students who have already developed significant skills through experience in the work force. This must be done in an equitable manner so as not to advantage or disadvantage any group or individual. It seems logical that, to do this effectively, the learning objectives and assessments should be, at least partly, individualised for each student.

Two main problems with respect to assessment were identified prior to the course implementation. These were:

- Some students in teams may want to do all of the work themselves and not share the workload with other team members. This may occur for several reasons; the most common is that the `high achievers' do not want to rely on or trust others to carry out tasks that could ultimately affect their own `marks'.
- Some students may not want to participate at all, or contribute very little to the team effort. The assessment strategy must ensure that the individual only, and not the team, is disadvantaged in this case. Note that contributing little or nothing to the team's project, and then trying to claim a disproportionate contribution and share of the project mark, falls into the broad definition of plagiarism and is not be tolerated.

These two aspects were accounted for in the early assessment strategy by using peer and self assessment which modified the team mark in line with perceived participation and contribution to the final submissions. Students had been assessed on team projects with the project marks being modified to an individual mark based on peer and self–assessment report (Brodie & Porter 2004). Weaknesses of this approach were identified. These were largely due to not providing appropriate incentive, through assessment, for the types of behaviour that were considered desirable such as collaborative learning and mentoring and included:

- Students were reluctant to learn new skills. For example, in the initial assessment system, those who were proficient at a particular skill (for example, report writing) tended to adopt that role in all projects because that gives the team its best chance of receiving a `good mark' for the projects.
- Students needed encouragement to learn from the diversity of skills and knowledge within the team through mentoring and peer assistance. Providing evidence of such assistance is necessary (Biggs 1995) to ensure real mentoring and sharing of learning goals and knowledge is present.

The ability to provide quality feedback, through critical appraisal, is also an important skill and assists learning (Savin-Baden 2004). Appraising approaches taken by other teams, providing and receiving feedback, assists learning (Acar 2004) and is considered to be a strong motivator for the teams involved (Frank & Barzilai 2004). However, to be effective, students are made aware that this feedback is not used as a differentiation tool for formal assessment. In fact, all assessment criteria, both formative and summative as recommended by Acar (2004), need to be clearly communicated to students to ensure the assessment strategy has the desired effect (Savin-Baden 2004).

The revised assessment strategy places the emphasis on *advancement* of skills, and learning new skills, rather than just achieving a minimum standard. This was achieved by each student individually negotiating, and being assessed on (as suggested by Heron 1989), objectives, goals and targets for each project within the PBL course. The direction was therefore determined by the learner within the constraints of the problem to be solved, which is seen as desirable for adult learning (Mergel 1998).

This approach recognises that not all students will have the same learning objectives, nor will they be faced with the same issues (particularly considering the student diversity mentioned earlier), so it is necessary to be flexible (Heimbecker 2005). It also recognises that true `engagement' can come from students negotiating their own learning objectives and constructing them within their own context. This should lead to a sense of `ownership' and enhanced motivation (Heimbecker 2005). The ENG1101 assessment strategy involves both individual and team assessment (refer to Figure 7), a mix of summative and formative assessments and provides students with guidance and encouragement to:

- Take responsibility for their own learning: this is generally referred to as `constructive alignment' (Biggs 1996), and `constructivism' (Mergel 1998).
- Identify their own individual learning objectives that allow them to extend and build on existing skill and competence.
- Develop suitable strategies to achieve these individual learning objectives.
- Provide a mechanism for students to monitor their own progress throughout the strand of PBL courses.

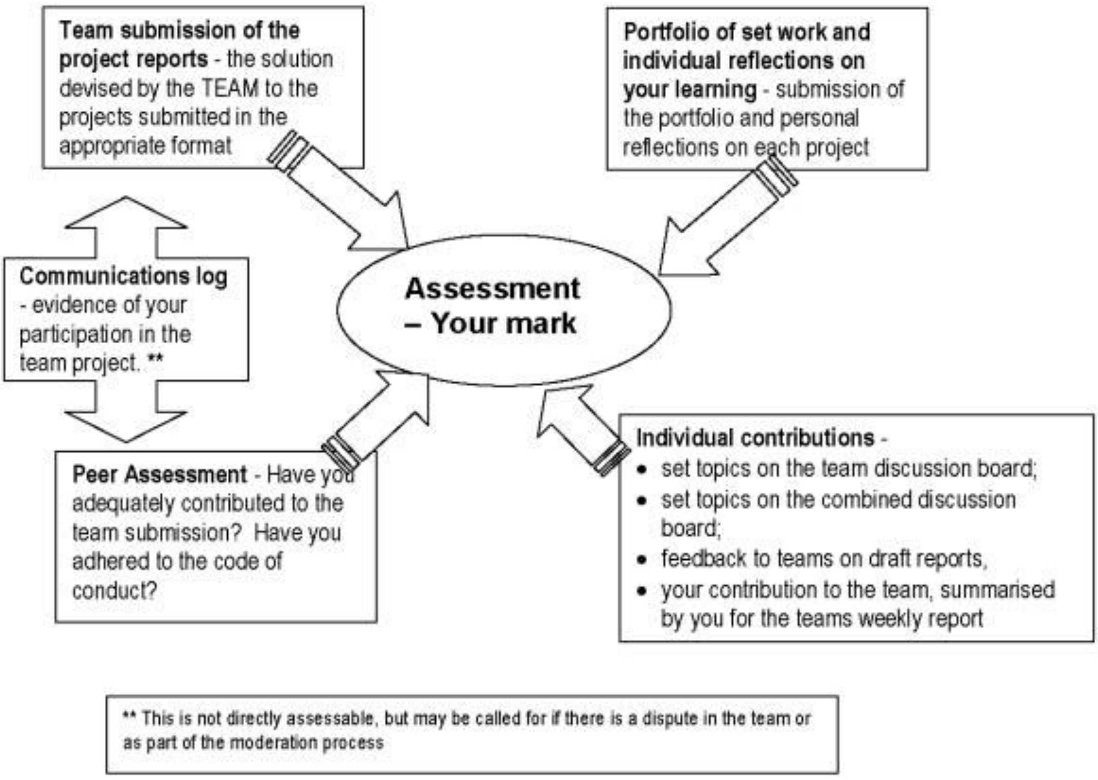


Figure 7-1 Overview of assessment scheme (Brodie 2003)

The revised assessment scheme involves four main sections that contribute to the student's individual mark:

- Team submission of project reports;
- Peer assessment of contribution within the team;
- Individual contributions;
- Individual portfolio of set–work and individual reflection on learning.

This strategy is entirely in accordance with the `constructivist paradigm' (Mergel 1998 ; Savin-Baden 2004), and the `collaborative learning' paradigm (Roschelle & Teasley 1995). The assessments are also used to discourage undesirable activity and as an incentive to encourage desirable behaviour, such as mentoring within the teams and mentoring between teams.

Mentoring within the team is a key element and it is essential that each team has an appropriate mix of skills which can be shared. An initial auditing of existing skills and competencies of each student is used to allocate students with different levels of skill in various fields into well balanced teams, which in turn encourages mentoring within the teams.

7.3 Operational Aspects

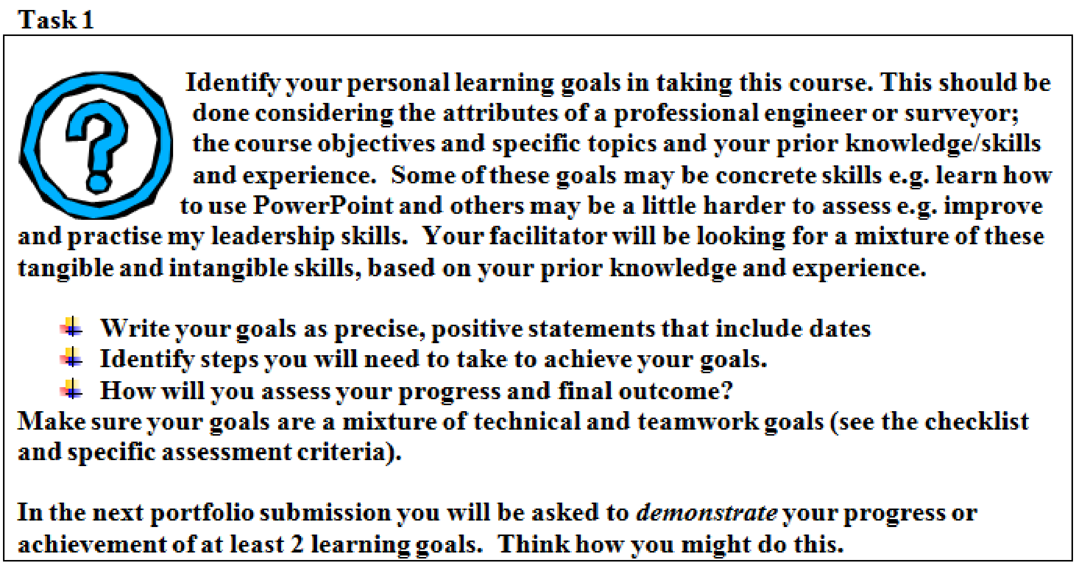
Students are required to use the discussion forums set up on the Learning Management System (LMS) for most of their communications within teams for the first few weeks, after which time they may negotiate within their teams for other alternative communication methods if they prefer. Each team has their own discussion forum and wiki pages, which only they and the course administration staff can access. In addition, groups of four or more teams are also given access to a combined discussion board to facilitate between–team communications.

Students' contributions to both team and combined discussion boards are assessed. It should be noted though, not all contributions to the discussion boards form part of the summative assessment. Threads, messages and replies are managed and assessed by facilitators having access to (and contributing to) these discussion boards on the

LMS. This provides an ideal mechanism for facilitators to monitor individual and team progress and validate peer assessment.

7.3.1 Team Project Reports

Some individual components of assessment are completed prior to the beginning of the first team report to ensure mentoring, sharing of skills and meeting of individual learning objectives. This is a foundational aspect for the team but completed as part of the first individual portfolio. Students are asked to identify their own personal learning goals for the semester, construct a plan to meet these goals (including required resources) and develop an evaluation strategy ("How will you assess your progress and final outcome") Figure 7-1. When the first team project is released students are required to negotiate suitable roles within their team with a view to meeting learning goals, sharing prior experience and participating in peer assistance. This is in accordance with research that suggests that adult learners want control over learning based on personal goals, and that learning will increase as a result (Knowles et al. 1998).



Task 1

Identify your personal learning goals in taking this course. This should be done considering the attributes of a professional engineer or surveyor; the course objectives and specific topics and your prior knowledge/skills and experience. Some of these goals may be concrete skills e.g. learn how to use PowerPoint and others may be a little harder to assess e.g. improve and practise my leadership skills. Your facilitator will be looking for a mixture of these tangible and intangible skills, based on your prior knowledge and experience.

- **Write your goals as precise, positive statements that include dates**
- **Identify steps you will need to take to achieve your goals.**
- **How will you assess your progress and final outcome?**

Make sure your goals are a mixture of technical and teamwork goals (see the checklist and specific assessment criteria).

In the next portfolio submission you will be asked to *demonstrate* your progress or achievement of at least 2 learning goals. Think how you might do this.

Figure 7-1 Task 1 of the first individual portfolio
(Brodie 2003)

Each team is required to prepare a plan that includes each individual's role and responsibility within the team, and their learning objectives. This approach recognises that not all students have the same learning objectives, nor are they faced with the same issues so it is necessary to be flexible. It also recognises that true `engagement' can come from students negotiating their own learning objectives and constructing them within their own context. This may also lead to a sense of `ownership' and enhanced motivation (Heimbecker 2005).

All team project reports are assessed by their facilitators using a comprehensive marking rubric (See Section 7.5 Assessment Rubrics). Constructive feedback is again provided to the teams at this time. Consistency of assessment between facilitators is achieved by staff training and documentation of requirements in a course facilitator's guide. The examiner (or course leader) performs a moderation role to further promote consistency between facilitators and to ensure that due diligence has been applied to crediting individual skills and competence.

Teams then have the opportunity to alter their submissions in light of the feedback and resubmit the final project report. This final submission is again formally assessed, and must provide evidence of changes or actions taken subsequent to the feedback outlining how and why the initial report was improved as a result. This opportunity to respond to feedback (and to carry out informal assessment of other's work by providing feedback), and collaboration within the team, are seen as critical to the learning process. In this way, the assessment becomes an integral part of the learning process, and should encourage students to engage in the learning tasks associated with the problem solution, which is one of the most fundamental tasks of education.

Each team report includes a comprehensive Team Reflection. Teams must review their strategies – code of conduct, peer assessment, problem solving, mentoring and communication. A critical analysis of progress and problems must be provided along with a plan for improvement.

7.3.2 Individual Portfolios

Students in ENG1101 are required to maintain a portfolio of set work and individual reflections on their learning within the course. Portfolios have been recognised by many engineering accreditation bodies around the world as offering an acceptable measure of student attainment of graduate attributes (McGourty et al. 2002).

Individual portfolio assessment in ENG1101 depends more on the process, reflection and self–evaluation rather than on specific quantitative criteria. The emphasis is on advancement of skills, and learning new skills, rather than simply achieving a minimum standard. This is achieved by each student individually negotiating, and being assessed on, objectives, goals and targets for each project within the PBL courses. The direction is determined by the learner within the constraints of the problem to be solved, which is seen as desirable for adult learning (Mergel 1998).

To assist students with this task, a comprehensive list of learning objectives (normally written as tasks that can be performed) is provided and each of these is linked to one or more course objectives. Students are encouraged to use this list as the beginning of what will become a portfolio of skill and competence. For example, one course objective is `Identify, analyse, discuss and apply elements of teamwork that affect team success'. The corresponding learning objectives for students to choose include:

- Identify necessary leadership qualities;
- Effectively lead a team;
- Analyse the dynamics of a team;
- Effectively negotiate with others within and outside a team;
- Seek and evaluate contributions of other team members;
- Utilise prior knowledge and experience of team members from diverse cultural and technical backgrounds;
- Establish and document roles and responsibilities within a team.

Students are encouraged to add their own objectives to supplement those provided. Teams are required to submit a plan, similar to the system noted in Isaacs (Isaacs n.d.) for the project, incorporating each team member's individual learning objectives, and these must all be agreed by peers within the team. A constraint is that these individual learning objectives must be consistent with course objectives (and graduate attributes) and be aligned to areas in which the student requires improvement (rather than an area of existing high level skill and competence). This encourages the development of new skills since the students are assessed on these teams whose plans demonstrate the development of new skills by its members will potentially receive higher marks.

By tracking progress in the achievement of objectives, the students can maintain an individual portfolio of achievements throughout the suite of PBL courses, and potentially through to, and even past, graduation as is recommended by recent literature (Besterfield-Sacre et al. 2002; Williams 2002). Because this improvement by individuals and the team collectively is formally assessed, mentoring within the teams is encouraged.

Each student's final reflection on the projects includes a personal assessment of the level of achievement in these skills. This is submitted with the individual reflections in the final project report and also forms part of the student's individual portfolio. Students are able to judge how well they have performed in these areas after receiving feedback on their preliminary team reports. As this process is carried out after each project, students can monitor their progress in each of these skills throughout the course.

7.4 Analysis of Assessment Scheme

This strategy for formal assessment of objectives provides documentary evidence that each student has achieved the minimum standard expected of a graduate as dictated by PBL course objectives, programme attributes, accreditation bodies, professional associations and defined graduate attributes. Stakeholders can only be given an assurance that the required graduate attributes have been attained if there is some evidence to point to their development by the graduates (Uni SA 2004).

The assessment approach, involving tailoring to individual students' existing skill and competence levels, also provides the flexibility for equitable assessment of students with skill levels that are already well above the required minimum standard. Students who may have highly developed skills in some areas, as is often the case with distance students who are already in the workforce, can now be assessed on an equitable basis with students who may not have the same starting level of skill.

In essence, students develop an individual log to record their progress in skill and competence achievement. This approach is similar to that used by several professional associations in Australia that have the responsibility, often under legislation, of assessing individual members against national competency standards before granting professional registration. It has also been successfully used in various forms in education settings, although it does not appear to be common in engineering or technical education.

The log or portfolio provides a structured record, in condensed but specific form, of the student's progress in the development of skills and competence.

The skills and competencies assessed in the portfolio are directly linked to course objectives and therefore graduate attributes. This portfolio of skills is essentially a professional development audit and provides a status report of the students' progress at any particular time.

The skills portfolio demonstrates, and formally records, the practical realisation and advancement of skills and competencies. Evidence of achievement of skills and competence is presented and assessed in the student's own portfolio. Although this is essentially self–assessed, there are several ways that students can demonstrate the achievement of a particular skill level:

- Peer assessment/agreement and documentation of performance during the conduct of the team projects (usually in accordance with the peer agreed team roles and predetermined individual learning objectives).
- Evidence of effective mentoring of others within the team in these skills.
- Individual requests supported with documentary evidence of conduct during the project (this may be used by students who enrol in programmes with advanced standing). This process records and tracks the student's achievement of skills and competencies in the identified skill areas.

This process allows facilitators to recognise existing areas of specialisation and also allows students to provide documentary evidence of the achievement of skills and competencies. It also allows the examiner to identify areas of specialisation where a student has achieved higher than minimum levels of skills, knowledge and competency, since the process provides a mechanism whereby achievement above the minimum required can be recognised, assessed and credited. This encourages students to attain skills and competencies in excess of the mandatory requirements for graduation.

The formal assessment strategy also encourages students to develop new skills in areas where they have previously identified a weakness. The opportunity for feedback and mentoring within and between teams is enhanced. Formal credit is given to individuals for providing feedback to other teams' work. Both inter–team and intra–team mentoring is assessed in the individual portfolios. It is believed that this increased mentoring will have the added advantage of encouraging better intra–team communication and should therefore foster better teamwork.

An initial team assessment begins by having teams discuss and formulate a Code of Conduct and Responsibilities detailing roles within the team including the facilitator; rules the team will work by; team meeting strategies (not only times and locations, including virtual, but of ensuring meetings are effective and efficient given they may not be meeting face to face) and problem solving strategies. Making this an assessment item ensures teams place sufficient emphasis on thinking through the issues. Throughout the semester, teams are encouraged to revisit these items, particularly the Code of Conduct, as the team matures and moves through the stages of team development. Initially students find this a tiresome exercise but in student evaluation surveys they acknowledge it was one of the most important and helpful exercises, as illustrated by the following student comment:

> *I thought the code of conduct was a waste of time. I really wanted to get into the problem. However by the end of semester I realised the coc [sic] was one of the most important things we did as a team. It helped us solve many nasty situations and by the end of the semester it looked like a formal legal document. It will certainly be the first thing I get the team to do in the following prob solve[sic] course* – **(Student comment)**

In the reflective portfolio, which is an individual assessment item, students must initially set individual learning goals and plan to meet these goals. These goals must be based on the course specifications. They must also consider and analyse their prior knowledge, experience and skills in setting these goals. At the end of the semester in the final portfolio submission students must re–examine these goals, discuss and self assess their levels of achievement and what assisted or hindered the meeting of these goals.

> *The goals I have set for myself are more than just something to make the facilitators happy, they are not just to be seen to be making an effort. Instead I see them as ongoing and applicable outside the realm of this subject and extending even beyond the completion of it.....They have been designed to challenge me in areas I perceive as personal weaknesses or lacking in applied experience.* – **(Student comment)**

7.5 Assessment Rubrics

Assessment, particularly in large classes can be problematic. Providing constructive, timely feedback is difficult, and so too is ensuring consistent marking standards when using several different markers. This is exacerbated when the assessment items are 'open–ended' and the answers are not well defined and depend on student assumptions, for example the initial scoping of a design brief.

The course learning objectives include the development and application of skills in basic engineering science (mathematics, physics and statistics), and it also has a large emphasis on the development of teamwork, communication (formal and informal), problem solving skills, self directed learning and reflective practice. In accordance with course learning objectives, it is essential that the assessment criteria used to provide student grades reflects these process skills and not just the outcome of a final technical report (Brodie 2008).

The course uses both criterion referenced and ipsative referenced assessments. Criterion referenced assessments seek a minimum standard of performance for each competency. This involves ordering skills and competencies in a coherent set and providing an overall interpretation of proficiency required. This is similar to standards–referenced which presents levels of performance against agreed quality levels (Griffin 1991).

Marking schemes were initially established along these lines, with learning objectives established for each problem and four levels of proficiency indicated (poor, adequate, good and excellent) but no other descriptors were provided. Critical analysis of this marking scheme was undertaken. Through an audit and review process (quality control) several shortcomings with marking schemes and process were identified. Of particular concern was that the marking scheme:

- lacked informative feedback to students,
- was difficult to apply equitably across teams and with different markers resulting in inconsistencies between markers and
- was not well supported by markers who found significant difficulties with interpretation and application of individual elements of the marking scheme.

Over several offerings of this course different marking schemes and assessment methods have been tried in an attempt to deliver consistency between markers, equity and quality informative feedback to students. The marking schemes attempted to minimise marker variation even where the content of submission might be quite different depending on the student teams' interpretation of the problem statement and subsequent assumptions. This led to the development of a marking rubric which offers clearer instructions and standards with each criterion often subdivided into several objectives, five levels of achievement for each objective with clear and consistent wording and a range of marks for each level dependent upon the weighting applied to each criterion. Refer to Figure 7-2.

The new rubric was tested by having several past team submissions remarked by three experienced markers. Results were analysed to determine if consistency between markers was achieved. Markers perceptions to the new rubric were also noted via a survey and focus group. Student feedback surveys are also analysed and presented to determine if student perceptions on useful feedback from assessments has been improved by the new rubric.

7.5.1 Background

Assessment information can be interpreted within different frameworks such as competency based, task referenced, goal based, and domain referenced (Griffin

1991), however there are three major frames of reference that are relevant to this discussion:

1. norm–referenced or normative assessment:– This compares relative performances of individuals assessed against what is considered typical or average, hence ‘norm’ referenced.
2. criterion referenced:– This is a measure of competencies against well defined competencies or degree of mastery, both breadth or scope, and depth.
3. ipsative referenced:– This is self–referenced assessment of an individual’s own interpretation of their performance and development in terms of their own indicators of progress (Griffin 1991, p. 93).

Different methods can be used to collect assessment information within each of these three frameworks. Each method has relative advantages and disadvantages and in different contexts one may be more suitable and authentic than others. Thus it is important to consider a range of methods using more than one assessment approach to improve fairness and validity. Dannefer, Henson et al. (2005) also recognised the value of peer assessment for formative purposes (including teamwork and interpersonal skills) in undergraduate medical schools. A range of approaches, including peer assessment, assessment and monitoring of mentoring and reflection is used in ENG1101 to develop team and individual learning goals.

Each of these assessment approaches needs an appropriate, reliable, fair, and equitable marking or grading method. Scoring or marking rubrics are often used for this task. They are popular because they can be adapted to a variety of courses and situations and they have the added advantage of providing feedback as well as a mark. They are especially useful in assessment for learning (as opposed to assessment of learning) where the assessment is an integral part of the learning process as it is in ENG1101. As rubrics contain qualitative descriptions of performance criteria, these can be useful in the formative function of the assessment item. This, according to Popham (1997) suggests that if appropriately designed, marking rubrics can become ‘instructional illuminators’.

To achieve this, it is important that the marking rubrics are properly designed. Popham (1997) warned that many rubrics in use were not suitable because of design flaws including inconsistencies in the performance descriptors across the different scale levels. These flaws can affect the instructional usefulness as well as the validity of the marking results. Tierney & Simon (2004) offered some suggestions, examples, guidelines and principles of how to design effective rubrics. Their focus was on consistency of the language used to describe the performance criteria across the scale levels which are designed for both learning and assessment. The descriptors are important because the descriptive language used communicates the levels of quality expected of the students as well as assessing them. The descriptors and objectives of the assessment item relate to what is valued in terms of the course objectives and informs the students what performance is expected, what level they may be at now, and what level they need to get to. In addition, rubrics facilitate assessment marking and grading if carefully designed with appropriate weighting assigned to criteria and scales.

If graduates are expected to develop as lifelong learners to be prepared for an uncertain future, then they must also become adept at objectively assessing their own learning (Williams 2002). Rather than disempowering learners with strict summative assessments, greater emphasis should be placed on technology–supported tools and techniques to assess context based learning. This will provide opportunities for students to learn to use these tools to critically and objectively assess their own learning and for sustainable assessment of their continuing development throughout their professional careers.

One viable alternative to the ‘traditional’ summative assessments is a well tailored assessment rubric that will focus students’ attention on the learning objectives rather than getting marks (Woodhall 2008). Such rubrics have recently been successfully used to assess, in an ‘objective and unprejudiced manner’ (Kumar & Natarajan, 2007, p. 100) students’ oral presentations as well as contributions to team efforts in the PBL context. Rubrics must be properly designed to facilitate this student learning as well as provide objective assessment of learning objectives.

Design of marking rubrics for observation and assessment of learning is a challenge. But the challenges of doing this fairly, along with providing constructive feedback, are outweighed by the benefits in supporting learners’ understanding of the individual or team progress. Tierney and Simon (2004) offer examples of poor rubrics particularly those with negative or discouraging wording and vague descriptors. Rubrics should offer a positive view of every performance level on the continuum focussing on what the student can do and offer helpful suggestions for improvement in each of the categories.

The literature also offers some 'guiding questions' for well designed and functional rubrics (Sigwart & Van Meer 1985; Tierney 2004). These include:

1. Are all performance criteria explicitly stated?
2. Are the attributes explicitly stated for each performance criterion?
3. Are the attributes consistently addressed from one level to the next on the progression scale?

These questions along with other aspects in the literature guided the design, review and improvement of the rubrics used in this investigation.

7.5.2 Development of Rubrics

Many different types of rubrics are commonly used in educational contexts. The rubrics developed for ENG1101 can be described as 'descriptive graphic rating scales' because they use generic traits as analytic performance criteria (Tierney & Simon, 2004). They guide the student teams, but without giving specific hints which were intrinsic in the old marking schemes e.g. "appropriate data analysis was done" or "explanation of the physics of heating applied to interior of car".

The rubrics have been developed in accordance with guidelines provided in the literature and cover the technical and reflective requirements of the team submissions. They allow for the open ended nature of the engineering projects, the student team's scope as well as PBL specific learning objectives. The PBL learning objectives are largely in the affective domain and have been difficult to assess with previous marking schemes. This is achieved by explicit performance criteria and attributes directly related to the learning objectives.

The new rubrics give guidance to students on performance criteria to be addressed, specific attributes within these criteria and the weightings applied. At the same time the rubrics are generic enough that they can be applied to the different design tasks, scope and specifications chosen by different teams. An example of a small section of the rubric is shown in Figure 7-2.

All assignment submissions in the course are electronic and it is therefore important that marking schemes and feedback are also in an electronic format. The rubric was developed as an *electronic form* (a structured document with areas/spaces reserved for entering information e.g. marks which are automatically added, specific comments from marker and tick boxes to indicate level of achievement or standard comment). This allows markers to select an appropriate level of achievement for each objective, add a typed comment, and allocate a mark with the specified range (each level of achievement has a range of marks depending on total assessment mark and a particular weighting e.g. ‘checking and critiquing 5%’, and for level 5 achievement there is a range of marks – ‘11.25 to 12’. The total mark for the assessment and the weighting for each criterion/objective can be easily changed in the original form document. When these data are modified, the range of marks for each level automatically updates.

The performance criteria are clearly stated in the left hand column, e.g. in the ‘Team Reflection and Evaluation’ section one of the listed performance criteria is “Problem solving strategy is researched, documented, applied and tested”. Specific attributes and objectives of this criteria are “Strategy” – a problem solving strategy is researched, documented, applied and tested and “Checking and Critiquing (more than simple proof reading) – evidence that team members supplied constructive feedback on critical aspects of the report”. Each of these attributes then has five levels of attainment, with consistent wording, where markers indicate student or team achievement.

The words used (for example: never, seldom, sometimes, usually, always) indicate the scale or level of achievement for each performance criteria attribute. The percentages represent a suggestion on the marks that might be attributed to each of these elements. In accordance with (Tierney & Simon, 2004) the scales that we used were generally: amount, frequency, and intensity as indicated by:

- An example of amount is: not, few, some, most, all;
- An example of frequency is: never, seldom, sometimes, usually, always;

• An example of intensity is: no, weak, some, strong, compelling;

The new performance criteria identify the dimensions of the required performance of a particular skill. This example illustrates how the different levels refer to the development of the skill on a continuum. This can be seen from the main words highlighted in the individual performance criteria.

Total marks available 250							
Performance Criteria	**Attribute**	**Level 1 –**	**Level 2 –**	**Level 3 –**	**Level 4 –**	**Level 5 –**	
TEAM REFLECTION AND EVALUATION – 50%							
Problem solving strategy is researched, documented, applied and tested 5% General feedback:	Strategy 0% (feedback only for this report)	0.0 to 0.0 marks ☐ Report is **not submitted** or discussion of problem solving strategy **not clear or evident**	0.0 to 0.0 marks ☐ Problem solving strategy is **poorly** researched, documented, applied and tested	0.0 to 0.0 marks ☐Problem solving strategy is **acceptably** researched, documented, applied and tested	0.0 to 0.0 marks ☐Problem solving strategy is **well** researched, documented, applied and tested	0.0 to 0.0 marks ☐Problem solving strategy is **extremely well** researched, documented, applied and tested	**0.00**
	Checking, and critiquing (more than simple proof reading) 5%	2.5 to 5 marks ☐ No obvious evidence of team members supplying constructive feedback on critical aspects of the report	5 to 8.75 marks ☐ **Few** team members supplied constructive feedback on critical aspects of the report **but not clearly demonstrated** or discussed	8.75 to 11.25 marks ☐**At least two*** team members supplied constructive feedback on critical aspects of the report and **could still benefit** from internal critiquing. * No. of active students in the team will be considered in this section	11.25 to 0.0 marks ☐evidence that **more than two*** team members supplied constructive feedback on critical aspects of the report * No. of active students in the team will be considered in this section	0.0 to 0.0 marks ☐ evidence that **most** team members supplied constructive feedback on critical aspects of the report	

Total mark for assessment can be modified

Weighting for each objective can be modified

Range of marks for each level updates wrt total mark and weighting

Marker enters mark dependent on level of achievement acquired, indicated by tick boxes. Marks are automatically summed

Figure 7-2 Section of new marking rubric

The criteria that best describes the observed performance is highlighted electronically or annotated in some way. A range of marks is indicated for each level dependent on the overall marks for the assessment piece and the weighting to each criterion. In addition some criteria may be listed 'for feedback only' indicating no contribution to the final marks of this particular assessment, but something that may need to be addressed in subsequent submissions.

The main criteria represent broad learning targets, and this increases the usefulness of the rubrics because they can be used universally for each of the projects. Because of this the rubric does not contain specific descriptions related to individual projects or problems, so comment fields and annotation in the project report were used to provide this level of feedback. Variability in the use between facilitators is reduced by having facilitator meetings where examples are used to provide consistent interpretation of what is expected as exemplars in each of the criteria. For example, ‘clear and concise’ becomes much easier for the facilitators to interpret when given some examples of what to look for as possible indicators of when a report might fall into this category rather than one either side of it.

7.5.3 Evaluation of Rubrics

Six student team submissions were chosen from a total cohort of 61 teams. These reports where blind marked by three experienced facilitators using the original marking scale. Level of achievement (poor, adequate, good, excellent) along with marks for each section or criterion where recorded. In addition a survey to determine the markers perceptions of the marking scale was administered. These perceptions included:

- The rubric allowed you to assess the report efficiently with respect to time spent on each team report
- The rubric made it easy to identify what element or criterion of the report was being assessed
- The rubric made it easy to chose the appropriate level of achievement
- The rubric made it easy to give an appropriate mark to indicate the achievement
- I am confident in the repeatability of the assessment if I were to mark this same assignment in the future using this rubric
- I am confident that another marker would achieve a similar grade for the same assignment using this rubric
- Overall the grading determined by the rubric gave an accurate indication of the quality of the report.

Over the course of the following semesters a new marking rubric was developed. A review of the problems and course objectives led to listing of specific performance criteria. Clear levels of achievement were added with consistent language for amount, frequency, and intensity. The rubric was continuously revised based on literature and input from facilitators. When the new rubric was finalised, the original six team reports where remarked by the same experienced markers. Again the perceptions of the markers were compared using the same questions.

The analysis included:

- The perceptions of the markers with respect to time, repeatability ease of use, validity and accuracy.
- Comparison of the actual marks for each criteria
- Comparison of the level of achievement for each criteria and objective.

7.5.4 Results of Evaluation

Old rubric

Analysis of the marks and levels of achievement allocated by markers using the old marking scheme indicated a wide range of views and interpretation of the marking scheme despite a face–to–face meeting prior to starting. The marking scheme could not be considered consistent in any listed criteria in either mark or level of achievement. Analysis of the final mark (total mark 200) for the team report showed a variation of between three and 21% between markers for the *same* report. There were discrepancies in feedback on the level of achievement for each criterion, with the possible exception of the criterion of “Spelling and grammar”.

For this criterion the indicated levels of achievement varied only by a maximum of two levels e.g. good to adequate or poor to adequate. Marks varied across the three markers from a maximum of five percent to a two percent difference for the total marks allocated for that criterion.

Overall, mark differences and variation in feedback are of considerable concern from a moderation equity and quality control perspective. The maximum variation for the old rubric was accorded to the criteria of the ‘experimental methodology’ devised by the teams. For this criterion, marks and levels of achievement varied as indicated in Table 7-1.

There were similar discrepancies for the mark attributed to the team reflection with marks varying from 16 to 30 for team 10, 15 to 25 for team 1 and 4 and smaller variations for the remainder of the teams e.g. 20 to 25, 20 to 24 etc. Results of this variation for each criterion obviously affected the overall mark or grade for the team.

Table 7-1 Comparison of marks and level of achievement for criterion of 'experimental methodology'

Team	Marker 1		Marker 2		Marker 3	
	Level (of achievement)	**Mark/40**	**Level**	**Mark/40**	**Level**	**Mark/40**
4	Good	35	Poor	10	Adequate	20
1	Poor/adequate	15	Adequate/good	25	Poor	12
10	Adequate	20	Excellent	40	Good	25

The data clearly shows the results are not reproducible, are inaccurate and are inconsistent. Perceptions of the markers supported these conclusions. There was no consist response from the markers with respect to efficiency and ease of identifying a particular element to assess. Overall markers believed that it was difficult to give an appropriate mark to indicate a particular level of achievement given the information and guidance provided on the marking scheme.

New rubric

The reactions and perceptions of markers to the new rubric were much more positive. The markers agreed the rubric was efficient to use (with respect to time) even given the increased complexity of the marking matrix. They agreed that the rubric made it easy to:

- Identify what element or criteria of the report was being assessed
- Choose the appropriate level of achievement
- Give an appropriate, repeatable and consistent mark for each criterion

In summary they agreed that the over–all grading determined by the rubric gave an accurate indication of the quality of the report considering all criteria and objectives that were assessed.

Analysis of the marking data from each of the criteria and objectives supports the postulation that the new rubric is more consistent and repeatable. Four of the teams (X01, 2, 3, 7) showed a total deviation of less than five percent across the three markers, which is considered acceptable. However two teams (4 and 10) showed a deviation of 14% and 13% respectively between marker 1 and the other two markers. Markers 2 and 3 were consistent with each other. See Figure 7-3.

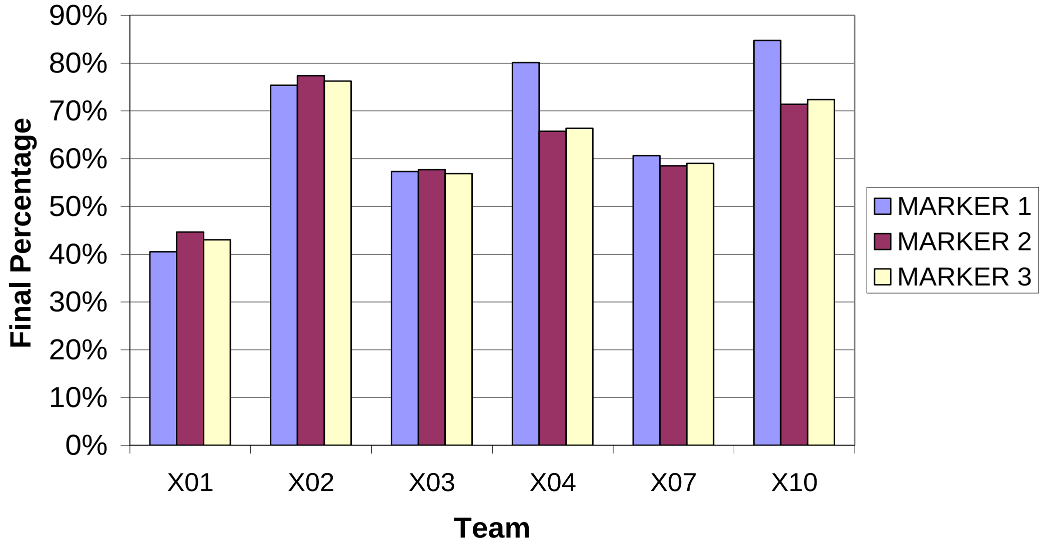


Figure 7-3 Summary of final marks for each team

The majority of the differences can be accounted for by just two criteria on the report section of the rubric – depth and completeness. These two objectives account for eight percent of the difference in marks. Minor differences can also be traced to the Presentation criterion (and in particular the Language objective) and the Graphs, diagrams and graphics criterion.

When using the new marking rubric, there was consistency between markers in the level of achievement for each criteria and objective. The discrepancy described above relates only to the marks and this is due to the wide range of marks available for each level.

Student feedback and evaluation is a major driver for change in curriculum, assessment and feedback. Whilst there are questions raised over the validity of student evaluations to improve teaching and learning, they do play a critical role in tertiary education. A number of identified purposes of student feedback include diagnostic feedback that will aid in the development and improvement of the course and provide research data to underpin design and improvement to courses (Bennett et al. 2006).

Assessment is a key aspect of student evaluations covering appropriateness of assessment tasks clear assessment criteria, and feedback provided. Figure 7-4 shows the results of student evaluation surveys over three years, 2005 to 2007. The original marking scheme was used in 2005. Continuous development of the marking rubric took place throughout 2006 using the feedback from both facilitators (markers), students, and some analysis of results. The 2006 data informed the development of the new rubric and is included here to demonstrate the temporal changes during the period of rubric development. The new rubric was finalised for use in 2007.

Over this three year period, student evaluations with respect to assessment and feedback continuously improved with results for all three questions showing a positive trend e.g. Neutral and Disagree to Agree and Neutral etc, data is shown in . There was a significant difference for all three questions between 2005, 2006 and 2007 (Kruskal Wallis test, Asymp. Sig = .000).

Table 7-2 Data for Student evaluations relating to assessment (2005 - 2007)

Student Survey Questions	**The criteria used to assess student work were clear.**			**Feedback from assignments was timely.**			**My understanding of the subject has improved as a result of feedback from assignments.**		
Year of offer (S1)	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**
Number of respondents	**155**	**179**	**189**	**155**	**179**	**189**	**155**	**179**	**189**
Strongly Agree	2%	14%	10%	1%	13%	20%	4%	16%	17%
Agree	12%	30%	66%	14%	37%	53%	15%	50%	63%
Neutral	53%	22%	18%	55%	21%	12%	50%	17%	10%
Disagree	17%	20%	4%	18%	15%	10%	19%	10%	4%
Strongly Disagree	10%	12%	1%	6%	12%	4%	6%	5%	5%
not answered	6%	2%	1%	6%	2%	1%	6%	2%	1%

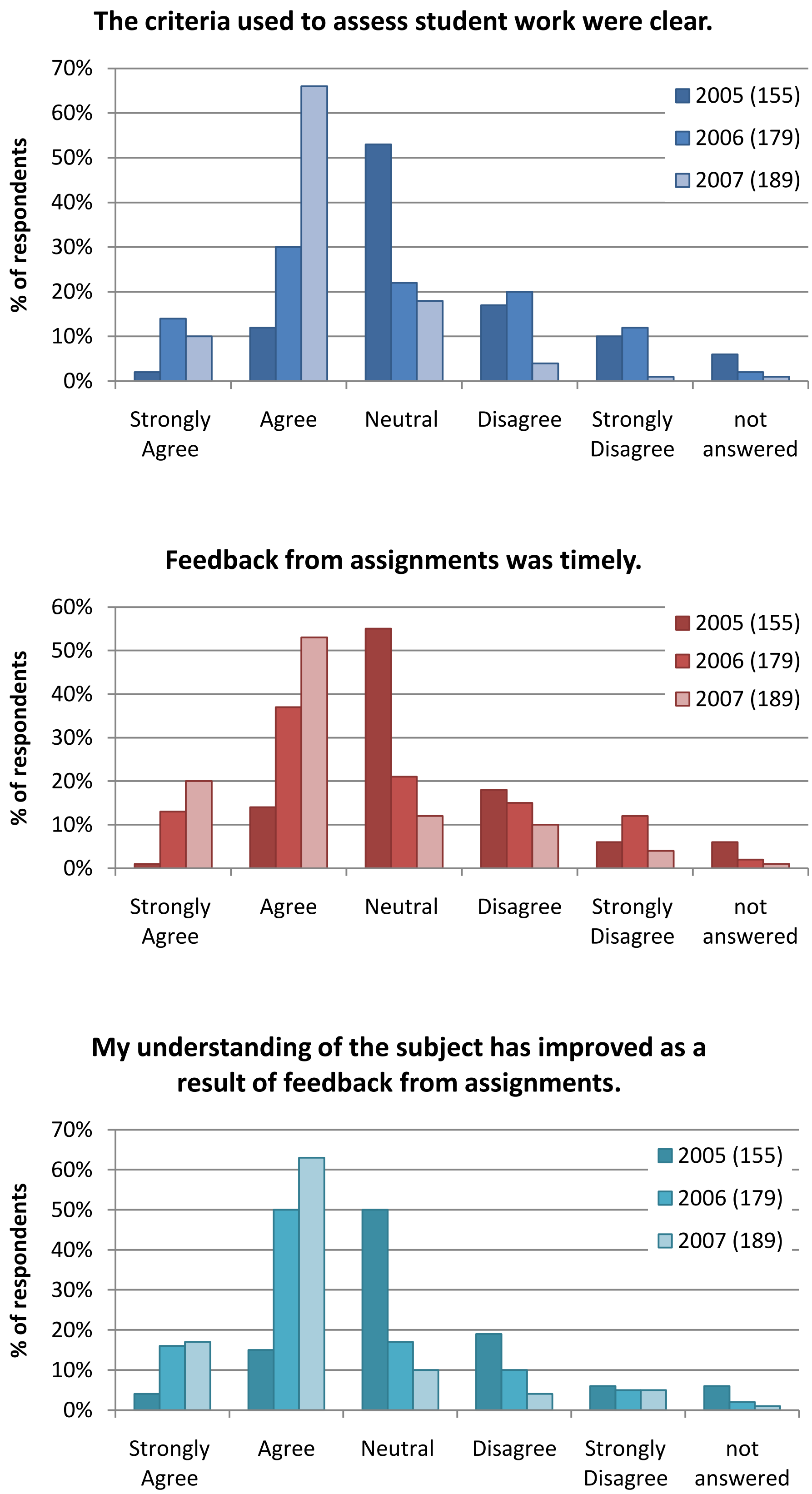


Figure 7-4 Student survey results relating to assessment over a three year period of development

The new rubric is much more comprehensive than previous marking schemes and spans three pages. It includes a comprehensive set of performance criterion covering teamwork, team reflection, peer mentoring, communication (formal and informal) and the technical components of the tasks. Each performance criteria has specific attributes and more consistent levels indicate achievement levels in all attributes.

Initially, when presented with the new rubrics, markers were somewhat apprehensive and daunted. However, the comprehensiveness of the scheme was soon realised as an advantage since each element and objective is easily identified and the consistent descriptors are easily interpreted.

Elements to note on the new marking rubrics are:

- Better clarity of the descriptors leading to easier use and greater consistency and more reliable interpretations by both students and markers;
- The performance levels are much clearer and are plainly differentiated;
- There is only one element to look at in each objective whereas the older rubric often had two or more, and sometimes new criteria were introduced across the levels;
- Good balance between general wording to make it universally usable for all projects;
- Easier use and detailed enough descriptions especially when coupled with feedback on the main project report; and
- Consistency across the levels of achievement for each of the attributes by the use of ‘parallel language’ (Tierney & Simon, 2004, p. 94)

There is generally a positive tone in the rubrics in terms of what was achieved rather than what was not done. This provides motivation to achieve higher levels and puts a positive spin on the expectations to promote learning. However, the rubric does set clear standards and expectations so, in particular, the lower levels do use words such as ‘never’, ‘not present’ or ‘no evidence provided’. This is clear feedback to missing documentation in the report.

The descriptors for each level deal with the same performance criteria and attribute so the progressive scale is meaningful. Older versions sometimes introduced new attributes or criteria across the levels and this led to some confusion and inconsistencies of markers and generally made it more difficult to use. In the examples above (Figure 7-2) the same attribute and performance criteria are present; it is just the degree (in terms of amount, frequency or intensity) than changes from level 1 to level 5.

7.6 Summary

The development and evaluation of marking rubrics has enabled a consistent, repeatable and reliable approach to assessment even with a large class with multiple markers. When using the PBL approach, clear assessment criteria for students are required without allowing students to either ‘reverse engineer’ the solution or guide the direction of research. Furthermore, the same criteria need to be suitable for numerous teams, problems/projects and solutions. The rubric developed allows the marker to give clear feedback to the students on the current level of achievement whilst effectively guiding students to address the course learning objectives.

Considering the improved consistency of both marks and level of achievement, feedback provided to the students and endorsement of the markers, the new rubrics are considered successful and far superior to the original. However, further work needs to be done on the criterion of ‘depth and completeness’ to minimise variation between markers.

The implementation of a quality review cycle in the course has helped, not only the development of the assessment scheme, but also other general learning and teaching components. It has forced the academic coordinator as well as facilitators to reflect on, review and continuously improve the course objectives, problem objectives and resources and equitable assessment procedures which promote learning.

The assessment strategy in ENG1101 is entirely in accordance with the `constructivist paradigm', and the `collaborative learning' paradigm. The assessments are also used as an incentive to encourage desirable behaviour, such as mentoring within the teams and mentoring between teams, and to discourage undesirable activity. The assessment is aligned with the course objectives and caters for prior learning and existing skills. This enables more effective use of student diversity and encourages mentoring within the teams.

The summative assessment provides the flexibility to assess, on an equitable basis, the attainment of skills and competencies at a higher level than the minimum requirements because it rewards an increase in skill levels and development of new skills, rather than assessment against some predetermined minimum criteria. This encourages students to direct study and energy into areas which will most benefit their future and professional careers.

8 Developing a Learning Community

8.1 Introduction

The international literature typically uses three main criteria to identify the development of a learning community (Misanchuk & Anderson 2001a; Rovai 2002; Kilpatrick et al. 2003b). These may be summarised as:

1. Recognition of the importance of a common goal and a shared commitment to succeed;
2. Using the diversity within the community to advantage to meet goals and enhance outcomes;
3. The ability to rely on and trust other members of the community.

Discussions within these communities are beneficial to learning. The communication encourages learners to develop and clarify their own thought processes through sharing ideas, reflecting and jointly construct knowledge. The learning communities also provide an opportunity for exposure to *cognitive dissonance* which is critical to intellectual growth (Anderson 2004a). Even students who do not possess advanced knowledge benefit from communication with more knowledgeable peers (Vygotsky 1978; Misanchuk & Anderson 2001b; Rovai 2002; Brook & Oliver 2003; Wallace 2003). The nature of these discussions, and their role in facilitating student understanding, is central to the development of lasting knowledge that can be used by students in future problem solving (Innes 2007).

This interaction and social aspect of learning often happens naturally in on-campus student cohorts, who form informal learning communities or have ready access to discussions in classroom activities. Indeed, educational approaches are beginning to place a greater emphasis on collaborative learning and team work as opposed to individual enquiry (Scardamalia & Bereiter 2006). However, social interaction, collaborative learning tasks and teamwork are often not available to distance students.

Whilst some students relish the independence and flexibility of distance or online education, they can also be disadvantaged by the isolation, lack of ‘classroom community', opportunities for discussion, debate and sharing of knowledge, and the general social aspects of the more traditional face-to-face university education.

Teamwork, and in particular virtual teamwork, can use the strengths of the diverse student cohort whilst also supporting individual learning and social needs.

Most research suggests that appropriately designed, delivered and supported web-based and online education can be at least equivalent to traditional face-to-face education (Russell 1999). A significant aspect of this design, delivery and support concerns the appropriate use of technology to facilitate and encourage the necessary discourse involving the learners and to develop communities of enquiry or learning communities.

In the case of problem-based learning (PBL), the communities of enquiry at the base level are essentially the PBL teams themselves. However, in ENG1101 the learning community operates at several levels. At the first level there is the team itself where the majority of discussions and construction of knowledge occurs. The next level is a 'group of teams'. Four to six teams interact on a 'combined discussion forum' to share ideas *between* teams. Lastly, at the top level, is the entire class cohort which forms the overarching learning community.

Student participation in the learning community, at all levels, has been enabled through the use of a Learning Management System (LMS) which provides a mechanism for sustained two-way communication. This enables the social construction of knowledge among learners at a distance. Collaboration, leading to social learning, is encouraged through curriculum (course) design, learning resources, assessment and facilitation of the team process.

In this chapter social learning in virtual space is explored before investigating qualitative and survey evidence of the three criteria of learning communities: recognition of a common goal, using diversity and trust are discussed in this chapter. Sections of this chapter have been peer reviewed and published in:

Brodie, L.M. & Gibbings, P. in press, 'Connecting learners in Virtual Space – forming learning communities', in L. Abawi, J. Conway & R. Henderson (eds), *Creating Connections in Teaching and Learning*, Information Age Publishing.

Gibbings, P.D. & Brodie, L.M. 2008, 'Team–Based Learning Communities in Virtual Space', *International Journal of Engineering Education*. Vol. 24, no. 6, pp. 1119–1129

Brodie, L.M. & Gibbings, P.D. 2007, 'Developing Problem Based Learning Communities in Virtual Space', *Connected 2007 International Conference on Design Education*, University of New South Wales, Sydney, Australia.

8.2 A Learning Community in Virtual Space

As established in the literature review, a learning community can be described as a cohesive community that "embodies a culture of learning in which everyone is involved in a collective effort of understanding" (Rogers 2000). Distance and online students are often excluded from dialogue and interactions which contributes to collaborative learning. This is despite the increasing emphasis on collaborative learning as opposed to individual enquiry as indicated by the literature e.g. (Johnson 2001; Scardamalia & Bereiter 2006; Hlapanis & Dimitracopoulou 2007).

Secondary to the opportunities for discussion, debate and sharing of knowledge is the development of the social aspect of learning which is present in the traditional face–to–face university education but typically missing in distance education. Teamwork, and in particular virtual teamwork, can use the strengths of the diverse student cohort whilst also supporting individual learning and social needs if the web–based and online education is appropriately designed, delivered and supported.

A significant aspect of this design, delivery and support concerns the appropriate use of technology to facilitate and encourage the necessary discourse involving the learners and to develop communities of enquiry or learning communities. The use of technology made possible the effective communication channels for distance students to engage in social learning. Even though students do not meet face–to–face this is still a form of 'social constructivism' where learners can share ideas with others and reflect on what has been learnt (Vygotsky 1978; Jonassen 1998). Where there is a collective effort toward a shared goal and dialogue is prompted by differences in background, experience and perspective, an effective learning community is formed and this is critical to collaborative learning in virtual space.

8.2.1 Social Learning

For distance students, working in a student team can be both a challenging and rewarding experience. USQ has a strong distance education tradition, based on the delivery of predominantly print based material, and students learn independently through interaction with that printed content. For most students ENG1101 provides their first opportunity to actively work with, and learn from, other students. Even though some students from different time zones and geographic locations on earth meet 'asynchronously', it is believed that virtual team meetings for distance students are as effective as physical meetings for on–campus students and foster the desirable attributes of teamwork, conflict resolution and negotiation of tasks.

The data in Figure 8-1 presents results from three years of the course survey from 2005 to 2008 covering 11 offers to both on–campus and distance students. During this period, 1377 students completed ENG1101 and 857 students responded to surveys (a response rate of 62.3% averaged over all offers).

Figure 8-1 indicates that approximately 80% of respondents agreed or strongly agreed that the social aspect of the course, the interaction via discussion forums and the team work, assisted their transition to university, their study and learning in this course and concurrent courses and anticipated study in future courses by forming study groups with students studying similar courses. It is also interesting to note that 10% of distance students disagree, strongly disagree or did not answer (1%). Of these 85 students, 72% answered that the ideal number of students in a team should be one or two. This would seem to indicate that these students generally do not enjoy working with others and for them, the social opportunities offered by the course, were not relevant.

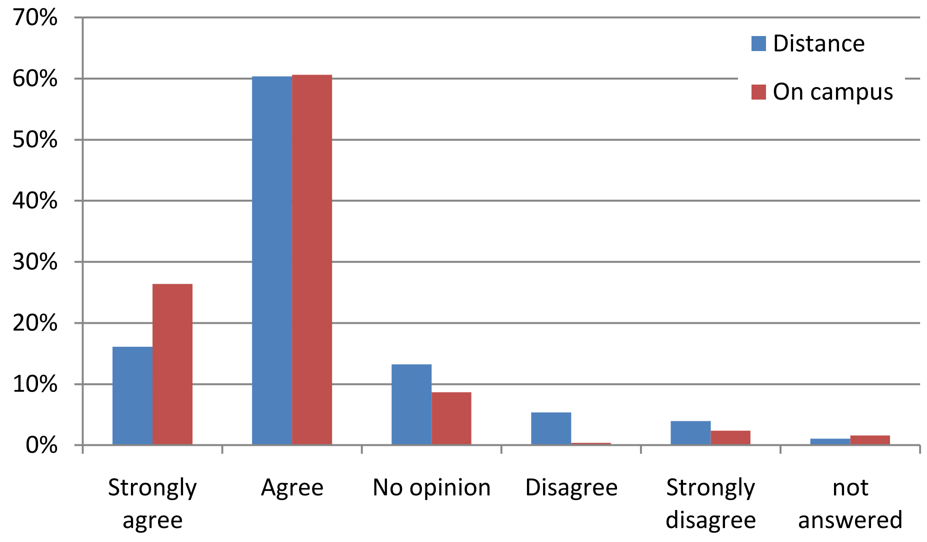


Figure 8-1 Student self perceptions of the social aspect of the course – the course helped me to meet other students

The survey results are corroborated by analysis of individual and team reflections and postings to discussion forums, examples are given below:

> *I enjoyed working with most members of my team and it was good to be able to talk to other students in the same position as me, I was also able to get help with other subjects from some of my team members –* **comment from portfolio**

> *'I also found that it was easy to communicate within a group via email and the Internet. I enjoyed this part of the course, as it allowed members to join in discussions at different times of the day and this suited the group as we all work different hours and have a range of internet access times available to us –* **comment from portfolio**

> *… we all have a lot of fun together even though we have never met face to face. Our team has found common interests and all show a genuine concern for each others welfare. –* **comment from team reflection (team report 3)**

> *Having other students who can mentor can be a lot less stressful..... I've found just by having people there to talk with, a lot of stress is reduced and*

> *the feeling of being alone with no one to help is diminished.* – **comment from portfolio**

> *The best aspect of the course was working so close with other members. As an external student it is difficult at times not really knowing anyone who is working through the same studies as you. I have made some really good friends, that I will keep in touch with after this semester is finished.* – **comment from portfolio**

The importance of social learning with respect to learning in general has been well documented in the literature (for example Dewey 1938; Salmon 1993; Brown & Duguid 2000; Kilpatrick et al. 2003a; Smith 2003) and is highlighted by the above quotes. There is evidence of the formation of learning communities within the teams, and that learning by the students has moved away from an individual constructivist focus as described by Piaget (1952), to social learning in a community. In contrast to Brown and Duguid (2000), evidence from ENG1101 indicates that this social aspect to student learning is occurring in the online environment and it is being improved by the judicious use of the communication features of the LMS. This ability of the internet, provided it is used appropriately, to significantly improve the learning experience in virtual space is a view supported by Tu and Corry (2002), and Reushle (2005, p. 10, 2006, p. 7).

8.2.2 Facilitation Role

Facilitators in ENG1101 are required to make contact with their teams on the discussion boards at least twice weekly, though for most facilitators daily contact is the norm especially in the beginning of semester. Facilitators ensure that all students are actively participating in discussions and other activities. This participation is also monitored by the teams and reported weekly in a team progress report.

The tone of the communications is scrutinised by facilitators to ensure students do not lose their personal identity through the discussions being dominated by any individual. A major issue, as noted by Smith (2005) was the withdrawal from teams by individuals as a defence mechanism. Facilitators' moderation and the teams themselves through the code of conduct ensure this does not happen in ENG1101.

This facilitation in ENG1101 coupled with the continual upgrading of the teams' code of conduct, alleviates the problems of frustration, fear and the 'cyclical movement' in and out of the communication discussions that were noted as major problems by Smith (2005).

The following sections explore the three criteria of learning communities.

8.3 Developing a Common Goal

The shared goal and collective effort is prompted through the course assessment scheme and facilitated by communication through the Learning Management System. As discussed in Chapters 5 and 7 teams are focused on process, sharing experiences and peer assistance in meeting individual learning goals. Discussions and negotiations occur through discussion forums on the LMS. Several discussion threads are placed on the team discussion boards to get teams started with the communications that are crucial to success in the course and they include:

- Introduce yourself,
- Team code of conduct and responsibilities,
- Team communication strategies,
- Peer and self assessment strategies (linked to the code of conduct)
- Key learning goals (individual and team) and concepts for problem 1.

Figure 8-2, Figure 8-3 and Figure 8-4 show the results to the survey questions relating to team goals. These questions were added to the learning survey in 2007 (450 responses with a response rate of 61.5%). The survey indicates that teams do discuss and formulate team goals, as separate from individual goals which are formulated in portfolios:

> *The personnal [sic] learning goals were very helpful in identifying your own areas of weakness, and also one of the assessments focused on the building of teams and how they move through different stages after being formed which i found was very interesting and something that could be applied within your team.* - **comment from portfolio**

The Portfolios, were the most helpful aspects of the course as it facilities learning by reflection. The portfolios of this course were linked to each other and follow a natural progression from initial learning, development, and reflection. I found the very useful in facilitating individual learning. I also found the reports very effective learning tool as well, but the actual content of the reports seemed to have no relevance to anything. But the ability to work within a team and develop this ability I feel is an invaluable skill. - **comment from survey**

These perceptions on team goals however, are not reflected in student portfolios with few students making individual comments on the merits or otherwise of a team goal. There are a number of potential reasons for this:

1. Team goals are discussed early in the semester and the individual open ended reflective pieces are submitted by students at the end of the semester. The discussions have perhaps faded from view by this time.
2. Stated team goals are often vague: *"To achieve the best grades for all members"; "....to support all members in achieving the aims of the course"*. These might be typical goals of a student in any course.
3. Teams focus and are encouraged to focus, on process. A requirement of all team submissions is a team reflection, the marking criteria for which includes topics of reviewing the team code of conduct, meeting strategies, problem solving strategies and forming plans for the future. The team goal is not explicitly mentioned.

Investigation of team goals and the effect on student engagement and learning is an area for future investigation.

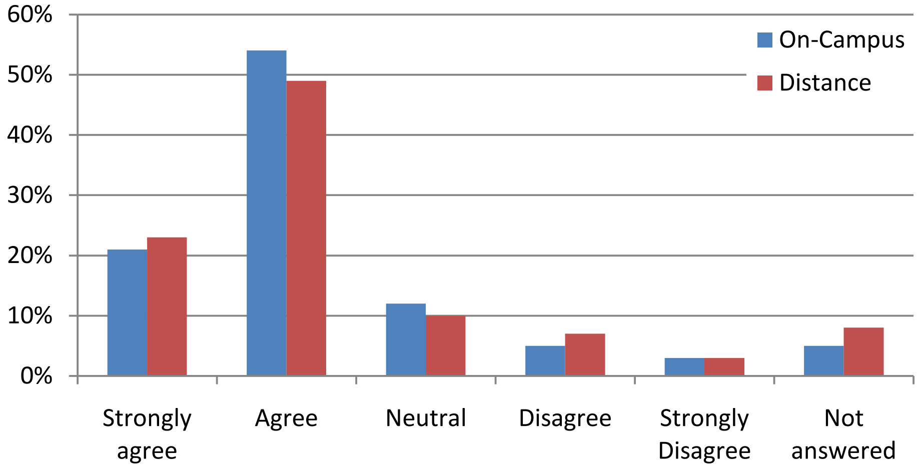


Figure 8-2 Our team discussed and agreed on goal/s

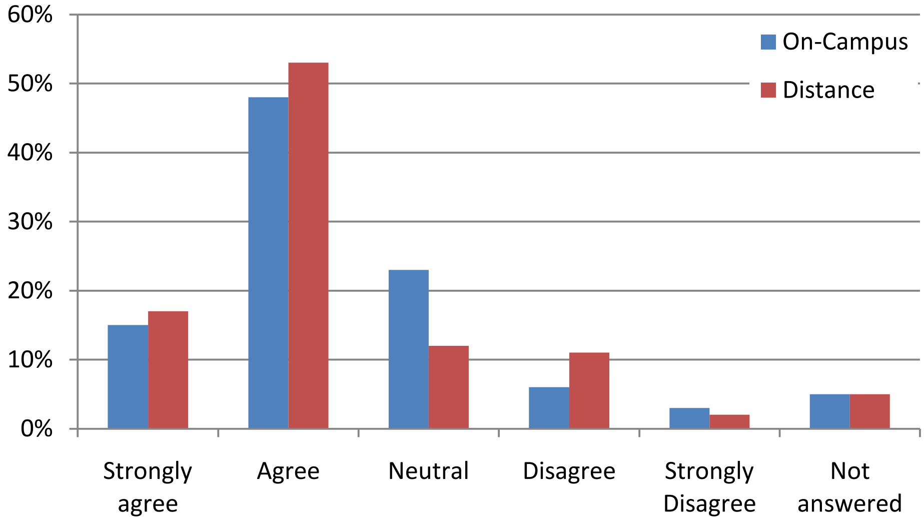


Figure 8-3 Having a goal kept our team focused

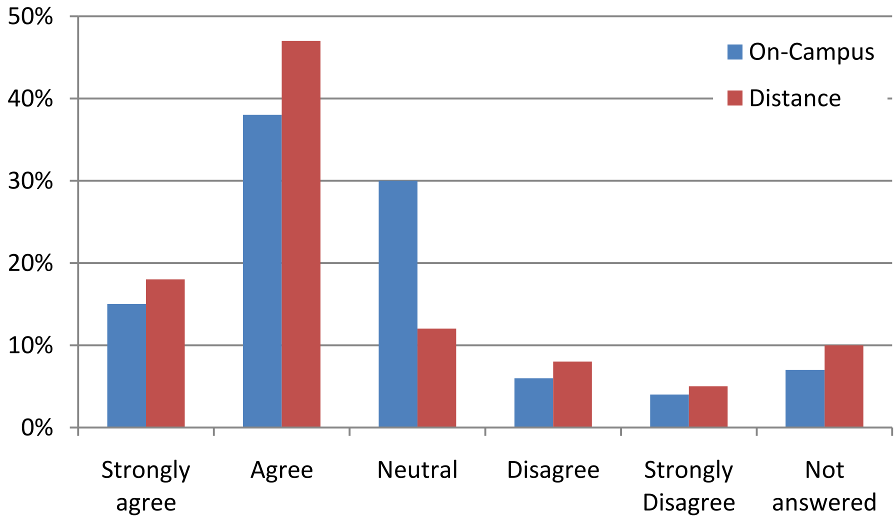


Figure 8-4 Having a team goal help me participate in the team more effectively

8.4 Recognising and Using Diversity

Student teams are encouraged to recognise diversity, prior knowledge and experience and learn from team members through a Mentoring Plan which is a requirement of Team Report 1. Mentoring or peer assistance is also featured in the criteria for team reflections and individual portfolio submissions. In team reflections teams must demonstrate and give evidence of peer assistance in order for the effort to be recognised through the assessment scheme. Kilpatrick et al (2003) suggest that 'respect for diversity enhances the learning capacity of a community'. In ENG1101 survey results identifying an appreciation of prior knowledge and learning from the skill and knowledge of team members are shown in Figure 8-5 and Figure 8-6. The on-campus and distance cohorts of students have identified that helping others and mentoring is a powerful contributor to team success and individual goals. This required them to embrace diversity and to identify and use individual strengths and weaknesses.

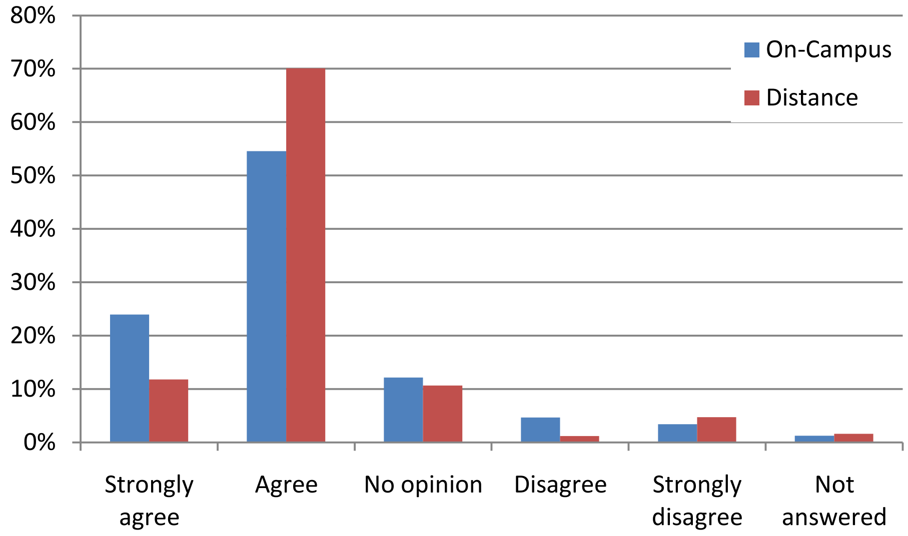


Figure 8-5 Student responses to 'my appreciation of how the prior knowledge and skills of my colleagues can be used to solve a problem has been increased'

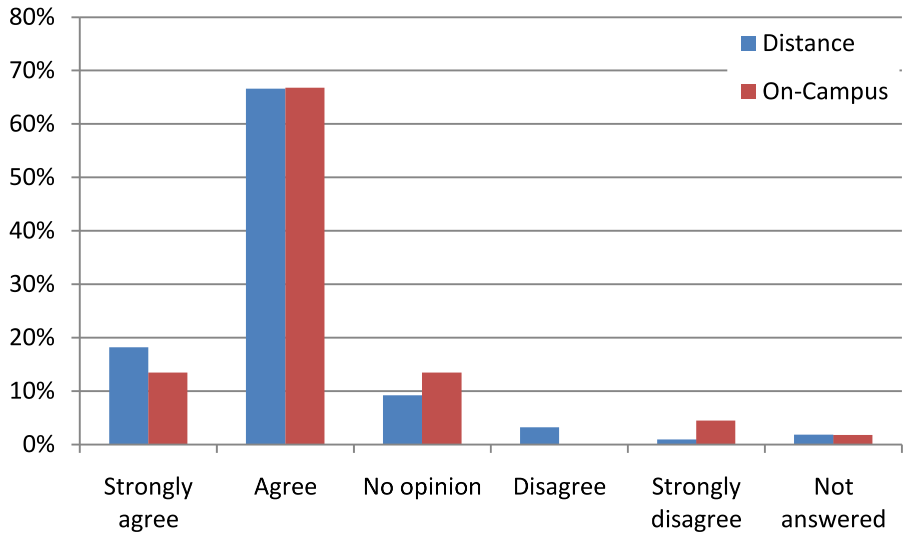


Figure 8-6 Student responses to 'I used the skills and prior knowledge of my team members to help my learning'

Mentoring, diversity and prior knowledge and skills are featured in the majority of student reflections and comments (from open ended survey questions). Examples of these are given below:

> *This course has also taught me that a variety of opinions in a team is often beneficial to its success, as it promotes in–depth discussion which leads to well thought out decisions. As well as this, it encourages team members to think about the concepts being learned more deeply, which helps in understanding and remembering them in the future* – **comment from portfolio**

> *I have learnt that a team of people can accomplish much more than one [of] the individuals by themselves.* – **comment from portfolio**

> *The diversity of the team is one of its greatest strengths; subsequently suggestions and comments always vary due to our different backgrounds, experience and individual viewpoints. This should result in a wide range of alternatives for us to always consider and be advantageous to us all.* – **comment from team reflection (team report 2)**

> *One of my team mates had suggested that he would like to learn more about PowerPoint, so we have been paired for this task. As I am quite comfortable*

> *with the use of PowerPoint, I developed a simple training package for my team mate to show him the basic tools that you can use with this software. We have also collaborated via MSN Messenger on the content of the presentation. I have enjoyed the opportunity to help a team mate learn a new skill* – **comment from portfolio**

> *Diversity works for the team because we: Solve a problem using different viewpoints; Use each others' skills to increase the team's output; Learn skills from one another* **– comment from team reflection (team report 2)**

> *One good thing about the course is that I can see how the other students tackle these things and learn from them.* – **comment from portfolio**

> *With so much interaction between other students in this course, it is hard not to learn a great deal. Each person has a large amount of useful information and with this combined into a team environment; this collective information can almost seem endless.* – **comment from portfolio**

Usage data, collected from the LMS from two typical semesters are presented and analysed. During any semester, dependent upon total enrolments, between 16000 and 18000 postings will commonly be made to the discussion forums. Early in the semester distance teams have significantly more postings than on–campus teams as they are establishing communication, building trust and 'getting to know' team members using the virtual environment. However towards the end of the semester the on–campus students are using the discussion forum at a similar rate to distance students even though they have the ability to meet face to face.

In addition to postings to discussion boards, students conduct virtual meetings in some form with most distance teams using chat software (e.g. MSN or Skype) for meetings. Minutes or records of the meeting are then posted to the discussion forum as a future reference and for students who could not attend the meeting.

Figure 8-7 Student usage of the LMS – total average time per student for each week of semester for two typical semesters shows typical student usage of the LMS in terms of total average time per student for each week of the semester. Distance students spend more time on StudyDesk establishing their learning community than on–campus students this is done in face–to–face meetings and timetabled tutorials, at least in the beginning of the semester. Analysis of two semesters' usage of the LMS does not indicate any substantial difference in usage in different semesters with the exception of small differences which can be accounted for in the timing of assessment items and vacation periods as illustrated in Figure 8-7.

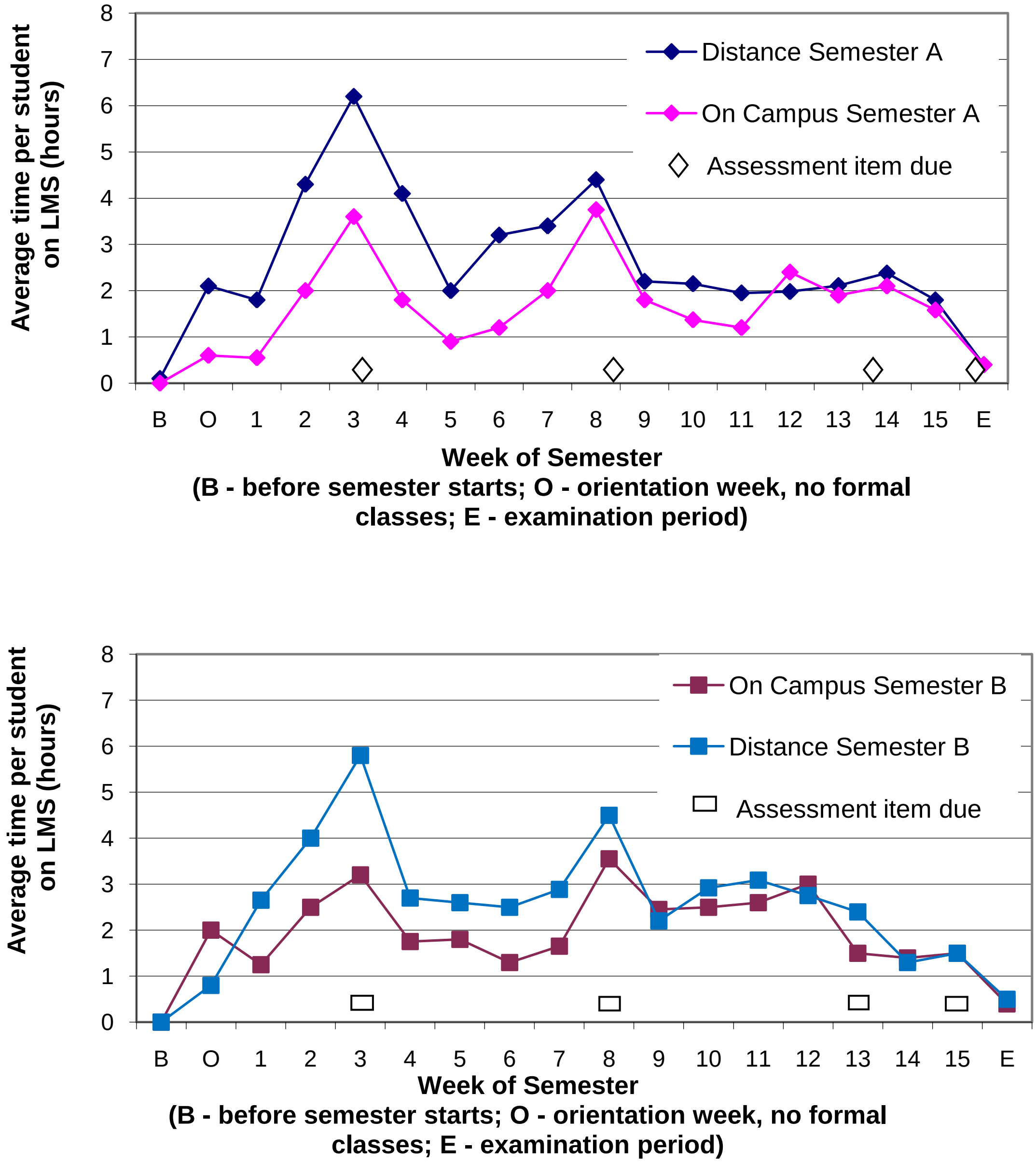


Figure 8-7 Student usage of the LMS – total average time per student for each week of semester for two typical semesters

8.5 Developing Trust in the Team

Trust (and the ability to rely on others in the team) is a critical element for efficiency within teams. This was also recognised by Kilpatrick et al (2003) and Rovai (2002) as essential to the success of collaborative work. The trust criterion has been the hardest to validate. There is significant anecdotal evidence to suggest trust is developed within the majority of the team as evidenced by reflective portfolios and the engagement of students in the discussion forums:

> *I have learnt how to trust other team members and use their gifts to enhance the team* – **comment from portfolio**

However the *level* of trust is difficult to evaluate and quantify. Evidence suggests that the majority of students readily share information and assign tasks, *trusting* that the information will be used appropriately and tasks completed to the required standard in the timeframe. However should a member or team feel that their trust has been breached or misplaced repeatedly, they are very reluctant to ‘forgive’. For example team members mostly understand and accept the low participation levels when work, family or illness are cited as the reasons. They will however only ‘carry’ the member or accept the excuse for a few weeks, unless in exceptional circumstances or the member has already gained significant trust by previous high levels of participation.

> *[name of student] did not contribute much to this report but we understood his circumstances. We really missed his input to this report as his contributions to team report 2 were of high quality and his expertise was valued by all in the team* –**comment from team reflection (team report 3)**

> *The team has decided for [sic] fully apply our agreed penalties for non participation this time. At the team meeting last night, all present agreed that we could no long believe [name] excuses. We are all busy and working long hours...* – **posting from team discussion board to facilitator**

It is recognised that ENG1101 and other web–based courses will build a different type of community from an informal learning community that might be expected in traditional classrooms. A sense of community can come about as a result of activity by those brought together by a common purpose (Rovai 2002), but in this case all doing the same course. Much like the situation described by Misanchuk and Anderson (2001a), ENG1101 students are assembled into teams and through the design of the assessment asks are encouraged into this 'community' Their common interest is passing the course and learning something in the process.

In the beginning this learning community exists within the boundary of the course, but evidence suggests that the community within the teams develop into more than this. Increasingly throughout the course, teams display evidence of communication as social interaction on a personal level as well as academic discourse: noted by (Misanchuk & Anderson 2001a) as the most important indicator of the existence of a learning community. This sharing of personal information leads to a 'shared emotional connection' (Brook & Oliver 2003, p. 2), which in turn leads to greater trust and sense of support from the team.

8.6 Summary

Developing and supporting a learning community working in virtual space meets many of the attributes of future global engineers as indicated in the literature: able to work in a virtual environment sharing tasks on a round the clock basis working across time zones and geography, communicating electronically and solving an array of, as yet unknown, problems. However, in responding to these educational demands, the pedagogy and course design must support student learning by this new model and not merely continue in the traditional paradigm. In the rush to take up online education the concept of a 'learning community' sharing knowledge and skills between members and acknowledging both shared and different learning goals is often overlooked or misunderstood by academics. Developing a learning community is more than just adding 'technology'. Course design and implementation must ensure that students are able to learn through jointly constructing knowledge.

By engaging in dialogue with other students in virtual space, in a supportive environment, they are active participants in their learning process. This active participation along with the opportunity to critically reflect on their own learning and behaviours, to validate new ideas and use them in new contexts are in line with adult and transformative learning and social construction.

Evidence from ENG1101 indicates that this social construction aspect of student learning is occurring in the online environment. It is supported by the judicious use of the communication features of the LMS but facilitated by the design and implementation of the curriculum. Team members, working in virtual space, can indeed 'transcend physical geography' and form an effective learning community which addresses the needs of distance education students

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9 Staff Training and Professional Development

9.1 Introduction

Academic staff play a critical role in student learning. In courses which are ‘learner centred’ and encourage deep rather than surface learning, the academics’ attitudes to teaching roles affect the effectiveness of students’ learning (Kember & Gow 1994). Critical to students’ learning and engagement with the course content are issues to do with facilitation versus instruction or transmission.

The facilitator role in PBL is essentially one of providing scaffolding (Greening 1998) and the facilitator’s role’s importance to student motivation and learning and group processes is emphasized in the literature (Gijselaers & Schmidt 1990; Eagle et al. 1992; Ambury 1995). Therefore understanding staff perceptions, concerns and ensuring the acquisition of appropriate skills is a cornerstone of PBL. This chapter discusses the difficulties of implementing PBL, in an online or face–to–face mode, from the staff perspective.

This chapter has been previously peer reviewed and published in:

Brodie, L., Aravinthan, T., Worden, J. & Porter, M. 2006, 'Re-skilling Staff for Teaching in a Team Context.', *EE 2006 International Conference on Innovation, Good Practice and Research in Engineering Education*, vol. 1, eds Doyle S & Mannis A, The Higher Education Academy, Liverpool, England, pp. 226-231.

Facilitation and training constitute a large research area and this research and the development and evaluation of training modules and resources is ongoing and an area for future work (Refer to Chapter 10).

9.2 Instruction to Facilitation

In constructivist learning environments, of which PBL is one paradigm, the literature strongly supports the view that the role of the tutor is one of ‘facilitation rather than instruction’ (Kember & Gow 1994) and therefore is quite different to the role of tutor in a didactic system (Greening 1998). The transition from lecturing (or tutoring) to facilitation is a large barrier for staff to overcome and adequate support for such a move can consume a large portion of staff development resources. Development of appropriate facilitation skills in academic staff supporting students in a PBL environment is critical to the success of student learning. Reporting the results of student surveys Zimitat and colleagues (1994) claim that 70% of students in a PBL course found good facilitation essential to the success of the method.

There are many definitions of facilitation in the education literature and the following is a small sample of definitions which have application to PBL:

- ‘Coordinating rather than leading an exercise so that all group members are encouraged to participate in the discussion or activity’;
- ‘Helping others think through what they want and organising themselves to achieve it’;
- ‘Facilitation is a collaborative process in which a neutral seeks to assist a group of individuals or other parties to discuss constructively a number of complex and potentially controversial issues’;
- ‘In education it is to help the learner forward, to manage a learner focused education process in an outcome based education model’.

The collective theme of these definitions is that facilitators should encourage participation in the solving of complex issues (or problems) by helping students identify common goals and the means through subsequent organisation to reach those goals. The literature in this area only discusses the critical role of the facilitator in face–to–face facilitation. It must be argued that in moving to a fully on–line delivery, the role of the facilitator and skills required to undertake effective interaction with students, are more complex and more critical to the success of the team and the learning of each individual student.

The literature supports the idea that teachers (or students for that matter) do not automatically know how to communicate or interact online (Coghlan 2001). Many require professional development and/or mentoring in the skills and techniques of facilitating:

> *…Since I had no previous experience as a facilitator, I was very anxious about this role that I had never played before*. – **quote from facilitator**.

The most effective way for teachers to learn how to be an effective online facilitator is for them to experience the process first hand – to undertake an online course themselves and experience what it's like from a student perspective (Salmon 2000; Ambrose 2001; Kempe 2001). This option has been explored in the Faculty but for the majority of staff involved in PBL courses, the time and workload constraints do not allow this. Staff teach into a number of courses and balance teaching and research workloads. There are also a number of sessional staff employed in facilitation roles and these staff usually undertake this work in addition to full time employment.

To bridge this gap a number of options were explored including development of support resources and professional development sessions. A Facilitators Guide was written for use by all staff in PBL courses (Brodie et al. 2002 ; Gibbings & Morgan 2005). This guide discusses the role of the facilitator, communication protocols and strategies, protocols for dealing with non participating students and administrative matters. However, this document was conceived only as a *guide* and more interactive and in depth professional development was clearly required.

Moreover, this training was required regularly as the Faculty has a policy of rotating all staff (where possible) through at least one of the PBL courses for profession development reasons. Workload considerations further dictate that each year there are also a number as sessional staff employed to act as facilitators.

> *This one–day workshop covered several activities including the introductory team–building activity aimed to simulate a team environment within the workshop participants, introduction to PBL at USQ and detailed information on facilitation, including sharing of experience from experienced facilitators. I found the workshop to have been well organized and the contents to be very valuable especially to a new facilitator like me. The workshop materials included the 'Facilitators' Guide' which I found to be a very useful reference manual in my day–to–day facilitation. The training and experience gained by attending this workshop gave me the confidence to fulfil my duties as a facilitator throughout the semester.* – **quote from a new facilitator**.

Whilst resources and formal training have been successful, up to a point, the greatest impact on the facilitation process and the engagement of staff in facilitating has been the establishment of a *staff team* philosophy. The development of a staff *team* has been supported by establishing a community of practice using both face–to–face meetings and online communication similar to that employed by student teams. Staff have a discussion forum where problems, solutions and ideas can be shared; staff regularly devise a *code of conduct* where a consensus is reached on how aspects of the course will be dealt with e.g. assessment procedures to be followed.

A paramount concern for staff was the change in focus away from content delivery to appreciation of team dynamics and problem–solving. Many have expressed misgivings about particular content not being delivered by an expert (themselves) and relying on self–discovery and learning by their students. While these concerns may have had some real basis early on in the course implementation, strategies have now been introduced to minimise “passenger students” who benefit from the efforts of others and to identify students requiring counselling (Aravinthan et al. 2005). Further research has also indicated that students do acquire technical content, provided the problems are carefully designed (Sabburg et al. 2006).

9.3 Achievements

Currently many academics are not comfortable with, nor have the skills, to move to using more cooperative learning techniques in the classroom and undertake the corresponding changes to assessment. The Faculty has seen the staff training taking place in the PBL courses as an ideal mechanism to give staff skills, confidence and motivation to change current teaching practices within the faculty. To date 24 out of a total of 54 faculty academic staff have been rotated through the 4 problem solving courses and hence have undertaken staff training. This list also includes the several senior staff (Dean and Discipline heads) plus six staff from the Faculty of Sciences. This has had a flow on effect with six other courses (e.g. Electronics and Hydrology) moved substantially to a more student centred approach in teaching and assessment.

This move has the potential to provide significant benefits for our distance student cohort by giving them much more equity with on–campus students. Many distance students comment favourably on the increased contact with other students and more interaction with staff in their course evaluations. This is, in part, due to the staff training on using discussion boards and online facilitation (Aravinthan & Worden 2006). All courses across campus now incorporate discussion boards as part of the educational package. Now staff understand the importance of 'seeding' discussions, and guiding and directing the discussion so that it has maximum benefits for the participating students.

One of the key objectives in staff training is continuous improvement in the course. Each year a problem area is identified and a strategy for improvement discussed, refined and implemented. An example of this is the assessment of the reflective writing portfolio undertaken by students in the first problem solving course. Grading of the reflective portfolios revealed that facilitators as well as students were not comfortable with reflective writing. Facilitators were uncomfortable with the concept of grading personal thoughts and feelings. How can you mark a student wrong or deduct marks? The results of assessment of the portfolio by different facilitators are shown in Figure 8-8(a). The range of average marks by individual facilitators was approximately 56% to 91%. Clearly facilitators had differing ideas and standards on what constitutes reflective writing (Brodie 2004).

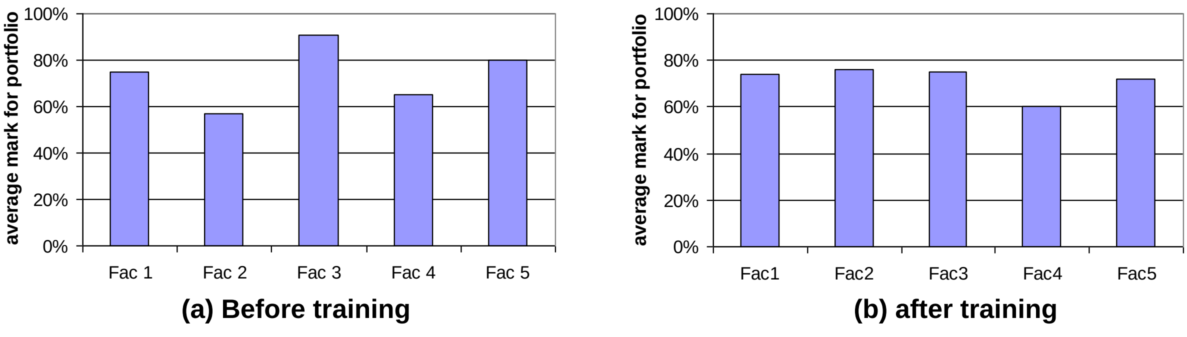

Figure 8-8 Average mark for reflective portfolio by facilitators

To correct this inequity a team training session was planned and run. A Facilitators Guide to Reflective Writing was written, and assessment rubrics designed (Brodie 2004; Brodie 2005). The results of this training and development can be seen in Figure 8-8(b). There was much closer correlation in the assessment marks. It is interesting to note that the one exception (Fac 4) did not attend the training session.

The increasing emphasis on and interest in student learning experiences has generated a new area of research within the faculty. Engineering Education research is now a significant research area for several staff, in addition to their area of technical expertise. These research areas include assessment strategies, reflective writing, student diversity, learning styles, PBL and cooperative learning. The results from this research and the success of the PBL courses have helped staff overcome initial concerns about course ‘content’ and student ‘learning’.

The staff training sessions have gradually evolved as staff experience and confidence increases. When initial training sessions were planned they were conducted by only one or two staff. Now the staff team has developed to the extent where the training sessions themselves are conducted by a *team*. This development of a staff team, both at the individual course level and on the strand level has been a significant achievement with benefits for the faculty. Staff not only have a better understanding of issues which students are facing, but staff development and research areas have also benefited.

There remains a mis–match between student expectations of facilitators and the facilitation delivered by the staff team. Students often expect singular guidance towards a solution to the problem, whereas the facilitator’s role is to suggest alternatives that need to be explored and evaluated by the student team. Failure to provide the “answer” is often interpreted as unhelpful by students who resist development into independent learners. The problem is more frequently encountered amongst the on–campus student teams that consist predominantly of school leavers. Conversely, distance students have acquired greater maturity in the workplace and are better equipped to be independent learners.

There is still room for enhancement in the area of staff training and professional development. However, feedback from facilitators indicates that the achievements to date are substantial.

The training, initially implemented for staff teaching into the PBL strand, has resulted in an increased interest in professional development across the faculty and the university. The development of training materials, developed by the author, for staff (full time and sessional) to support teaching in cooperative and collaborative learning environments has been seen by faculty as a significant contribution to improving learning and teaching performance. This work has attracted university funding and is currently being developed for use in all faculties of the university.

9.4 Summary

The successive offerings of the PBL courses confirm the following major conclusions:

- Staff must be convinced of the benefits of PBL. The best way to be convinced is to be involved in a PBL course and have first hand experience of student centred learning;
- Both students and staff could misunderstand the role of facilitator. Facilitation is an acquired skill, which can only be improved by continuous training;
- More effective training is required to produce staff with greater confidence with this instructional strategy;
- All staff training needs effective evaluation and follow up to determine its longer term effectiveness – Have training benefits flowed on to students?
- Students receive the benefits of PBL, only when staff team is committed to its implementation;
- The overall benefit to student learning through PBL courses can only be achieved though consistent integrated goal/s that are supported by all staff and management.

Since the implementation of the PBL courses in 2002, at least 64% of the faculty teaching staff through these courses. Many staff commence their period on the staff teams with a negative impression of PBL and the courses they are required to facilitate. Often this early attitude mellows during the course offering and some staff attitudes change to one of acceptance of the pivotal role these courses play in contributing to graduate attributes of our students. A few resist the change to facilitation and remain wedded to didactic teaching strategies.

Staff play a critical role in student learning and in courses which are learner centred, and encourage deep rather than surface learning, the tutor or academic's attitudes to teaching roles effect the success (Kember & Gow 1994)

The facilitator role in PBL is essentially one of providing scaffolding (Greening 1998) and their importance to student motivation and learning and group processes is emphasized in the literature (Gijselaers & Schmidt 1990; Eagle et al. 1992; Ambury 1995). Therefore, understanding staff perceptions, concerns and ensuring the acquisition of appropriate skills is a cornerstone of PBL. This chapter discussed the difficulties of implementing PBL, in an online or face–to–face mode, from the staff perspective. Facilitation and training constitute a large research area and this research and the development and evaluation of training modules and resources is ongoing. It has attracted funding through a university wide competitive grant for implementation in all faculties.

10 Conclusion and Further Work

10.1 Areas for further investigation

As outlined in the introduction, the research reported in this dissertation spans several broad areas including virtual teams, distance education, engineering education, assessment, staff professional development and problem based learning. Each of these areas forms a body of research area in its own right. The innovative research undertaken for this doctorate is unique in that it takes an overarching view and develops a model of how to deliver PBL to students studying by distance education. Underpinning this delivery of PBL is the verification of the ability for large classes of undergraduate students to work in virtual teams.

A model of student barriers to participation and learning was developed and proposed in Chapter 6. Current data supports the model, but further development and refinement of the model is possible. In particular, further investigation of students learning in a true virtual team environment will be of interest to many academics. The self efficacy, learning style, team role and individual personal characteristics of a student will all impact on their ability and motivation to work with, and learn in, a team environment. The addition of a virtual environment is an additional complication and adds an aspect that warrants further study.

The current literature focuses on virtual teams which are formed in a ‘contrived’ business environment or have the ability to meet face–to–face to establish the basic fundamentals of a team e.g. a goal and trust between members. Little literature exists on teams formed without the use of ‘sensory’ communication devices like telephone, telephone conferencing and audio/visual conferences and formed for the purpose of *learning* as opposed to producing an outcome or artefact. Further investigation of the dynamics and formation of true virtual teams (with no face–to–face meetings or use of videoconferencing) formed for learning is recommended.

In any team environment, differing motivation and levels of engagement will be present. In an educational setting, those ‘hitchhikers’ and ‘couch potatoes’ need to be identified and intervention strategies put in place quickly. In an extreme situation, students not fully participating in team activities and tasks, and then claiming a disproportionate mark in assessment, could be interpreted as plagiarism. At best, such students may be able to pass without meeting the course objectives utilising the work and good will of their colleagues. The role of the team itself is self monitoring and corrective action is very important. However, early and effective identification of such students is crucial, along with the development of strategies and/or materials to support them and the team. The task falls largely to the facilitator and it is important that staff training enables staff to recognise and deal with these situations.

Facilitation and training for academics moving from a didactic to collaborative teaching environment constitute a large research area, but this has been somewhat neglected by universities. Traditionally universities focus on training which assist academic staff in discipline specific research. Teaching and associated professional development for academic staff pursuing that career path have been largely neglected and left up to individual staff members to pursue. However, staff are now investigating different teaching techniques to cater for the diverse needs of university classes and the new generation of university students and those initiatives are being recognised more widely in the sector.

Whilst many courses are now using collaborative learning approaches, of which PBL is one, the sustainability of these courses in the long term is questionable. The ‘champion’ often spends considerable time developing skills and materials however without suitable investment in staff training, these innovations often give way to traditional didactic delivery when the instigator moves on or is reallocated to another course. Further research into staff perceptions and needs for effective *facilitation* are recommended.

To summarise, the major areas for further work are:

- Further investigation of the formation and dynamics of true virtual teams. These teams operate with no face–to–face meetings or use of videoconferencing and are formed specifically *for learning* and not the primary purpose of production of an artefact.
- Development of strategies and/or materials to support low and non participating team members. Early identification and intervention is crucial if appropriate action is to be implemented.

- Further development and refinement of the model for barriers to student participation and learning to investigate and situate the learning aspect in appropriate literature, that is individual approaches to learning and effect on team.
- Facilitation and training constitute a large research area and this research and the development and evaluation of training modules and resources is ongoing.

10.2 Conclusions

The design of and implementation of a PBL curriculum at USQ was undertaken by the author in response to numerous demands, both internal and external to the University. These included professional accreditation bodies worldwide requiring graduates to be competent in teamwork, problem solving, communication and life–long learning skills. The accreditation procedures, especially those proscribed by Engineers Australia now focus on *outcomes*. Institutions must now demonstrate exactly how students attain the required graduate attributes, not only in technical and discipline specific areas but also in the area of ‘soft skills’.

These ‘soft skills’ are now seen by industry and graduates as some of the fundamental skills which determine ‘success’ in a fast and ever changing profession. The information age has radically transformed the profession of engineering and changing social and community expectations of engineers continue to impact on the requirements of the profession. The requirements inevitably trickle down to tertiary institutions: those training and educating the professional engineers and technologists for society.

The need to educate professional engineers to meet the growth in the sector and the needs of society are placing increasing demands on an already stressed tertiary sector. Government reviews predict a large increase in demand for university places for students, other than the traditional school leaver who studies on–campus in a full time mode.

USQ has already responded to these demands for an inclusive approach to university education. The university offers a range of entry paths and study patterns to all courses and this has led to a diverse and non–traditional student cohort. USQ offers access to education to students who have a broad range of educational backgrounds and work (life) experiences to draw on. These students demand a different approach to education. They require flexible study patterns and recognition of the prior knowledge and skills they bring to their university study.

These students are career focused and wish to be active participants in the learning process. A team based approach to *some* courses allows students to share prior knowledge and experience, which eases the apprehension felt by older students entering the university education system. The diverse mix of students in a team environment allows both learning and mentoring to take place, to the benefit of all involved.

This team environment, along with the open ended contextual problems, closely simulate a professional engineering practice, abet one that supports individual student learning. The course encourages and supports attention to *process* setting in place strategies which can be applied not only to other courses but also professional practice. This is done using a virtual environment which has been identified as a key requirement for future global engineers.

The success of the innovation, implementing PBL in a virtual team environment, has been evidenced by student surveys (Likert scale responses and short answer), unprompted student portfolio entries and interviews. Student teams, dispersed around the world, engage in PBL by meeting and communicating electronically to solve a set of open–ended engineering and spatial science problems.

An innovative peer–assisted learning approach builds on the diversity of prior knowledge and experience within each team. Students are encouraged to identify gaps in their knowledge and plan strategies to fill those gaps while solving authentic engineering problems, facilitated by a member of the academic staff team.

Current literature emphasizes the need for educational institutions to move from traditional, didactic education to a learner–centred model which extends to professional development and scholarship of teaching. This move, while a significant and radical change, will be critical to the long term success of educational institutions. A major barrier to this transformation is staff attitudes to change

(Spender, 2002; Brodie & Porter, 2004). The PBL educational paradigm means that the roles of academics change with a greater emphasis on design and preparation, guidance and support, and managing and delegating rather than lecturing and tutoring (Brodie & Borch, 2004). Staff have been supported in this transition by developing an ongoing staff training program for both full time and sessional staff , developing a staff *team* philosophy and development of staff resources e.g. Facilitators' Guide (Gibbings & Morgan, 2005; Brodie et al 2006) and assessment rubrics (Brodie & Gibbings 2009b). The professional development and support of staff is identified as one of the key areas for successful delivery of PBL to students working in virtual teams.

This professional development and support for the scholarship of learning and teaching (including research in education) is also critical for universities. Increasing emphasis is being placed on student learning in addition to the traditional research outcomes. The research experience (proposed in Chapter 4 and adopted for this dissertation) is one of continuous growth in consulting the educational literature and research methodologies and their practical application to teaching. It supports an informed approach to learning and teaching and places the move to a new research field within the grasp of all academics. Moving academics along the research continuum (Figure 4-2) and having staff take an interest in the scholarship of their teaching as already been implemented within the faculty through the Engineering Education Research Group (EERG) which is chaired by the author. This group has undergone significant growth and is now a strong contributor to the faculty's research output.

The success of this group is underpinned by development of an effective 'learning community'. This was identified by the author as a fundamental aspect for successful student teams and has been applied not only to the course but also to the research group.

The three main criteria for development of a learning community include the recognition of a common goal; sharing the diverse skills and experience of team members to meet the identified goal/s; and the ability to rely on and trust team members.

Within the course, these aspects of the learning community are fostered and developed by the innovative use of technology (the LMS) and effective assessment of both process and progress of the team.

The assessment supports the basics of team development, fosters mentoring and peer assessment and encourages reflective practice at both the individual and team level. Through this strategy key graduate attributes of problem solving, communication teamwork and life–long learning are developed. In addition they are developed by students working in a virtual environment.

The literature consistently points to the need for engineering graduates of the future to obtain the skills and abilities to work in interdisciplinary, multi–skilled teams sharing work tasks on a global and around the clock basis, working with digital communication tools and working in a virtual environment (NAE, 2004; Thoben & Schwesig, 2002). These attributes are difficult to attain through traditional, didactic educational programs as they cannot be learnt passively.

Problem based learning (PBL) in a team gives students a more interactive experience of university learning than traditional lectures and tutorials. Identifying and finding appropriate resources rather than using a set text or lecture notes, solving open–ended engineering problems and working towards individual learning goals boosts a sense of self achievement and begins a student's road to lifelong learning.

While PBL has been widely used in engineering education, and its growth continues, there are few high quality references in the literature to it being used in a completely virtual environment. This dissertation investigates the major areas of research which impact on the successful implementation of such a paradigm: the theory of PBL, assessment, engineering and distance education, virtual teamwork, student learning and staff professional development. It presents a case study of successful implementation, data from several sources to provide validation and contribution to the current body of knowledge of these areas. The contribution to the knowledge area is evidenced by peer reviewed publications, national awards and the uptake of the concepts and resources by other institutions and academics.

The research reported in this dissertation has had several significant outcomes. The personal learning journey of the author has fostered the development of an interest in engineering education research within the faculty. This has occurred by an increased understanding and awareness of educational research methodologies and literature and passing this on to other academics in incremental stages enabling them, in turn, to move along the research continuum from novice to expert. Researching and gaining an understanding of a learning community, initially applied to student teams, but subsequently applied to EERG has promoted its growth.

Professional development, again initially developed and investigated to support improvements in the course ENG1101 *Engineering Problem Solving 1,* has also had further impacts. Staff, at a faculty and university level, now have access to professional development materials to support them in a move to cooperative and collaborative teaching techniques.

Lastly, the development of the course, and the subsequent investigation and evaluation has demonstrated that PBL can be successfully used to deliver key graduate attributes to students working entirely in virtual space. This allows universities and education providers to deliver courses in a flexible way to cater to an increasingly diverse market. Students can gain the benefit of interacting with other students, to construct their own knowledge and to be part of a social network without having to attend face-to-face classes and in a time frame with suits their lifestyle.

For the profession of engineering the benefit of PBL in virtual teams is that it provides graduates with skills for the future. These skills will support individuals in a career where technology and the global economy will have an increasing impact on the profession. Communication, problem solving and teamwork have always been critical to the profession of engineering but developing and using these skills in virtual space is a new challenge. This course and the research of this dissertation prove that it is a challenge engineering educators can meet.

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Appendix A

Appendix A contains selected publications of the author relating to the dissertation.

Publication	Page
Brodie, L. 2009, 'eProblem Based Learning – Problem Based Learning using virtual teams', *European Journal of Engineering Education*, vol. 34, no. 6, pp. 497-509.	227
Gibbings, P. & Brodie, L. 2008, 'Assessment Strategy for an Engineering Problem Solving Course', *International Journal of Engineering Education*, vol. 24, no. 1, Part II, pp. 153-161.	240
Gibbings, P. & Brodie, L. 2008, 'Team-Based Learning Communities in Virtual Space', *International Journal of Engineering Education*, vol. 24, no. 6, pp. 1119-1129.	249
Brodie, L. 2007, 'Reflective Writing By Distance Education Students In An Engineering Problem Based Learning Course', *Australasian Journal of Engineering Education*, vol. 13, no. 1, pp. 31-40.	260
Brodie, L. & Porter, M. 2008, 'Engaging distance and on-campus students in Problem Based Learning', *European Journal of Engineering Education*, vol. 33, no. 4, pp. 433-443.	269
Brodie, L. 2009, 'Transitions To First Year Engineering – Diversity As An Asset', *Studies in Learning, Evaluation, Innovation and Development* vol. 6, no. 2.	280

European Journal of Engineering Education
Vol. 00, No. 0, Month 2009, 1–13

Taylor & Francis
Taylor & Francis Group

eProblem-based learning: problem-based learning using virtual teams

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(*Received 1 April 2009*)

Literature on engineering education stresses the need for graduates to have skills such as working globally in a multicultural environment; working in interdisciplinary teams; sharing of tasks on a global, around the clock basis; working with digital communication tools and in a virtual environment. In addition, accreditation criteria include attributes such as problem solving, communication, life-long learning skills and ethics. Problem-based learning (PBL) is well established in traditional on-campus settings in many professions but its use in 'virtual' or online environments is not well-documented, particularly in engineering. However, it is ideally suited to delivering many of the required attributes. A fully online PBL course has been successfully delivered to engineering students studying via distance education. Students work entirely in a virtual mode, conducting online team meetings and utilising a variety of technologies to communicate and solve complex, real-world engineering problems. Design, implementation and evaluation results are discussed.

Keywords: virtual teams; problem-based learning; distance education

1. Introduction

The University of Southern Queensland (USQ) is a small regional university. It has gained an international reputation for distance education with approximately 75% of students studying by traditional distance education or in an 'online' mode. The university has five faculties – business, science, arts, education and engineering and surveying.

The Faculty of Engineering and Surveying offers postgraduate courses and four articulated undergraduate programs – Associate Degree (AD – 2 years), Bachelor of Technology (BTech – 3 years), Bachelor of Engineering or Bachelor of Spatial Science (BEng – 4 years) and double degree programs (5 years), e.g. Bachelor Engineering and Business or Bachelor of Engineering and Science. These undergraduate programs can be based in one of nine major areas of study – agricultural, electrical and electronic, mechanical, civil, spatial science (surveying), geographic information systems, mechatronic, computer systems and environmental.

The flexibility of the distance education programmes combined with multiple entry paths to programmes and the rapidly changing demographics of Australian universities leads to a

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ISSN 0304-3797 print/ISSN 1469-5898 online

DOI: 10.1080/03043790902943868
http://www.informaworld.com

diverse student cohort. The majority of distance students are of mature age, working in industry, with a significant base of practical, industry and life skills. Our on-campus student cohort is younger and has more traditional academic skills (including math, physics, computer and information literacy etc). Traditionally, this student diversity has been seen by academics as a disadvantage.

The challenge was to use this student diversity to advantage by unlocking the potential of each student to share and learn from other students as well as the 'expert', the academic, by the use of a carefully constructed online problem-based learning (PBL) pedagogy, active online facilitation to develop effective problem solving, mentoring, virtual teamwork and electronic communication skills.

This paper discusses the use of electronic communication media, to engage a diverse cohort of students in PBL whilst working in *virtual* teams. Students must set individual learning goals in line with prior knowledge and experience whilst teams plan and mentor members to meet these goals. Results include analysis of discussion boards for team communication, student perceptions of their learning and development of teamwork and communication skills, and student final grades. The results from anonymous student learning surveys have been validated by a thematic analysis of unprompted student reflections.

2. Engineering education, technology, distance education and virtual teams

Brisk (1997) stated in a paper sharing his views on engineering education for 2010 that 'engineering education must fully exploit telecommunications and information technology to improve teaching and learning' and that 'engineering educators will move from simply passing on knowledge to becoming facilitators for students' learning'. He also argued that engineering education should exploit technology to provide distance education to achieve better use of resources and self-paced learning. In short, a move from traditional face-to-face delivery of content to not just distance education where material is delivered in a print form, but interactive *online education.*

Anderson's (2004) model for online learning, as shown in Figure 1, can be adapted as a foundation for online PBL. The model provides a framework for the interactions between multiple students and the academic facilitator via synchronous and asynchronous communication. Technologies can deliver resources and the content required to support individual student learning in a learning community and teamwork in a virtual environment.

The PBL in a virtual environment is an innovative strategy to deliver key graduate attributes necessary for engineering graduates to cope with future requirements of the profession. Reports from engineering accreditation bodies world-wide recommended a refocusing of engineering education to outcomes rather than process and included key graduate attributes of teamwork, problem solving, communication and life-long learning (IEEE 2002, Engineering Council UK 2003, Engineers Australia 2004, ABET 2007). These accreditation bodies now require engineering faculties to demonstrate that their graduates are meeting all these requirements in addition to the traditional math, science and engineering fundamentals.

Whilst delivering these skills in a traditional setting may require new teaching methodologies and a changing role for academics, current literature also goes on to suggest that desirable graduate attributes should be expanded 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 (Thoben and Schwesig 2002, National Academy of Engineering 2004).

To deliver the requirements of 'virtual environments' and electronic communication skills, technologies such as discussion boards, chat and email must be integrated into the delivery

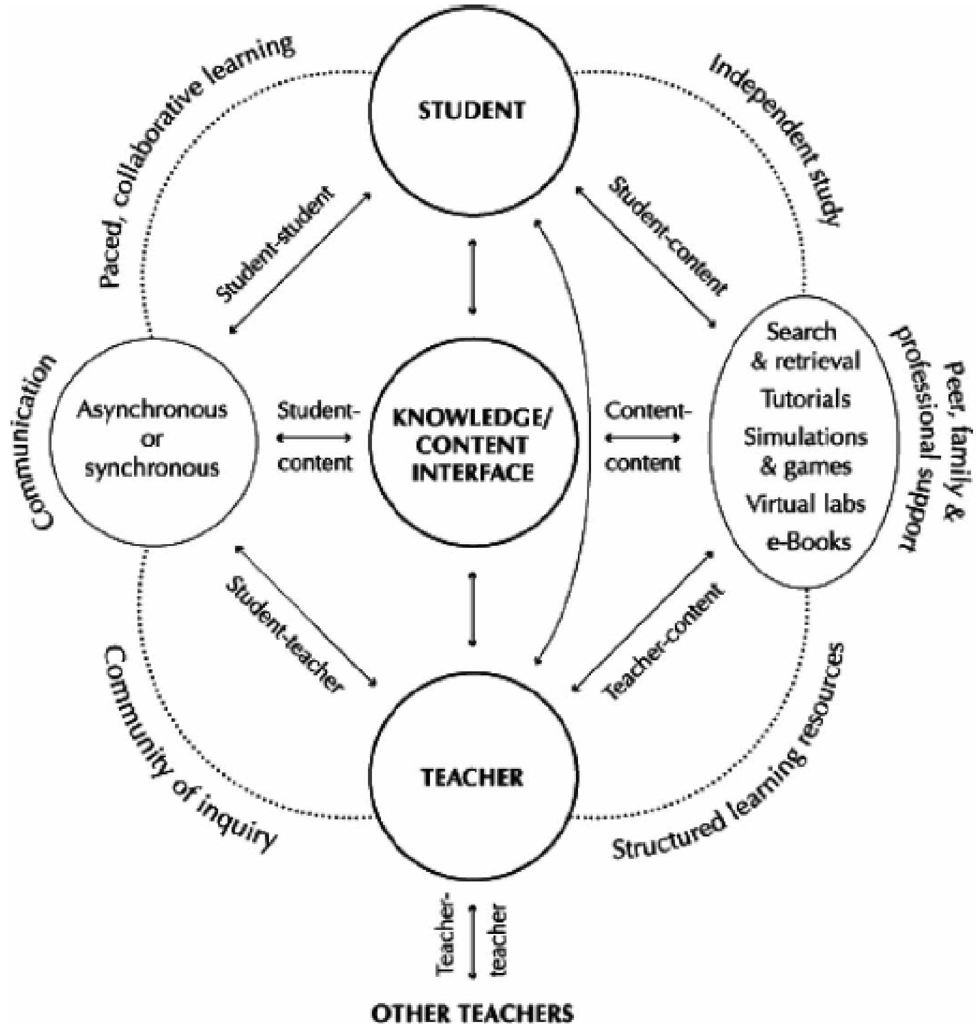

Figure 1. A model for online teaching and learning (Anderson 2004, pp. 49).

of meaningful content and cater to the individual learning style of students. Using fast developing technologies therefore provides opportunities and serious challenges to engineering and engineering educators.

Many of these technologies are already being utilised by universities to supplement existing courses and to tap into the new market of distance and online education. Likewise virtual teams and associated research are making their way into the education literature.

2.1. *Virtual teams*

A virtual team is the one whose members share a common purpose or goal, and work interdependently. Members are separated by distance, and therefore perhaps time, culture, organisational and international boundaries. They are linked only by communication technologies.

The literature focuses on virtual teams used by organisations, in a business setting. There is significantly less literature that discusses the use of true virtual teams in education, and in particular, distance education and PBL. Advantages of virtual teams in higher education, and in particular distance education, can be summarised as follows:

- Giving an opportunity to create a learning community, particularly for distance education students.
- Allowing students to work collaboratively to generate new knowledge, and thus creating opportunities for students to manage their own learning.
- Allowing for flexibility in work hours, place of work and study.
- Increased communication between sometimes isolated students.
- Individual participation and contribution to the conventional face-to-face team can be better measured, with the aid of computer technologies, to determine the effectiveness of the team.
- The skills learnt in a virtual team environment are in high demand in most organisations.
- Allows students to interact with individuals from many different societies, thus greatly improving their awareness and appreciation of culture in today's global world.

To realise these advantages, careful pedagogy, scaffolding and support systems must be in place. These also help to overcome the disadvantages that can be experienced in attempts at virtual collaboration.

Organisations that have embraced virtual teamwork discuss problems such as difficulty building and maintaining trust within the team and the loss of communication cues from facial expressions, voice tone and gestures. These difficulties have been overcome by at least an initial face-to-face meeting for team members and the use of communication technologies such as video conferencing. In our distance education context, neither of these opportunities are available and alternative resources and supports must be embedded within the pedagogy and assessment.

Additional difficulties for virtual teamwork in a distance education context include developing skills necessary for organising, running and facilitating teams and recognition by students that these skills are different from participating in face-to-face meetings and teams. Utilising the technology to actively engage students in the team can also obscure team problems, e.g. a lack of motivation to participate may be caused by a difficulty in using the communication technology. Likewise, a facilitator must be confident in the technology themselves and be able to discern technology problems from team problems. Facilitators must be willing to mentor, engage and interact with students on a team and individual basis dealing with a range of issues covering technology, team dynamics and individual learning.

The extent of student-to-student and academic-to-student interaction forms greatest difference between virtual and traditional teaching methods. In a strict lecture format, interaction at all levels is usually low. In PBL, interaction and collaborative learning in teams promotes problem solving and higher-order thinking skills. With the supported use of technology, these benefits can be translated to virtual classroom and distance students through developing a learning community, but the extent of interaction and the effects of this interaction on student learning needs further investigation.

3. A course structure to develop a learning community

3.1. *Background*

A comprehensive review of the faculty curriculum revealed the need to make significant changes in light of new requirements to embed core graduate attributes within the programmes. The conclusion of the review determined that these requirements could be best met by an integrated strand of engineering problem solving courses that employed a PBL approach. This would have the added benefit of introducing first year students to 'real' engineering; more effectively engaging our diverse student cohort, and reducing the early attrition from the programmes.

Four core courses were replaced with four traditionally taught courses. Each PBL course developed specific course specifications and implementation strategies to meet the required 'academic' and technical content and to also cater for the increasing skill set of the students. This paper will deal specifically with the first of the PBL courses, ENG1101 Engineering Problem Solving 1.

The introduction of PBL is not unique to engineering education. Hassan *et al.* (2004) reviewed and summarised the use of PBL world-wide specifically in engineering education. Whilst the summary is not exhaustive or complete it does demonstrate that PBL in engineering education is well-grounded pedagogically, has wide implementation (in universities in UK, USA, Canada, Australia and Asia) and many interpretations from single courses to the widely known project organised problem-based learning at Aalborg University.

The transition for PBL from the conventional face-to-face mode to distance education has been much slower. Taplin (2000) suggests that the predominant view, held by educationalists and researchers, is that PBL may not be appropriate for distance education due to the perceived need for face-to-face contact and direct student support mechanisms. Price (2004) indicates that PBL '...should not, in theory, be well suited to distance learning mode of study' due to the difficulty to adequately accommodate the PBL process and the variety of problems that could be identified for study. There are several examples of PBL used in a quasi distance education mode, where the internet is used for part of the course delivery but PBL's application to distance education and students' working in virtual teams, with no face-to-face contact, using a variety of electronic communication systems was largely undocumented.

Approximately 75% of the total faculty cohort study by distance education, i.e. off-campus and are located across Australia and the world. Students have no opportunity to meet (face-to-face) with other team members or the team facilitator. In moving to a virtual environment, the teaching team realised that they would have to spend considerable effort establishing a learning community for the students to engage with their team, their facilitator and other students in the course in line with Anderson's (2004) model for online learning. This community is necessary to achieve the benefits of teams that include the opportunity to collaboratively generate new knowledge, manage own learning and cooperate with others in the processes of negotiation and discussion. Robey *et al.* (2000) states that communities can develop despite distance and that a learning community should not be absent in the virtual learning environments.

For the distance students, working in a totally virtual environment with no face-to-face contact, the effort required in establishing a true 'team' for the students and, in addition, a 'learning community' was underestimated by facilitators. Initially teams focussed on the *outcome*, and hence students took on familiar tasks and roles that did not necessarily result in *learning*. The development of a structure to facilitate student learning and learning communities evolved over several semesters, and was promoted by a carefully planned assessment scheme designed to support and reward meeting individual and team learning goals via mentoring and critiquing.

3.2. *Course implementation*

All students are divided into teams of eight. Whilst this is larger than the current literature advises, the larger team size allowed for students to drop the course and not affect the viability of the team. Initially, the allocation of team members was somewhat random, simply ensuring that each team had a mixture of Associate Degree (2 year programme), Bachelor of Technology (3 year programme) and Bachelor of Engineering (4 year programme) students of all majors. In Semester 1 (2007), the teaching team trialled a 'skills audit' of students' prior knowledge and abilities for team formation to ensure teams have a solid basis for mentoring and peer learning within each team. This forms the basis for learning communities. The use of appropriate and supported communication technologies provides the medium for peer and collaborative learning to take place.

The USQ uses a standard learning management system (LMS) for all courses – WebCT Vista 4.0. This LMS offers facilities such as links to URLs, chat, discussion boards and electronic submission of both team and individual assessment items. The teaching team has shown through a longitudinal study validated by analysis of reflective portfolios that the LMS along with a carefully planned and implemented pedagogy can successfully and effectively develop a learning community for the students to work in and supports the construction of knowledge.

This formation of a learning community and the construction of knowledge for students is supported by team facilitators. Each team is allocated a USQ staff member to act as mentor to the team. The facilitator guides, not only the solution of a technical problem, but also helps teams through processes of team formation, conflict resolution and problem solving. This role of *facilitating* or guiding student learning, as opposed to lecturing, is often a large change for staff and staff attitude and uneasiness with this change is a major barrier. To support this change requires considerable institutional support for staff training by implementing regular professional development for facilitators.

3.3. *Assessment*

To evaluate the success of the course, team and individual student learning has to be appropriately assessed in line with the course objectives. The assessment strategy involves individual reflective portfolios, team solutions to the problems (submissions of both draft and final versions) and self and peer assessment. In addition, it also includes providing evidence of mentoring within the team, team reflections and strategies for team improvement and research methodologies.

An initial team assessment has teams formulate a 'Code of Conduct and Responsibilities' detailing roles within the team including the facilitator; rules the team will work by; team meeting *strategies* (not only times and but methods of ensuring meetings are effective and efficient given that distance teams do not meet face-to-face) and problem solving strategies. In *virtual* teamwork, it is necessary that place teams sufficiently emphasise on thinking through these issues. Throughout the semester, teams are encouraged through assessment to revisit these items, particularly the code of conduct, as move through the stages of team development. Initially, students find this a tiresome exercise but on reflection they acknowledge that it was one of the most important and helpful exercises.

In the reflective portfolios, which are individual assessment items, students must initially set individual learning goals and plan to meet these goals. These goals must be aligned with the course specifications and their prior knowledge, experience and skills. At the end of the semester, in the final portfolio submission students re-examine these goals, reflect and self assess their levels of achievement.

3.4. *Evaluation*

A number of instruments have been used to evaluate the course and determine if PBL and virtual teams can work and support students to meet individual and course learning objectives.

Student grades, where assessment is carefully mapped to course objective, is one indication of success. Similarly, student surveys also provide data on self-perceptions of learning, identifying course difficulties and providing feedback. Analysis of type and number of student communications and media used provides evidence on the collaborative learning happening within virtual teams. This learning is validated by analysis of the reflective portfolios. Where students have independently recognised skills of knowledge learnt has been mapped to several levels of learning in-line with Blooms taxonomy of the cognitive domain, although complete discussion of this data is outside the scope of this paper.

4. Results and analysis of student evaluation

In Semester 1 (2007), there were 116 day students and 188 distance students. These enrolment numbers are taken at the end of the semester. Numbers, particularly in the distance cohort, did decrease over the semester but mostly this occurred in the first 3 weeks of the course, and is typical for most first semester courses. There were 17 day teams and 31 virtual (distance) teams.

Figure 2 shows the average number of content specific postings (not social communications) per student to the discussion boards for the distance and on-campus cohort. Assessment items, both team and individual, were due in weeks 4, 8, 10, 13 and 15.

The first team assessment item, due in week 4, was preceded by a spike in the activity in the discussion board. This is also demonstrated in the time students spent communicating asynchronously with team members as shown in Figure 3.

There was a small difference in the average number of postings per student between the distance and on-campus students. Distance students, on average, made 49 posting, and on-campus students, 36 over the course of the 15 week semester. This represents only the asynchronous communication. Given that on-campus student have the opportunity to meet face-to-face, a larger difference was expected. Nearly all the virtual teams used additional synchronous communication, i.e. Windows Live Messenger (MSN) for team meetings as well as email. Whilst the LMS does provide chat rooms for teams, this was not utilised extensively due to server problems that made the chat rooms unstable and liable to 'freezing'.

The number of postings on discussion boards are slightly different from previous semesters where analysis indicated that on-campus students where making use of the technology more than distance students (Brodie 2006). The specific reasons for this change are not clear, but minor changes to assessment and, in particular, the timing of the assessment pieces might account for the differences.

Since the inception of the course, an evaluation study with three separate areas of investigation has been conducted. These include 'course', 'facilitator' and 'learning' evaluations, which were validated by analysis of reflective portfolios and focus groups. These studies have monitored

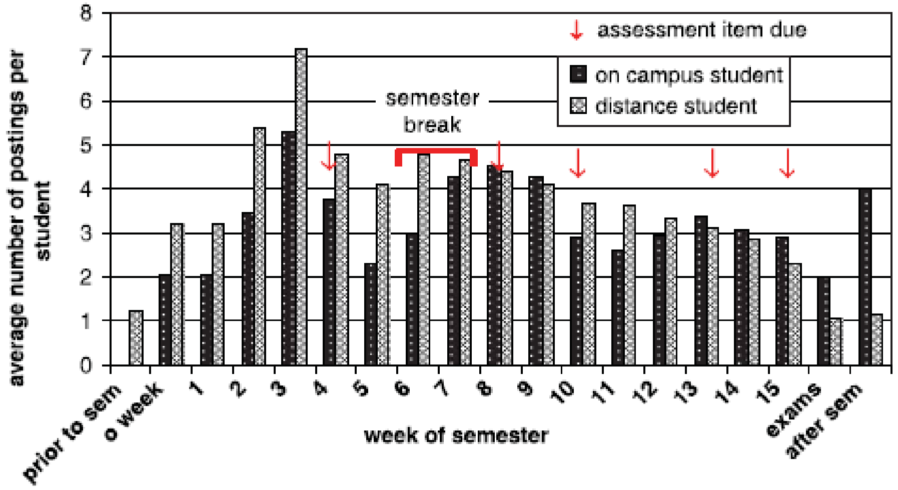

Figure 2. Use of discussion boards for distance and on-campus students.

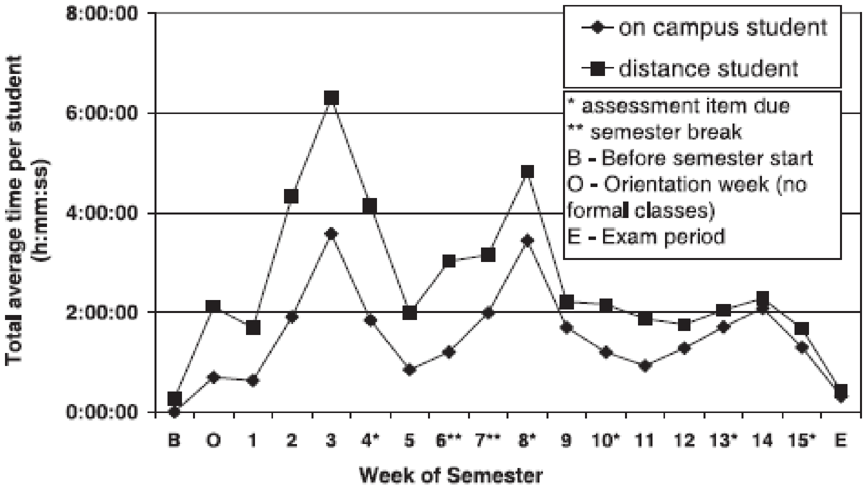

Figure 3. Time on asynchronous communication, e.g. team discussion board.

students' perceptions of their learning, the course and the guidance provided by the facilitator. The study has enabled the staff team to consistently and effectively improve resources, assessment and delivery methods. Study results have also been supported by qualitative information from student reflective portfolios.

In Semester 1 (2007), there were 168 responses to the course evaluation questionnaires out of a total of 304 students enrolled at the end of the semester. Of these, 277 were still active participants in the course, hence giving a response rate of 60.3%.

Figure 4 shows the results of the student (course) survey. It indicates that

- Seventy-six percent of the students believed that the course content was presented in ways that were realistic to the real-world of engineering and surveying, and this increased their ability to seek out suitable resources and assisted in their overall learning. Only 7% of students disagreed with this statement.
- Seventy-one percent agreed that the learning resources were adequate for the study of the course.
- Seventy-three percent agreed that this course helped them to make connections between other more theory-based courses and the real-world of engineering.
- Seventy-two percent of student agreed that they had 'learned a lot in the course'. This 'learning' was inline with individual learning objectives set with respect to prior knowledge and the course objectives.

Questions in the survey indicated that individual learning covered technical content, teamwork, communication skills, reflective practice and its benefit, recognition of prior knowledge of self and others and problem solving skills. Figure 5 shows results from the learning survey in response to the following questions:

- My confidence in my ability to learn independently was improved.
- The course increased my ability to work in a team.
- My problem-solving skills were enhanced.
- During the course, my appreciation of how my prior knowledge and skills and those of my colleagues can be used to solve a problem has been increased.

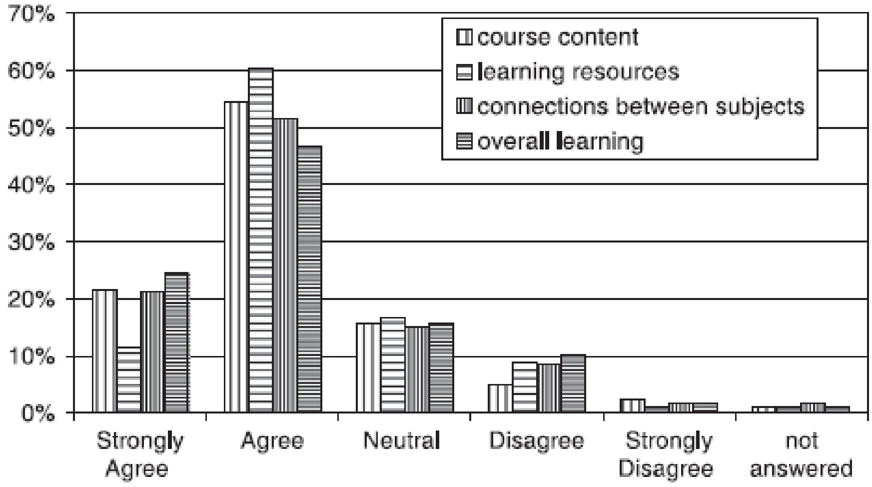

Figure 4. Results from course evaluation survey (S1 2007).

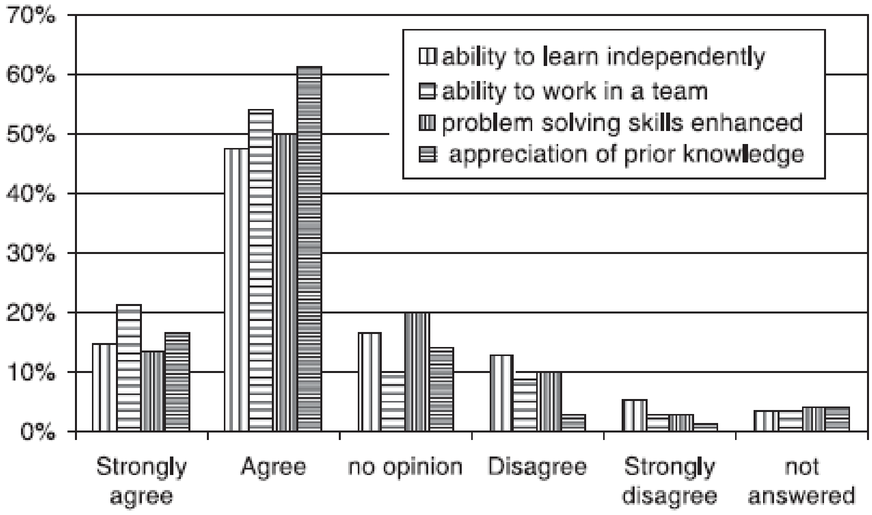

Figure 5. Results from learning survey (S1 2007).

The course also had other positive impacts. Approximately 73% of students believe that the course provided an opportunity for social interaction to occur, an opportunity that most distance students might not have had if it were not for this course using group work and being offered in virtual space through a reliable LMS. This has significance in providing a social support network for isolated distance students.

Sixty-eight percent of the Semester 1 cohort of students believed that the course had increased their computer skills. This was particularly true of the distance students who used the computer extensively for team communication – chat, discussion boards and email. Twenty-seven percent of students, on reflection, could also see the relevance of these skills for their future career as analysed by portfolio entries.

Qualitative evidence in the form of analysis of portfolios and feedback on anonymous evaluation forms also indicates that the implementation strategy is meeting course objectives. These include, in addition to teamwork and technical content, an appreciation of diversity within a team, peer mentoring, individual learning goals, life-long learning and helping students' transition to university as indicated by a thematic analysis of reflective portfolios.

The continuous study has also informed our problem development and assessment strategies. Sabburg *et al.* (2006) reported on the success of teaching physics concepts through the PBL methodology used in ENG1101. This investigation concluded that the problems offered by the course had most benefit for students with less than 1 year of physics in year 11 and 12 (at a school level). This is a significant proportion of our distance cohort; however, we must also cater for the students with a more traditional entry route to the programme, i.e. year 12 physics.

Whilst these students can play a mentoring role within teams, we also need to cater more specifically for their learning goals. The investigation also shows that the problems are pitched at the physics concepts in which student have the greatest prior knowledge. This process of monitoring student learning and engagement has directly informed the development of the course and the problems the student teams work on.

A small selection of problems and their corresponding learning objectives are briefly described in Table 1. In addition to technical learning objectives, inherent in all problems are technical report writing and professional communication practices, mentoring and sharing of knowledge across disciplines, cultures and prior experience. Recently, problems have centred on the Engineers without Borders Challenge, which gives more scope for interdisciplinary work and cultural context (Bullen *et al.* 2007; Brodie 2008).

Figure 6 shows the final grades of the semester for the distance and on-campus cohorts. Students are graded from high distinction (HD) to fail according to the total percentage achieved over the semester in all assessment items. Cut off percentages are preset according to university regulations, and are shown in brackets after the grade. Thus to be awarded a HD, a student must have achieved 85% or greater. The fail grade is divided into three categories as shown in Table 2.

The semester results indicate that the distance students working in virtual teams do not achieve significantly different grades than the on-campus students ($p > 0.05$), despite the potential for communication difficulties and the virtual aspect of team work. This could be due to a number of factors including increased motivation to study as the majority of these students are currently employed in the engineering or surveying professions. On average, they are also older and have a more mature approach to study.

However, distance students do struggle with the demands of the course. In particular, they comment on the loss of flexibility to timetable of their study according to work and other commitments, and the reliance on a computer with internet access. Many distance students are currently employed in remote locations, often working demanding rosters, i.e. 3 weeks on, 1 week off. With traditional courses, they can structure their study timetable to work around this. However,

Table 1. Problem outline and learning objectives.

Problem scenario	Main learning objectives
A baby is found dead in a stolen car (in Australian summer). Teams are asked to provide technical advice to a legal team working on the case	Heat, temperature, experimental methodology, statistics, errors and uncertainties, ethics and the role of engineers in society
Predicting the life span of an old timber bridge with decaying wooden pylons	Force, pressure, basic statistics and dynamics, statistics, errors and uncertainties, Australian standards
Redesigning a failed winery to become a boutique brewery and orange juice factory (to use as much existing equipment as possible)	Fluid flow (laminar, turbulent, in pipes, viscosity etc), design principles including costing
Maintenance of an unsealed road on a sand island	Force, pressure (with a view to limiting types of vehicles and tyre pressures to minimise damage), Investigation of surfacing options, installation and ongoing maintenance costs

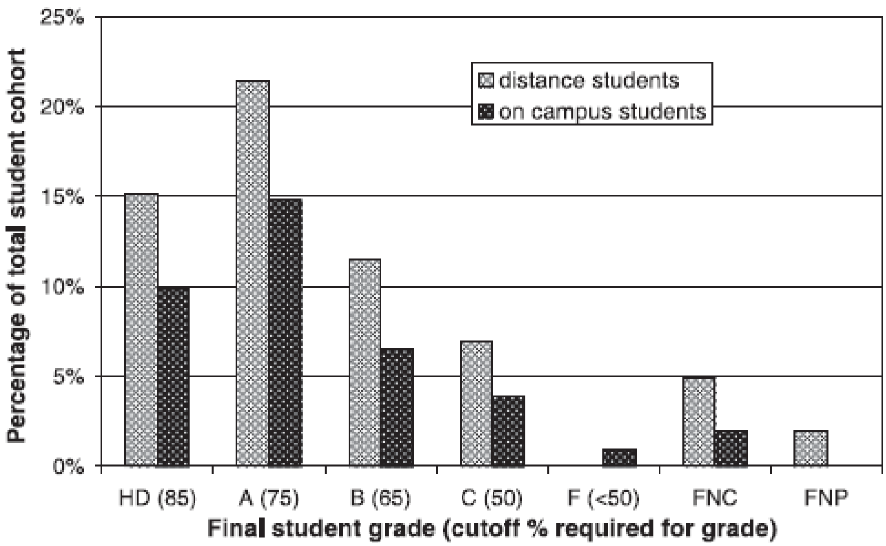

Figure 6. Final student grades (S1 2007).

Table 2. Description of possible fail grades.

Fail grades	Description
F – fail, <50%	Student completed all required assessment items but did not achieve a total of 50% or greater
FNC – Fail, Did Not Complete	Student did not submit all required assessment items
FNP – Fail, Did Not Participate	Student was still officially enrolled in the course but did not submit any of the required assessment items

in this course they must have regular contact with their team. Whilst teams are encouraged and supported to find times and meeting strategies that cater for all student needs, obviously not all circumstances can be satisfactorily met. Hence, the distance students have higher numbers of FNC and FNP grades, but this is not significantly different from other courses with a traditional delivery method indicating it as a phenomenon of distance education and not the pedagogy of the course.

5. Conclusion

In 2001, the Faculty of Engineering and Surveying embarked on an ambitious plan to deliver a PBL course to students working entirely in virtual space. These students communicate entirely via email, chat and discussion board and have no face-to-face contact either with other students or the team facilitator. Not only was this successful but research now shows that traditional on-campus students are embracing the flexibility offered by virtual teamwork. This development, extending current theories of online education, e.g. Anderson (2004) and the associated development of resources such as staff training and relevant curriculum now offers the opportunity for students to interact globally, opening avenues for learning opportunities with students from overseas universities. For a geographically isolated country like Australia, learning and working with international students would be a worthwhile exercise benefiting all participants.

The teaching team has successfully developed a learning community that engages the student, and supports the construction of their own knowledge. It has been demonstrated that PBL can be delivered to engineering and surveying students, working in multidisciplinary and diverse teams, in a totally virtual environment. Teams working without any face-to-face contact either with other team members or academics (facilitators) can construct their own knowledge in line with specific course objectives. The aim of developing graduate attributes of teamwork, communication and problem solving skills has been successfully met. In addition, key academic content is being delivered along with other desirable attributes such as life-long learning; appreciation of cultural and educational diversity within a team; working electronically and an appreciation of prior knowledge and experience held by the individual students and as seen in others.

The continued development of the course, associated staff training and investigation and evaluation of results is providing significant support for student learning, and has the potential to engage engineering students in truly global teams.

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About the author

Lyn Brodie is a Senior Lecturer in the Faculty of Engineering and Surveying. Her research interests include engineering education, PBL, assessment and the first year experience. She is a board and founding member of the USQ Teaching Academy and Director of the Faculty Engineering Education Research Group. Lyn was the academic team leader for the teaching team, which successfully designed a strand of PBL courses for the faculty. These courses are unique in that they

deliver a team-based PBL course to distance education students of the faculty. These teams meet and work virtually to solve opened engineering problems. Her work has been recognised through several awards including a University Award for Design and Delivery of Teaching Materials, Carrick Institute Citation and Australian University Teaching Award for Innovation in Curricula Learning and Teaching, USQ Associate Learning and Teaching Fellowships (2008 and 2009) for curriculum and assessment development and recognition from the Australian Association of Engineering Educators for innovation in curricula. On several occasions, Lyn has been a visiting Associate Professor to the University of Hong Kong – Centre for Advancement of University Teaching, consulting in both PBL and online curriculum development and assessment.

Int. J. Engng Ed. Vol. 24, No. 1, pp. 153–161, 2008
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Assessment Strategy for an Engineering Problem-solving Course*

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The operational aspects of an assessment strategy for an Engineering Problem-Based Learning (PBL) course initially involved an audit of existing and varied student skills and competence to facilitate their effective deployment into well-balanced teams. This balance encourages effective mentoring within and between teams. The strategy included summative and formative assessment, the former being tailored to individual students' existing skill levels. Throughout, the emphasis is on advancement of skills and competence rather than simply achieving a minimum standard. The strategy provides the flexibility for equitable assessment of students with different initial skills and competency, which proves particularly relevant to students studying in the distance mode who may have considerable professional experience and advanced skills and competence in some areas. By tracking progress, students develop an individual portfolio of achievements that can be continued throughout their study programmes and professional lives.

Keywords: problem-based learning; engineering education

BACKGROUND

SINCE 1967, when it started, the University of Southern Queensland (USQ) has developed an international reputation for offering high quality academic programmes in the on-campus (internal), off-campus (distance) and online delivery modes. It shows in winning the Australian Good Universities Guide University of the Year Award 2000–2001, winning the Commonwealth of Learning Award of Excellence for Institutional Achievement at the third Pan-Commonwealth Forum on Open Learning in Dunedin, New Zealand in July 2004, and being chosen as the inaugural winner of the 1999 International Prize for Excellence in On and Off Campus Leadership and Innovation by the International Council for Open and Distance Learning. In October 2005, the USQ problem-based learning (PBL) academic team won the Australasian Association for Engineering Education Award for Excellence in Engineering Education for curriculum development in the PBL courses, was chosen as a 2005 finalist in the Australian Award for University Teaching, and won a Citation for Outstanding Contributions to Student Learning in the 2006 Carrick Australian Awards for University Teaching.

The university operates several satellite campuses throughout the world, with the principal one at Toowoomba, approximately 130 kilometres west of Brisbane, Australia. The Faculty of Engineering and Surveying (FoES) is one of five faculties at the university.

In recent years, the technical ability of engineering graduates in general has been questioned, with most of the criticisms relating to a lack of skill and competence in core areas of basic mathematics and science, and issues such as retention of knowledge and inability to transfer basic knowledge to real-life engineering scenarios [1]. As well as technical competence, it is also important for engineering graduates to acquire a range of generic, or transferable, skills that will allow them to operate effectively in a future professional environment. Unfortunately, it has been recognised that engineering education does not completely address gaps in critical generic skills [2]. Deficiencies have been identified in the ability to work in multi-disciplinary teams, in the ability to work in a global virtual environment, in digital communication skills [3]; in ability to adapt to change and solve problems in unusual situations, in ability to think critically and creatively and in a commitment to continuous lifelong learning and self-improvement [4].

FoES recognised that educational approaches were required that would address these deficiencies and provide engineering graduates with the enhanced skill and competence necessary to carry out their professional responsibilities in today's virtual global environment. The use of PBL provided a mechanism to do this and demonstrate that participants had developed the necessary professional skills required by the surveying and engineering professional accreditation bodies [5, 6]. It was also an opportunity to establish an innovative teaching practice in engineering education at USQ that was outside the dominant transmission model normally used in universities [7], and that recognised that learning may be more effective when undertaken in groups [8].

* Accepted 8 October 2007.

Consequently, in 2001, FoES introduced a problem-based learning (PBL) approach for several courses to ensure that graduates developed problem-solving skills and the ability to work effectively in multidisciplinary teams. This was consistent with the university's vision that graduates be well advanced in discipline expertise, professional practice, global citizenship, scholarship and lifelong learning. The PBL approach was also consistent with the faculty's philosophy that engineers and surveyors (spatial scientists), being predominantly problem solvers, must be able to use the latest technology to find creative solutions to multidisciplinary problems throughout their professional lives. It was considered that PBL would be a preferred strategy to achieve this since it purposefully creates situations from which motivated learners should not be able to escape without broadening their perspectives and acquiring new skills [9].

Students learn to work together in multidisciplinary teams to solve problems by collaboration [10] using a system similar to the interdisciplinary PBL platform described by Acar [11]. Rather than project-led education (PLE) or project-organised learning (POL), which involves projects supported by theory-based lecture courses [12] and usually focuses on team-based activity relating to large-scale open-ended problems [13], at USQ teams are given a number of smaller-scale open-ended problems to solve; hence the strategy is truly PBL.

The PBL strand consists of a series of four consecutive courses, with an additional final year research project seen as the capstone. The main objectives of the first two PBL courses, which are compulsory for all students in the faculty, are to develop the fundamental skills needed for participating effectively in multidisciplinary teams and to expose students to a wide range of problem-solving tools. Subsequent problem-solving courses are designed to expand and improve these skills, and to impart fundamental technical content in several discipline areas.

STUDENT DIVERSITY

At USQ students may elect to study in the on-campus (internal) or off-campus (distance) modes. Distance students study from various geographic locations around the world, which enriches the learning experience with cultural diversity, but also creates its own set of logistical problems. These are further complicated in the problem-solving courses by the fact that students in the same team may be studying at Associate Degree (two year), Bachelor of Technology (three year), Bachelor (four year), or Double Degree (five year) levels. Students enrolled in the PBL courses may also be studying different majors offered in the faculty: Agricultural, Civil and Environmental Engineering; Electrical Engineering, Electronic and Computer Engineering; Mechanical and Mechatronic Engineering; Surveying and Land Information. Because of different disciplines, different study modes, and different programmes, existing knowledge, expectations, level of interest and other cultural and personal differences, the difference in learning objectives of each individual student can be profound, and this can complicate the assessment process. It is interesting to note that most of these elements have been identified by others as core principles that need to be considered when designing education for adult learners [14].

Most students studying in distance mode do so because they are already employed in some capacity in industry. Because they are already in the workforce, many have different skill levels and personal competency attributes compared to internal students, and their '*learner context*' [15, 16] will be quite different. There is also a possibility of high school leavers not yet possessing the skill set to truly be independent learners. It is clear that during the setting of objectives and assessments there needs to be some recognition of prior learning or skill, particularly for those students who have already developed significant skills through experience in the work force. And this must be done in an equitable manner so as not to advantage or disadvantaging any group or individual. It seems logical that, to do this effectively, the learning objectives and assessments should be, at least partly, individualised for each student.

It is also recognised that peer-assisted learning (mentoring within teams), which can have a motivating effect on the teams [10], and mentoring between teams, must be encouraged and rewarded. Gibbings and Brodie [17] reported the development of an assessment strategy for the first of the PBL courses offered in FoES at USQ to overcome identified shortcomings, and to effectively assess achievement and advancement of skills and competence, in a way that recognises diversity and prior skill and learning, and that does this in an equitable manner.

ASSESSMENT—STRATEGIC ASPECTS

Students enrolled in ENG1101 are placed in teams of up to eight members. Each team is allocated a staff member to act as a facilitator whose role is explained by Gibbings and Morgan [18, 19]. The facilitator is also responsible for assessing his/her teams, although others have cautioned against this since there can be a conflict in roles in being a judge and facilitator at the same time [12]. To help alleviate this conflict, an examiner is appointed who has overall responsibility for administration and assessment of the course, and staff training and coordination. Consistency of assessment between facilitators is achieved by staff training and documentation of requirements in a course facilitator's guide [18]. The examiner performs a moderation role to further promote consistency between facilitators and to ensure that due diligence has been applied to the assessment process.

A search of the literature reveals a plethora of assessment methods employed in engineering education today. It is commonly agreed that the assessment methods should be compatible with the learning objectives and consistent with the general course pedagogy. With respect to PBL this means assessment to establish the individual's knowledge, skill and competence rather than testing for factual knowledge [20].

While the effort to improve engineering graduates' skills and competence in areas that have been identified as deficient [3, 4] are admirable, many engineering programmes encounter difficulties with assessment of these attributes, particularly portfolio assessment [21]. Though the traditional written assessment still appears to be the dominant method of assessing students in engineering courses, it is of questionable validity as a means of assessing students' ability to apply technical skills and knowledge to real-life situations, and even less valid for assessing the real-world skills or 'soft skills' [22], mentioned earlier, that engineering graduates are expected to perform in their professional work [23]. For PBL assessment to be authentic it must embody a range of non-traditional assessment techniques. It must also be an integral part of the actual course work; a philosophy that applies to any course that employs a constructivist paradigm [23], as ENG1101 does, if the assessment is to be consistent with the pedagogy.

A frequent criticism of the assessment of team projects is that individual students in the teams often receive the same group mark irrespective of their contributions [23]. Peer assessment has been successfully used in the past as a means of discriminating individual performance within groups by multiplying the team mark by an individual multiplier [23]. The individual multiplier is arrived at by peer evaluation of the individuals' contribution to the team's performance [23]. Reflective reports or portfolios have also been used to encourage students to reflect on their learning and the group's processes [23].

In accordance with the recommendation of Frank and Barzilai [10] and others [for example, 23], the assessment strategy in ENG1101 is entirely in accordance with the 'constructivist paradigm' [15, 24], and the 'collaborative learning' paradigm [9, 25]. The assessments are also used as an incentive to encourage desirable behaviour, such as mentoring within the teams and mentoring between teams, and to discourage undesirable activity. In accordance with this philosophy, Gibbings and Brodie [17] reported on a strategy to update the assessment scheme in the first PBL course to account for the following:

- Some students in teams may want to do all of the work themselves and not share the workload with other team members. This may occur for several reasons, the most common is that the 'high achievers' don't want to rely on others to carry out tasks that could ultimately affect their own 'marks'.
- Some students may not want to participate at all, or contribute very little to the team effort. The assessment strategy ensures that the individual only, and not the team, is disadvantaged in this case. Note that contributing little or nothing to the team's project, and then trying to claim a disproportionate contribution and share of the project mark, falls into the broad definition of plagiarism [26] and cannot be tolerated.
- Incentive is provided for students to learn new skills. For example, under the earlier assessment system, those who were proficient at a particular skill (for example, report writing) would tend to adopt that role in all projects because that gives the team its best chance of receiving a 'good mark' for the projects.
- Real incentive is provided to encourage mentoring within the teams. Assessment also requires that teams provide evidence of such mentoring—if it is important, and students need to learn it, and it is in accordance with learning goals, then it should be assessed [27, 28].
- Incentive is provided to individuals to encourage the appraisal of other teams' proposals (mentoring between teams) and to provide appropriate feedback to these teams. Evidence must also be provided by teams of what action was taken as a result of this feedback. This mentoring and feedback by peers, or 'trial and error', is considered by Savin-Baden [15] and Acar [11] to be an important part of learning, and is also considered to be a strong motivator for the teams involved [10]. However, to be effective, students are made aware that this feedback is not used as a differentiation tool for formal assessment. In fact, all assessment criteria, both formative and summative as recommended by Acar [11], are clearly communicated to students to ensure the assessment strategy has the desired effect [15].
- Personal reflection by the individual is encouraged, and direction is provided to students on the requirements of an individual portfolio of reflections. The assessment scheme was changed to place less emphasis on the team mark for the projects and on the project solution, and more emphasis on what the individual has learned, and how and why the individuals' skill and competence levels have increased.

In ENG1101 students had in the past been assessed on team projects with the project marks being modified to an individual mark based on peer and self-assessment reports [29]. Some weaknesses of this approach were noted and these were largely due to not providing appropriate incentive, through assessment, for the types of behaviour that were considered desirable such as collaborative learning and mentoring. Others such as Savin-Baden [15] have also recognised that assessment could undermine collaborative learning and the team process that is necessary in PBL.

The revised assessment strategy described by Gibbings and Brodie [17] places the emphasis on advancement of skills, and learning new skills, rather than just achieving a minimum standard. This was achieved by each student individually negotiating, and being assessed on [as suggested by 30], objectives, goals and targets for each project within the PBL course. The direction was therefore determined by the learner within the constraints of the problem to be solved, which is seen as desirable for adult learning [24].

This approach recognises that not all students will have the same learning objectives, nor will they be faced with the same issues (particularly considering the student diversity mentioned earlier), so it is necessary to be flexible [31]. It also recognises that true 'engagement' can come from students negotiating their own learning objectives and constructing them within their own context. This should lead to a sense of 'ownership' and enhanced motivation [31].

This assessment strategy provides students with guidance and encouragement to:

- take responsibility for their own learning: this is generally referred to as 'constructive alignment' [32, 33], or 'constructivism' [24];
- identify their own individual learning objectives that allow them to extend and build on existing skill and competence;
- develop suitable strategies to achieve these individual learning objectives;
- provide a mechanism for students to monitor their own progress throughout the strand of PBL courses.

TEAM SELECTION

Initial Skills Audit

The assessment method reported by Gibbings and Brodie [17] involves the initial auditing of existing skills and competencies of each student and continual skill assessment to map student's progress throughout the full suite of PBL courses. The skill assessment is used to allocate students with different levels of skill in various fields into well balanced teams, which in turn encourages mentoring within the teams.

Questions are written in easy to understand language, worded to overcome potential problems with cultural diversity and expressed in terms of how well students believe they can perform certain defined activities. These initial skill audit questions are also linked to the course objectives wherever possible. For example, part of a course objective is: 'Communicate information in a professional manner'. A related task that describes one of the skills that students are expected to achieve is: 'Prepare a professionally written technical report in English on a word processor'. The corresponding questions that appear in the initial skill audit are:

1. How would you rate your ability to use a word processor?
2. How would you rate your English expression, grammar and spelling?
3. How familiar are you with standard referencing styles?

Students grade their performance of each of these activities by checking a box against a 5-point scale where 1 denotes little or no knowledge, and 5 denotes experienced and expert in all aspects.

At this stage there is a possibility that some students may either underestimate or overestimate their skill levels. Consequently students are advised that:

- the audit is not part of any formal assessment;
- if students underestimate skills in a particular area, they may be placed in a team with someone else, who is supposedly strong in this same area, who may be charged with the responsibility of mentoring them in this skill. This will be ineffective and inefficient for both parties, and their team will be disadvantaged due to not having well balanced skills;
- if they overestimate skills, then they may be asked to mentor another team member in this skill area. In this case mentoring won't be effective and they and the team will consequently be penalised.

ASSESSMENT—OPERATIONAL ASPECTS

Assessment Scheme Overview

The assessment scheme involves both individual and team assessment, and a mix of summative and formative assessments. Figure 1 shows how these assessments are linked and how each element contributes to student's individual marks.

The assessment scheme involves five main sections that contribute to the student's individual mark:

- communications log;
- team submission of project reports;
- peer assessment of contribution within the team;
- individual contributions;
- individual portfolio of set-work and individual reflection on learning.

Communications log

Management of the course is largely through use of the WebCT Vista ©™ e-learning system. This platform provides access to web-based material, online quizzes and surveys, and communication facilities such as electronic mail, discussion boards and synchronous chat sessions. Students are required to use the discussion boards for most of their communications within groups for the first few weeks, after which time they may negotiate within their teams for other alternative commun-

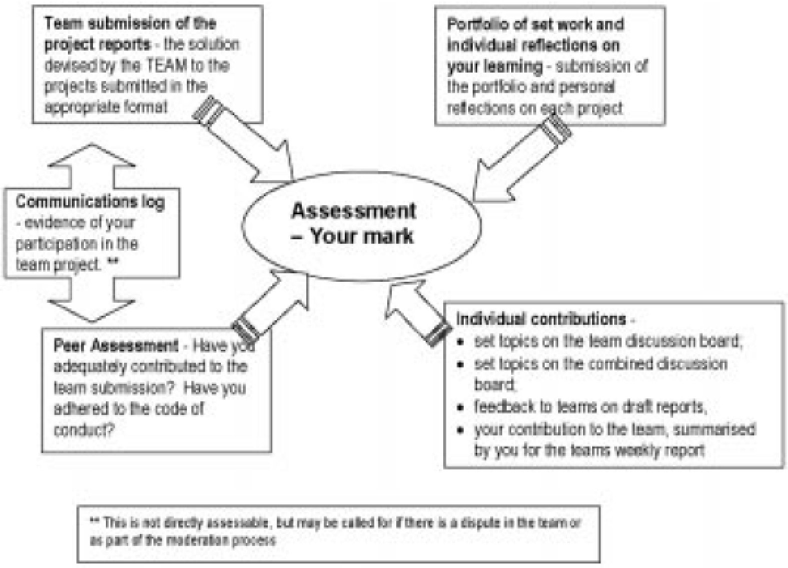

Fig. 1. Overview of assessment scheme.

ication methods if they prefer. Each team has their own discussion board, which only they and the course administration staff can access. In addition, groups of four or more teams are also given access to a combined discussion board to facilitate between-team communications.

Students' contributions to both team and combined discussion boards are assessed. It should be noted though, not all contributions to the discussion boards form part of the summative assessment. Threads, messages and replies are managed and assessed by facilitators having access to (and contributing to) these discussion boards on WebCT. This provides an ideal mechanism for facilitators to monitor individual and team progress.

Team project reports

Before the first project is released, students are required to undertake an online quiz dealing with fundamental technical concepts. This is used to focus attention on the technical skills and competencies that should be gained from the projects. This assists students to identify their own personal learning goals for the project, and provides a base for comparison to determine to what extent their learning goals were achieved.

Students are required to negotiate suitable roles within their team for each project. This is in accordance with research that suggests that adult learners want control over learning based on personal goals, and that learning will increase as a result [14]. There is convincing evidence that those who take some initiative and become involved with their own learning in this way, will learn more than those who take a more passive approach [34].

Each team is required to prepare a plan that includes each individual's role and responsibility within the team, and their learning objectives. This approach recognises that not all students have the same learning objectives, nor are they faced with the same issues (particularly considering the student diversity mentioned earlier), so it is necessary to be flexible [31]. It also recognises that true 'engagement' can come from students negotiating their own learning objectives and constructing them within their own context. This may also lead to a sense of 'ownership' and enhanced motivation [31].

Teams are required to publish preliminary project reports to the combined discussion board by a designated date. Assessment marks are awarded for work done to date, and members from other teams and facilitators have the opportunity to provide feedback on what has been submitted. Individuals are given formal credit for this activity as part of the summative assessment strategy.

All team project reports are assessed by their facilitators using the same marking rubric. Constructive feedback is again provided to the teams at this time. Consistency of assessment between facilitators is achieved by staff training and documentation of requirements in a course facilitator's guide [18]. The examiner performs a moderation role to further promote consistency between facilitators and to ensure due diligence has been applied to crediting individual skills and competence.

Teams then have the opportunity to alter their submissions in light of the feedback and resubmit the final project report to a course assignment drop box in WebCT. This final submission is again formally assessed, and must provide evidence of changes or actions taken subsequent to the feedback outlining how and why the initial report was improved as a result. This reflection, opportunity to respond to feedback (and to carry out informal assessment of other's work by providing feedback), and collaboration within the team, are seen as critical to the learning process [35]. In this way, the assessment becomes an integral part of the learning process, and should encourage students to engage in the learning tasks associated with the problem solution, which is one of the most fundamental tasks of education [36].

Peer assessment of contribution within the team

One of the first tasks required of the teams is that they negotiate, agree and document a team 'code of conduct'. This sets out roles and responsibilities for all members of the team and includes what is expected of the facilitator. Amongst other 'rules', penalties will be detailed for non-participation, or less than acceptable contributions, by individuals.

At the completion of each project the teams are required to agree and report on the contributions of individuals within the team. This is normally expressed as a percentage of the team mark that each individual should receive. Of course there is an appeal mechanism for individuals who feel the team has not allocated them what they consider an appropriate percentage, but experience has shown that this is very rare, mainly because the 'rules' were agreed by the team at the beginning and all individual team members know exactly what to expect. The team mark for each project is multiplied by the stated individual percentage to arrive at an individual mark for each team member.

Individual contributions

The individual contributions comprise two separate parts:

- submissions and contributions to the team efforts;
- submissions and contributions to individual tasks.

Contributions to the team effort are evidenced by postings to the discussion board and include:

- contributions to the team weekly reports (posted to team discussion board);
- contributions to initial activities such as team code of conduct, team communication strategy, project key concepts, timelines (posted to team discussion board);
- feedback to other teams on their project draft reports (posted to combined discussion board).

Individual tasks that don't affect the team include:

- participating in an initial project online assessment to focus attention on technical skills (discussed in the 'team project' section of this paper);
- postings in response to selected topics for discussion (only some contribute to summative assessment), for example, teamwork, team dynamics, leadership, conflict resolution, etc. (both team and combined discussion boards);
- individual portfolio (detailed in the 'individual portfolio' section of this paper).

Individual portfolio

Students in ENG1101 are required to maintain a portfolio of set work and individual reflections on their learning within the course. Portfolios have been recognised by many engineering accreditation bodies around the world as offering an acceptable measure of student attainment of graduate attributes [37–38]. Individual portfolio assessment in ENG1101 depends more on the process, reflection and self-evaluation rather than on specific quantitative criteria [24]. And the emphasis is on advancement of skills, and learning new skills, rather than simply achieving a minimum standard. This is achieved by each student individually negotiating, and being assessed on, objectives, goals and targets for each project within the PBL courses. The direction is determined by the learner within the constraints of the problem to be solved, which is seen as desirable for adult learning [24].

To assist students with this task, a comprehensive list of learning objectives (normally written as tasks that can be performed) is provided and each of these is linked to one or more course objectives. These are presented in a spreadsheet and students are encouraged to use this as the beginning of what will become a portfolio of skill and competence.

For example, one course objective is 'Identify, analyse, discuss and apply elements of teamwork that affect team success'. The corresponding learning objectives for students to choose include:

- Identify necessary leadership qualities.
- Effectively lead a team.
- Analyse the dynamics of a team.
- Effectively negotiate with others within and outside a team.
- Seek and evaluate contributions of other team members.
- Utilise prior knowledge and experience of team members from diverse cultural and technical backgrounds.
- Establish and document roles and responsibilities within a team.

Students are encouraged to add their own objectives to supplement those provided.

Teams are required to submit a plan, similar to the system noted in Isaacs [35] for the project, incorporating each team member's individual learning objectives, and these must all be agreed by peers within the team. A constraint is that these individual learning objectives must be consistent with course objectives (and graduate attributes) and be aligned to areas in which the student requires improvement (rather than an area of existing high level skill and competence). This encourages the development of new skills since the students are assessed on these—teams whose plans demonstrate the development of new skills by its members will potentially receive higher marks. By tracking progress in the achievement of objectives, the students can maintain an individual portfolio of achievements throughout the suite of PBL courses, and potentially through to, and even past, graduation, as is recommended by recent literature [21, 39]. Because this improvement by individuals and the team collectively is formally assessed, mentoring within the teams is encouraged.

Each student's final reflection on the projects includes a personal assessment of the level of achievement in these skills. This is submitted with the individual reflections in the final project report and also forms part of the student's individual portfolio. They are able to judge how well they have performed in these areas after receiving feedback on their preliminary team reports. As this process is carried out after each project, students can monitor their progress in each of these skills throughout the course.

ANALYSIS OF ASSESSMENT SCHEME

This strategy for formal assessment of objectives provides documentary evidence that each student has achieved the minimum standard expected of a graduate as dictated by PBL course objectives, programme attributes, accreditation bodies, professional associations and defined graduate attributes. Stakeholders can only be given an assurance that the required graduate attributes have been attained if there is some evidence to point to their development by the graduates [40].

The assessment approach, involving tailoring to individual students' existing skill and competence levels, also provides the flexibility for equitable assessment of students with skill levels that are already well above the required minimum standard. Students who may have highly developed skills in some areas, as is often the case with distance students who are already in the workforce, can now be assessed on an equitable basis with students who may not have the same starting level of skill.

In essence, students develop an individual log to record their progress in skill and competence achievement. This approach is similar to what has been adopted by several professional associations in Australia that have the responsibility, often under legislation, of assessing individual members against national competency standards before granting professional registration. It has also been successfully used in various forms in education, for example, Albert and Morrison [41] and Harley [42], although it does not appear to be common in engineering or technical education. The log or portfolio provides a structured record, in condensed but specific form, of the student's progress in the development of skills and competence.

The skills and competencies assessed in the portfolio are directly linked to course objectives and therefore graduate attributes. This portfolio of skills is essentially a professional development audit and provides a status report of the students' progress at any particular time.

The skills portfolio demonstrates, and formally records, the practical realisation and advancement of skills and competencies. Evidence of achievement of skills and competence is presented and assessed in the student's own portfolio. Although this is essentially self-assessed, there are several ways that students can demonstrate the achievement of a particular skill level:

- Peer assessment/agreement and documentation of performance during the conduct of the team projects (usually in accordance with the peer agreed team roles and predetermined individual learning objectives).
- Evidence of effective mentoring of others within the team in these skills.
- Individual requests supported with documentary evidence of conduct during the project (this may be used by students who enrol in programmes with advanced standing).

This process records and tracks the student's achievement of skills and competencies in the identified skill areas. This process allows facilitators to recognise existing areas of specialisation but still provide documentary evidence of the achievement of skills and competencies. It also allows the examiner to identify areas of specialisation where a student has achieved higher than minimum levels of skills, knowledge and competency, since the process provides a mechanism whereby achievement above the minimum required can be recognised, assessed and credited. This encourages students to attain skills and competencies in excess of the mandatory requirements for graduation.

The formal assessment strategy also encourages students to develop new skills in areas where they have previously identified a weakness. The opportunity for feedback and mentoring within and between teams is enhanced. Formal credit is given to individuals for providing feedback to other team's work. Both inter-team and intra-team mentoring is assessed in the individual portfolios. It is believed that this increased mentoring will have the added advantage of encouraging better intra-team communication and should therefore foster better teamwork.

CONCLUSION

The strategy of an initial skill and competency audit for students offers several major benefits. It allows the tailoring of assessment to individual needs and caters for prior learning and existing skills. This enables more effective use of student diversity and encourages mentoring within the teams.

This strategy provides a mechanism to allocate individual assessment marks from team projects. The summative assessment provides the flexibility to assess, on an equitable basis, the attainment of skills and competencies at a higher level than the minimum requirements because it rewar increase in skill levels and development o skills, rather than assessment against some p termined minimum criteria. This enco students to direct study and energy into which will most benefit their future and p sional careers.

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IJEE 2096

Int. J. Engng Ed. Vol. 00, No. 0, pp. 1–11, 2008
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Team-Based Learning Communities in Virtual Space*

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This paper examines how a learning management system (LMS), coupled with sound pedagogical approaches, is used to develop learning communities for students undertaking a problem-based learning university course. Students use the LMS to undertake team-based work, including meetings, communications, and submission of assessments. Data collected on students' usage of the LMS communication technology, and quotes from students' reflective portfolios, demonstrate that effective learning 'communities' are being created in virtual space. Despite never meeting in person, off-campus students formed functional teams and reported developing a great sense of 'community', which fostered mentoring and collaborative learning. The LMS supported the development of an online learning environment that encouraged reflective thought and dialogue with others, both of which are critical to transformative learning and social constructivism. The learner was compelled to become an active participant in the learning process, which allowed students to appreciate the value of participation, trust, mutual respect, and diversity.

Keywords: learning communities; learning management system; WebCT; problem based learning, teamwork

INTRODUCTION

THE UNIVERSITY OF SOUTHERN QUEENSLAND (USQ), in operation since 1967, is a regional university that has developed an international reputation for offering high quality academic programmes in the on-campus (internal), off-campus (distance), and on-line delivery modes. The USQ operates several satellite campuses throughout the world with the main campus located at Toowoomba, Australia.

The Faculty of Engineering and Surveying (FoES) is one of five Faculties at the USQ. This faculty is unusual in that it offers nine majors (agricultural, civil, computing/software, environmental, electrical/electronic, mechanical, mechatronic, surveying (spatial science), and GIS) with no departmental subdivisions. Approximately 75% of the faculty's 2500 students study by distance education.

In 2001, FoES introduced a problem-based learning (PBL) approach for several courses to ensure that graduates developed problem-solving skills and the ability to work effectively in multi-disciplinary teams. In these PBL courses, students learn to work together in teams to solve open-ended problems [1–3]. This paper concentrates on the first of these PBL courses (ENG1101), which is compulsory for all students in the faculty. The main objectives of this course are to develop the fundamental skills needed by students to participate effectively in multi-disciplinary teams, develop communication skills, and to expose students to a wide range of problem-solving tools. The aim of this paper is to demonstrate how the electronic communication features of learning management systems (LMS) are used to facilitate the effective formation of PBL student teams studying in the distance mode, and to create learning communities [4–8] in virtual space.

BACKGROUND

Problem based learning

Problem Based Learning (PBL) is a specific instructional approach that was first implemented by Howard Barrows in medical education in the early 1970s and has since been further developed and refined [9–11]. PBL is based on engaging the learner in activities that simulate the demands of real life professional practice and, consistent with the goals advocated long ago by Dewey (1916), PBL moulds and prepares students for self-directed, life-long learning. One of the main goals of PBL is to develop thinking and diagnostic skills that not only provide the ability to solve the specific problems presented, but to provide skills that can be applied to the solution of new problems.

The educational and philosophical theories underpinning PBL were not explicit in early PBL literature [12, 13] and the pioneers simply thought that learning in small teams using authentic cases and problems would make medical education more interesting and relevant for their students [12, 14]. From these beginnings, PBL has been incorporated into a wide range of professional studies

* Accepted 20 May 2008..

including nursing, dentistry, social work, management, engineering and architecture [15] and has spawned a plethora of educational terminologies with an almost unclassifiable array of categories [14]. Consequently, numerous instructional models that focus on PBL are popular today though most agree that the PBL strategy is entirely in accordance with the 'constructivist paradigm' [7, 16, 17] and 'collaborative learning' concept [18, 19]. There seems to be strong support for the notion that computer-based learning environments can be effectively used to support constructivism and transformative learning [20, 21] and may even offer some advantages over other educational contexts [22] but this does not seem to have been extended in the literature to PBL in the fully online mode.

At the most elementary level the problems in the PBL model involve a multidisciplinary exploration of a subject [23] in which learners examine the topic from several perspectives over a short period of time. At a higher level, the instruction usually begins with a goal or action oriented decision that the learner must make. The difference being that while the goal based scenario uses problems from the past, or specially created problems, action based learning focuses on a real life problem that needs immediate action from the learner. Greenwood and Parkay [24], Merseth and Lacey [25], and Wasserman [26] have all identified that perhaps the most popular approach is that modelled along the traditional lines of the business and law schools as described by Christensen [27], Spizizen and Hart [28] and Stevens [29]. In this approach the instruction centres round a description of some event that took place, which is relevant to the professional activities of the learners. For the purpose of this paper, PBL will be defined as a constructivist learning paradigm where small groups of students engage in cooperative learning and collaborative problem solving to solve complex problems in authentic project contexts. As explained by Gibbings and Brodie [30], ENG1101 teams are given a number of smaller scale open-ended *problems* to solve, hence the strategy is truly PBL. This is slightly different from project-led education (PLE) or project-organised learning (POL), which involve *projects* supported by theory based lecture courses [31]. These methods usually focus on team-based activity relating to large scale open-ended problems [32].

Interest in PBL arose in engineering higher education in response to criticisms that programs failed to equip graduates with collaborative problem-solving skills required for life long learning and the reality of the work place [15, 33, 34]. In many cases educational outcomes focused on the technical and quality aspects and neglected the necessary professional skills. The need for problem solving skills, teamwork and communication skills, as well as technical skills and knowledge acquired through problem based learning, have been highly prioritized in recent reports from major engineering accreditation and professional bodies [36–39]. In response, PBL is now becoming popular in disciplines such as engineering and surveying where students must learn to apply knowledge, not just acquire it. Additional attributes identified by Thoben and Schwesig [40] of sharing work tasks on a global and round the clock basis; working with digital communication tools; and working in a virtual environment, are ideally suited to online education.

Distance education

Distance education is not a new phenomenon in higher education. As far back as the late 1800s, correspondence programs were used in the United States to deliver educational material to students. Initially materials were print based but, as technology evolved, so too have distance education programmes and methodologies. In the rush to develop new markets, many higher education institutions have used the latest electronic communication technology and turned to distance education [for example, 41]. This has been supported by the recent maturing of research into learning in an online environment [42], and consequently modern online courses are usually designed and modelled on stable and well recognised theoretical and practical foundations. PBL however does not seem to have fully made the transition into online education [43]. Stacey [cited in 21] reported that an electronic environment can be structured to facilitate effective social constructivist learning in small discussion groups, but again this did not involve PBL.

Limited references are available in the literature to online PBL, online group-based cooperative learning, or even what constitutes an effective online learning experience for adult learners. The majority of references to PBL report the need for some face-to-face team meeting. A notable exception is Kilpatrick, Barrett and Jones [4] who report a recent growth in learning, including online learning, through participation in 'communities of common purpose' facilitated by developments in communication and information technologies, though these authors were not strictly referring to higher education and PBL.

It is the authors' opinion that physical meetings are not necessary to successfully conduct PBL in the distance mode, provided effective use is made of electronic communication features such as discussion boards, chat facilities and web resources that are available in a modern LMS. ENG1101 is a fully online PBL course for first year engineering and surveying students. It relies entirely on electronic communication and resources, and requires no face-to-face meetings of teams enrolled in the distance mode. In this course, students located in different time zones and geographic locations around the world successfully communicate and solve a range of contextualised engineering problems. The course successfully uses appropriate technology (chat, discussion and web) to enable students to participate in team-based activities in virtual space. In the process, students learn teamwork, communication skills, use of internet technology, as well as discipline specific technical knowledge.

Student diversity

In Australia, student demographics have changed dramatically in the last 10 years, with only 41 percent of university students being the traditional school leavers, and 37 percent of students having attendance patterns other than internal full time modes [44, 45]. This contrasts with USQ where, largely due to the broad range of entry and study options, around 15 percent of students enter undergraduate university courses directly from high school and only 15 percent are internal full time students [46]. As noted by Gibbings and Brodie [2, 3, 30] this has led to a very diverse student population in FoES, including people with trade backgrounds or other tertiary qualifications and many mature age students because:

- students may elect to study in the on-campus or distance modes,
- distance students study from various geographic locations around the world,
- students may study at Associate Degree (two year), Bachelor of Technology (three year), Bachelor (four year), or double degree (five year) levels, and
- students may study any of the nine different majors offered in FoES.

Most students studying in distance mode at the USQ do so because they are already employed in some professional capacity, and the distance mode allows them to study and work at the same time. Owing to the great range of prior experience, and cultural and age differences, these students have different skill levels and personal competency attributes, and their '*learner context*' [47, 48] differs. Gibbings and Brodie [2, 3, 49] report that this rich student diversity is seen as an advantage in the PBL context and they describe how it is used to assist in the learning process by encouraging mentoring within and between PBL teams. This is in accord with Kilpatrick, Barrett and Jones [4] who describe the 'profits that can accrue from building on the synergies' in teams of individuals with a common interest', and Flora, Flora and Wade [50] who contend that, by accepting diversity, teams are demonstrating they are willing to accept new ideas and change, both of which are necessary for community development and learning.

To take advantage of this diversity, students enrolled in ENG1101 are placed into teams of up to eight members selected so as to balance members' existing skills within the teams [2, 3, 49]. Each team is allocated a staff member to act as a facilitator as explained by Gibbings and Morgan [51]. An initial skill assessment is used to allocate students with different levels of skill in various fields into balanced teams, which in turn encourages mentoring within the teams [3]. It is important from a professional perspective that students in these diverse teams learn to work together. In a global society they will have to work and interact with others who are different from themselves and who, in many cases may, be dispersed nationally or globally.

Use of an LMS

Students in the PBL teams who are enrolled in the distance mode are dispersed across Australia and the world and can only meet 'virtually'. Student teams have generally found asynchronous communication is preferable to enable effective communication across different time zones. The course is managed through use of the WebCT Vista ©™ learning management system (LMS). This platform provides access to web-based resource material, online quizzes and surveys, and communication facilities such as electronic mail, discussion boards, and synchronous chat sessions.

Initially students must indicate they are active in the course by completing an online 'permission to release email address' form. Once this has been received and acknowledged, teams are formed of up to eight students and each team is allocated a USQ academic to act as a facilitator. An email is sent from the course examiner to each team providing information on members' and facilitator names and email contact details. Students are then directed to USQStudyDesk, which is the portal for the (LMS), for further details on the course.

The LMS provides: a general discussion board for administration and general enquiries; a team discussion board that only the team and the course administration staff, including their facilitator, can access; a combined discussion board to facilitate between-team communications; a chat and whiteboard for each team (if requested); electronic submission for both team and individual assessments; and a link to the course resource page. The course resource page is a separate web where students find assessment details, general information about the course and resources for each specific problem.

Several discussion threads are placed on the team discussion boards to get teams started with the communications that are crucial to success in the course. Individual student responses to these threads are compulsory and they include:

- Introduce yourself
- Team code of conduct and responsibilities
- Team communication
- Times and strategies
- Key learning concepts for problem 1.

Facilitators in ENG1101 are required to make contact with their teams on the discussion boards at least twice a week, though for most facilitators daily contact is the norm. Facilitators ensure that all students are actively participating in discussions and other activities. This participation is also monitored by the teams and reported weekly in a team progress report. The tone of the communications is scrutinised to ensure that students do not lose their personal identity through the discussions being dominated by any individual. This ensures that students maintain their identity, noted by Smith [52] as a major issue, and therefore students in ENG1101 generally don't employ the defence mechanism of withdrawal that was observed by Smith in her teams. This facilitation in ENG1101, coupled with the continual upgrading of the teams' code of conduct, alleviates the problems of frustration, fear and the 'cyclical movement' in and out of the communication discussions that were noted as major problems by Smith [52].

Team code of conduct

One of the first assessable tasks required of the teams is to negotiate, agree, and document a team 'code of conduct'. Teams are guided by their facilitator to investigate and reflect on teamwork and the requirements and characteristics of successful teams, and to consider what is expected of their team mates and facilitator. They then formulate a list of 'rules', which are essentially individual and team rights, roles, responsibilities, and consequences, that govern the way in which their team will operate. Over the course of the semester, teams revisit this code and modify it as their team matures and different situations arise.

The code of conduct includes team communication protocols. Teams are encouraged to consider not only appropriate methods of communication, but also strategies to ensure these methods are effective and efficient. In light of the vast student diversity mentioned earlier, teams are encouraged to tailor their communication strategies to suit individual requirements. Some teams work entirely on the discussion board, others supplement this with chat sessions, on MSN (or similar) and email, that are outside the LMS. Very few teams work entirely from one technology and such teams tend to struggle with the course requirements [43]. Owing to age, background, and socio-economic diversity, some students have poor keyboard skills and limited knowledge of computers and communication protocols. Many teams mentor members on the installation and use of MSN or other chat facilities. They also agree on specific 'rules' in their codes of conduct to ensure that all members have equal opportunity to contribute during online team meetings. Where teams meet outside the LMS and the overview of a facilitator, they are encouraged to place a summary of meetings on the discussion board. This enables the facilitator to monitor team participation and progress, and allows students who were unable to attend a 'meeting' to keep up with team progress. New threads appear for each problem on the teams' discussion boards, which are designed to stimulate discussion and student thinking on teamwork, conflict resolution, individual learning goals, mentoring and technical concepts. Responses to these threads form part of the course assessment. Students can also initiate their own new threads to enable team discussions on the current problem.

Assessment of communication

The assessment scheme involves individual contributions to the team effort, self and peer assessment, and team output, and includes a mix of summative and formative assessments. The assessment scheme was recently changed, as detailed by Gibbings and Brodie [2, 3, 30], to more effectively monitor and encourage self directed learning by setting and meeting individual learning goals, mentoring within the team and individual participation and contribution to the team effort. Four main sections contribute to a student's individual mark:

- Team submission of project reports
- Peer assessment of contribution within the team
- Individual contributions
- Individual portfolio of set work and individual reflection on learning.

The authors reported that, under the revised assessment scheme, mentoring within and between teams was improved, since it formed part of the formal assessment, and the subsequent increase in mentoring had the added advantage of encouraging better intra-team communication and therefore fostered better teamwork.

As suggested by Wild and Omari [53], if the web is considered as a learning environment in only a conversational framework, it must still include interactive and reflective components. Whilst the web itself can facilitate some of the necessary conversational framework, or stimulate some of the elements of instructional dialogue, it is necessary to emphasise some type of dialogue or interactivity between the student and the object of learning, and to provide facilities for this interactivity and subsequent feedback to occur [53–55]. This view is consistent with [56], which identified that narrative was both a desirable and necessary method of representing most knowledge types. Consequently the use of the communication features of the LMS to facilitate within-team and between-team communications is seen as a critical element to the success of PBL in virtual space.

As recommended by [57], students are also required to maintain a portfolio of set work and individual reflections on their learning within the course so the assessment depends more on the process, reflection, and self-evaluation than on specific quantitative criteria. This strategy is supported by Laurillard [58], who identified reflection as one of the four main components of effective teaching. Gilbert [59] made a similar assertion, but he interpreted it, in the context of web-based teaching, as trainees needing the opportunity to reflect on their learning and adapt their learning and conceptions in light of that reflection.

RESULTS

Teamwork and communication

In Semester 1 of 2006 a total of 309 students enrolled in ENG1101, of whom 113 were in on-campus mode and 196 in distance mode. Students spent a total of almost 10 000 hours in 155 000 sessions on the LMS, and they posted a total of nearly 16 000 messages to the discussion boards. This communication accounted for 67.5% of student time (6750 hours) spent on the LMS. Figure 1 shows the average number of postings on discussion boards for distance and on-campus teams. The average number of postings per student was equally shared between on-campus and distance students. This is an interesting result as it was assumed that on-campus students would make significantly less use of the 'virtual' communication methods, however these statistics indicate that on-campus students appreciate the flexibility offered by electronic communications and virtual teamwork.

Figure 2 shows the distribution of sessions and percentage of total sessions spent on all the functions offered by the LMS. It should be noted that, for administrative reasons, the email addresses provided by students on their enrolment forms were used in preference to the email facility offered by WebCT Vista ©[TM]. The chat rooms within WebCT where poorly utilized, with many teams using other mechanisms for chat such as MSN.

The electronic communication methods used in this course develop skills that engineering and surveying graduates of the future will require in professional life. Professional consultancies are increasingly using dispersed multi-disciplinary teams on large projects [60]. The ability to communicate effectively electronically and solve problems at a distance is currently missing in the attributes of many university graduates [60]. This course is ensuring USQ graduates can meet these demands, evidenced by student comments:

> I work in the construction industry and team work is essential. The biggest problem we have with the [qualified] consulting engineers is their inability to communicate with each other, especially at a distance. We have to get them to site and face to face to work through design issues. I believe you should do at least one project [at university] where all the teams work remotely from the other team members. (Student comment)

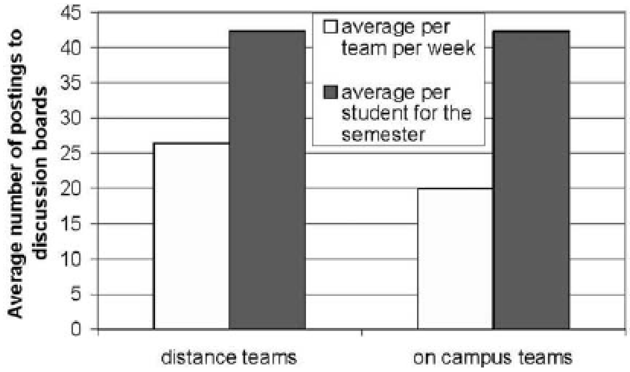

Fig. 1. Discussion board activity for off-campus and on-campus students.

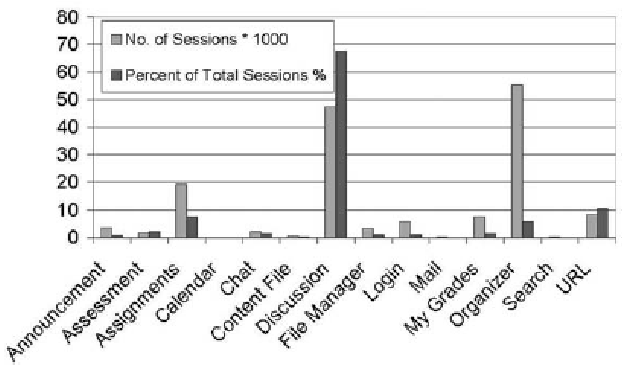

Fig. 2. Activity on the learning management system.

> . . . it will become common for an individual engineer to have a working relationship with many companies simultaneously and to receive and present work over a secure Internet connection (Student comment)

> . . . I feel that working externally [distance mode] and communicating solely via the internet, exacerbates the issues that can arise when working in a team. You have to put in extra effort to communicate effectively. i.e., correctly word your statements so that they cannot be misinterpreted. It's from this aspect of the subject that I feel I have learnt the most thus far. I am surprised at how I am actually using these communication skills in my day-to-day work now with success. (Student comment)

The technical 'content' in ENG1101 is only part of what the students are required to learn. The process of forming and working in functional teams in virtual space is one of the main objectives of the course and results demonstrate that this is being achieved. This is evidence that the focus on a common interest by all members in the teams can indeed 'transcend geography' [4].

> I am beginning to understand that problem based learning is not just a topic within this course; it is the whole concept of the course. (Student comment)

Community

For distance students, working in a student team is a novel experience. For most, the course offered by FoES provides their first opportunity to work actively with other students. Even though some students from different time zones and geographic locations on Earth meet 'asynchronously', the authors believe that virtual team meetings for distance students are as effective as physical meetings for on-campus students and foster the desirable attributes of teamwork, conflict resolution and negotiation of tasks.

> I also found that it was easy to communicate within a group via email and the Internet. I enjoyed this part of the course, as it allowed members to join in discussions at different times of the day and this suited the group as we all work different hours and have a range of internet access times available to us. (Student comment)

> . . . we all have a lot of fun together even though we have never met face to face. Our team has found common interests and all show a genuine concern for each others welfare. (Student comment)

> I enjoyed working with most members of my team and it was good to be able to talk to other students in the same position as me, I was also able to get help with other subjects from some of my team members. (Student comment)

> I enjoyed working with most members of my team and it was good to be able to talk to other students in the same position as me, I was also able to get help with other subjects from some of my team members. (Student comment)

> 'Having other students who can mentor can be a lot less stressful. I guess being in a team there is sense of connection between members and so they feel happier to help those they know. I've found just by having people there to talk with, a lot of stress is reduced and the feeling of being alone with no one to help is diminished. (Student comment)

These quotes highlight the social aspect of learning in the PBL course, the importance of which has been well documented in the literature with respect to human learning in general [for example 4, 5, 6–8]. There is evidence of the formation of learning communities within the teams, and that learning by the students has moved away from an individual constructivist focus as described by Paiget [60], to something much like 'social constructivism' [62, 63]. The existence of this social construction aspect to student learning in communities was also recognised by Pea [64] when he noted that the acquisition of knowledge can be socially constructed when there is a collaborative effort toward a shared goal and that this can occur through dialogue prompted by differences in individuals' perspectives. In contrast to Brown and Duguid [5], evidence from ENG1101 indicates that this social aspect to student learning is occurring in the online environment and it is being improved by the judicious use of the communication features of the LMS. This ability of the internet, provided it is used appropriately, to significantly improve the learning experience in virtual space is a view supported by Tu and Corry [65], and Reushle [20, 22].

It is recognized that ENG1101 and other web-based courses will build a different type of community from an informal learning community than might be expected in traditional classrooms. A sense of community can come about as a result of activity by those brought together by a common purpose [41], but in this case all doing the same course. Much like the situation described by Misanchuk and Anderson [66], ENG1101 students are assembled into teams and practically 'forced' into this 'community'. Their common interest is passing the course and (we hope) learning something in the process. In the beginning this learning community exists within the boundary of the course, but evidence suggests that the community within the teams develop into more than this. Increasingly throughout the course, teams display evidence of communication as social interaction on a personal level as well as academic discourse: noted by [66] as the most important indicator of the existence of a learning community. This sharing of personal information leads to a 'shared emotional connection' [67], which in turn leads to greater trust and sense of support from the team. Figure 3 demonstrates that ENG1101 provides an opportunity for this social interaction to occur, an opportunity that most external students might not have had if it were not for this course using group work and being offered in virtual space through a reliable LMS.

Mentoring within the team has resulted in students learning from each other and valuing the diversity of the team. As recognised by

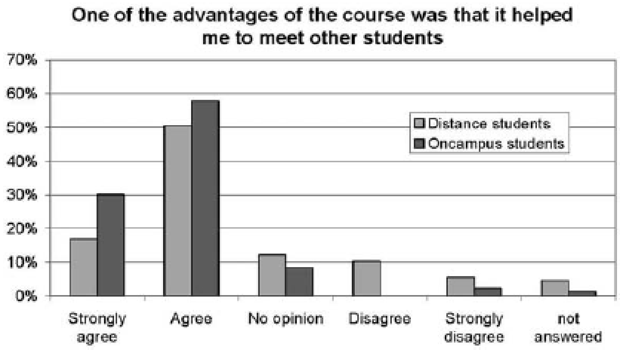

Fig. 3. The course provided an opportunity to meet other students.

Brown and Duguid [5], this has allowed teams to produce more creative solutions than would be possible from an individual. The sense of community within the teams has led to true collaboration since it involves the sharing of creation, understanding and discovery [68].

> One of my team mates had suggested that he would like to learn more about PowerPoint, so we have been paired for this task. As I am quite comfortable with the use of PowerPoint, I developed a simple training package for my team mate to show him the basic tools that you can use with this software. We have also collaborated via MSN Messenger on the content of the presentation. I have enjoyed the opportunity to help a team mate learn a new skill. (Student comment)

> Diversity works for the team because we: Solve a problem using different viewpoints; Use each others' skills to increase the team's output; Learn skills from one another. (Student comment)

> One good thing about the course is that I can see how the other students tackle these things and learn from them. (Student comment)

> With so much interaction between other students in this course, it is hard not to learn a great deal. Each person has a large amount of useful information and with this combined into a team environment; this collective information can almost seem endless. (Student comment)

Schrage [cited in 4] sees this collaboration as essential because our society is so complex its intricacies can't possibly be understood without accepting the contributions of peers.

In late 2006, 27 initial student portfolios (submitted after week four of the semester) and 25 final student portfolios (submitted at the end of the course) were investigated. Three common threads were found in most final individual portfolios. Interestingly, these three are criteria used to identify the development of 'learning communities' [4].

1. Students recognised the importance of a common goal, and a commitment to succeed.
2. They realised they needed to respect and take advantage of the great diversity within the team to enhance potential outcomes. If it is accepted that the ENG1101 teams are indeed a learning community, then this view is supported by Kilpatrick, Barrett and Jones [4] who suggest that 'respect for diversity enhances the learning capacity of a community'. This required them to adapt to this diversity and to identify and use individual strengths and weaknesses. They also identified that helping others and mentoring is a powerful contributor to team success and individual goals.

> This course has also taught me that a variety of opinions in a team is often beneficial to its success, as it promotes in-depth discussion which leads to well though out decisions. As well as this, it encourages team members to think about the concepts being learned more deeply, which helps in understanding and remembering them in the future. (Student comment)

> I have learnt that a team of people can accomplish much more than one [of] the individuals by themselves. (Student comment)

3. Trust (and ability to rely on others in the team) is a critical element for efficiency within teams. This was also recognised by Kilpatrick, Barrett and Jones [4] and Rovai [41] as essential to success of collaborative work.

> I have learnt how to trust other team members and use their gifts to enhance the team. (Student comment)

Contemporary adult education literature calls for a transformative approach (based on constructivism) where the student is empowered to reflect on and transform their own beliefs, attitudes and opinions. Reflective thought and dialogue with others are critical to this transformative learning [20, 22]. It is important that students have an opportunity to not only reflect on the social dialogue but also on what learning has occurred [20] and how this has taken place. Accordingly, it appears that students in ENG1101 found that the reflection required to complete their individual portfolios helped their learning, and they also acquired knowledge about how they learn as individuals. Since students in ENG1101 are required to document this reflection in a visible text-based portfolio, this should encourage them to provide 'well reasoned reflective contributions involving disciplined and rigorous higher order thinking processes of analysis and synthesis' [20, 22], and quotes from student reflective portfolios should therefore be reliable sources of information about the student experience.

> The individual side of the course should help me in my academic and professional career by making me a more efficient learner. It will achieve this by helping me to 'learn how I learn. (Student comment)

> Reflection helps learning, it helps me realise exactly what I've learnt during the process of completing the report/s. (Student comment)

With careful design of learning objectives, support mechanisms and communication strategies, the course enables team PBL to be effectively delivered to students who study in virtual space. A longitudinal study carried out over the last five years indicates the following.

- 84% of students agree or strongly agree that the course increased their appreciation of how prior knowledge and skills of their colleagues and themselves can be used to effectively solve problems.
- 85% of students believe the course improved their problem solving skills.
- 81% of students agreed that the course increased their ability to work in a team.
- 73% of students agreed that the ability to learn independently increased.
- 79% believed their communication skills had increased.

Qualitative data from student portfolios also supported this assertion:

> I now believe a virtual team can work if the right individuals are put together, despite their diverse professions, cultures and geographies. If a virtual team can work I believe a face to face team cannot fail. I will use the same negotiating skill, project task identification knowledge, the same focus to a specific goal, strength and weakness identification skills and the same effective communication skills we have used in this project in my everyday team work. (Student comment)

Recent research suggests that the physical separation of adult learners in distance educational programmes is a major contributor to high drop-out rates [Morgan & Tam, cited in 20]. It appears that this separation leads to a decrease in the sense of community, increased feelings of disconnection, isolation, distraction, and lack of engagement [41]. The LMS used in ENG1101 creates an online learning environment that supports the critical concepts of sharing, reflection, and rational communication, all of which are highly valued by advocates of transformative learning [20]. An effort has been made to create learning communities in virtual space by using the LMS to cultivate a climate that is, as recommended by Reushle [20], supportive, safe, tolerant, respectful, nurturing and participatory.

CONCLUSION

This paper has described the successful matching of the communication power of an LMS with established pedagogical principles to produce enhanced learning outcomes. The communication features of the LMS have been used to create an online environment that takes advantage of a diverse student profile and supports student learning as a social community activity. The shared purpose of completing the ENG1101 PBL problems and passing the course have encouraged collaboration and mentoring within and between student teams, while the LMS has provided the vehicle for students to socially construct learning.

There is evidence that students in ENG1101 are learning through jointly 'constructing' knowledge through dialogue on the LMS with other students and facilitators. This is in line with the adult learning concept of transformative learning, the essence of which is grounded in constructivism. Students have ample opportunity to critically reflect and to validate new ideas to interpret these learning experiences in their own contexts, all of which is important for adult learning. The virtual e-leaning atmosphere created through the use of the LMS in ENG1101 for distance students has been shown to offer an environment that is conducive to this type of learning.

It has been demonstrated that by appropriate application of both technology and sound teaching principles, PBL can successfully deliver the required educational outcomes when offered to distance students in the online mode. Provided that sound pedagogical approaches are entrenched in the course design, it is possible to use an LMS to create effective learning communities in virtual space.

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Reflective writing by distance education students in an engineering problem based learning course *

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SUMMARY: The University of Southern Queensland (USQ) is a regional university and is also Australia's largest provider of distance education, winning national and international awards for its flexible programs. Currently in the university, over three quarters of the student body are enrolled in the distance mode and study off campus. The USQ Faculty of Engineering and Surveying in a curriculum review introduced a strand of four courses using problem based learning (PBL). PBL is a successful concept implemented in a number faculties and disciplines worldwide, largely in response to criticisms of traditional engineering education. However, there are few references to PBL being delivered entirely to distance engineering students working in virtual teams. The role of reflections and the reflective process was seen as critical to the success of student learning in a PBL course and was integrated into the assessment schedule. The reflections of the distance education students in the first PBL course were analysed for evidence of learning and depth of reflection. Results indicated that neither students nor facilitators (the academics providing support for each team) had a clear understanding of the process of reflection. Initially students wrote mostly in the "retell" mode. Little evidence of critical analysis or evaluation of the team project, team processes or individual learning was evident in their reflections. A significant discrepancy between markers and a clear understanding of the requirement and benefits of reflective writing was also apparent. Possible solutions to these issues are discussed.

1 USQ GENERAL INFORMATION

USQ began 40 years ago as an Institute of Advanced Education and gained university status in 1990. The University has five faculties: Engineering and Surveying, Science, Education, Arts, and Business. The University has approximately 26,000 enrolments, of which some 35% are international students. Students can choose between three modes of study: on-campus, distance and online. The majority of students, approximately 77%, study off campus by distance education, making USQ an international leader in distance education (USQ, 2005).

The Faculty of Engineering and Surveying (FOES) has approximately 2600 students, of which approximately 600 study on campus. The remaining students use the flexible education offered by the university to work and study simultaneously at locations across Australia and the world. The faculty offers 26 programs of study over 1, 2, 3, 4 and 5 year (double degree) programs through to doctoral studies. There are 9 majors offered, including agricultural, spatial science/GIS, electronic, civil and mechanical engineering (USQ 2006).

In early 2000, the FOES embarked on a major review and restructure of its programs to prepare for the re-accreditation of its programs by the Institution of Engineers Australia (now Engineers Australia). Recent reports from major engineering accreditation and professional bodies have prioritised the need for problem solving skills, teamwork and communication skills in graduates (IEAust, 1999; IEEE, 2002; ABET, 2003). This has been in response to criticisms that programs failed to equip graduates with collaborative problem-solving skills required for life long learning and the reality of the work place (Wilkerson & Gijselaers, 1996; Boud & Feletti, 1997; Brodeur et al, 2002; Felder & Brent, 2003). Fundamental aspects of

* Paper D07-019 submitted 11/05/07; accepted for publication after review and revision 13/09/07.

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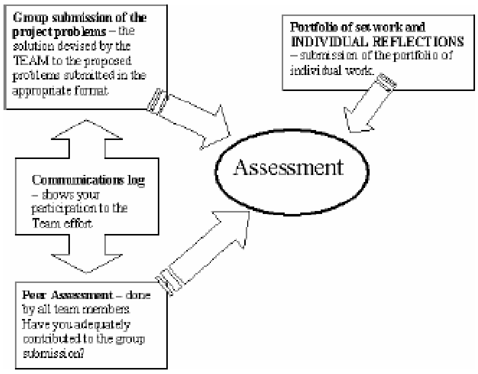

Figure 1: Assessment strategy (Brodie, 2002a).

engineering education – multidisciplinary teamwork, communication, problem solving, *application* of knowledge and the skills for lifelong learning – are ideally suited to problem based learning (PBL). As a result of the review and in light of these required attributes, the faculty introduced four new courses or subjects using PBL (Porter & Brodie, 2001).

This paper discusses the results from the reflective writing exercises undertaken by the distance education students in the first PBL course over three offers delivered in semester 1 of the academic year.

2 PBL, REFLECTION AND ASSESSMENT

PBL is a pedagogical strategy where students are presented with open ended, contextualised, real world situations. They develop content knowledge, application of knowledge and problem solving skills by defining the problem, sourcing resources (including prior knowledge and experience of team members) and identifying gaps in their own knowledge (Mayo et al, 1993). PBL is now a widespread teaching method in disciplines where students must learn to apply knowledge, not just acquire it (Wilkerson & Gijselaers, 1996; Brodeur et al, 2002).

Student learning occurs within small group discussions and the academic assumes the role of a facilitator, not a lecturer (Aspy et al, 1993; Barrows, 2000). Thus the amount of direct instruction is reduced and students assume a greater responsibility for their own learning (Bridges & Hallinger, 1992). As they can share prior knowledge and experience with the group, mentoring and peer assistance assumes a more prominent role in the student learning experience and helps build a learning community. This shared and interdependent learning experience can be successfully done in an online or virtual environment given appropriate scaffolding. The novel approach taken by the FOES in delivering PBL to distance education students supports learning in virtual teams and develops problem solving skills (Brodie & Gibbings, 2007; Gibbings & Brodie, in press).

In addition to the standard problem solving process, PBL adds the steps of abstraction and reflection (Koschmann et al, 1994; Hmelo-Silver, 2004). Reflection is a very important part of the learning process and the theory on learning and reflection comes from a number of different sources. It is grounded on Kolb's (1984) work on the learning cycles and Schon's (1987) ideas about reflection. Students must be given time to synthesise their new knowledge and reflect upon what they have discovered. This is particularly important in PBL where learning is sometimes covert – problems are solved and projects completed without the student being aware that skills and knowledge have been acquired and enhanced. Students must be allowed, and prompted if necessary, to reflect individually and as a group. Reflection, therefore, should become a key part of assessment.

Figure 1 overviews the assessment strategy adopted for the first course in the PBL strand at USQ. The assessment strategy varies slightly for each of the four PBL courses. In the first course, students were assessed on four team projects and the project mark was modified to an individual mark based on peer and self assessment reports. This constituted 75% of the total mark for the course with the final 25% from an individual reflective portfolio.

The intention of the reflective portfolio is to use the writing process as an effective means to facilitate students' critical thinking about the aspects of course content, issues, group dynamics and individual learning.

Norris & Ennis (1989, pp. 176) define critical thinking as "reasonable and reflective thinking that is focused upon deciding what to believe or do". Keefe (1992, pp. 123) notes "Reflective reasoning moves beyond simple rules, relationships, and principles to higher frameworks of meaning – analogy, extrapolation, evaluation, elaboration, invention". These skills and behaviours are the basis of Bloom's work where he catalogued six levels of learning beginning with the lowest level, knowledge, through to the highest level – evaluation as shown in table 1. The last three of these skills – analysis, synthesis and evaluation – are indicative of critical and reflective thinking.

Initially, students focus on knowledge, comprehension and application of subject matter. These three levels of learning are the easiest, especially if the application is in a limited context, eg. worded problems from a text book. For higher levels of learning, application of knowledge in real world problems, students must be able to analyse, synthesise and evaluate. Reflection is a key part of moving into these higher levels of learning (Kanuka, 2005).

Appendix A

Table 1: Bloom's six levels of learning (Bloom, 1956).

	Process	Explanation
Increasing difficulty	Knowledge	Recognition and recall of information and facts – describing events
	Comprehension	Interprets, translates or summarises given information – demonstrating understanding of events
	Application	Uses information in a situation different from original learning context
	Analysis	Separates wholes into parts until relationships are clear – breaks down experiences
	Synthesis	Combines elements to form new entity from the original one – draws on experience and other evidence to suggest new insights
	Evaluation	Involves acts of decision making or judging based on criteria or rationale – makes judgements about

Table 2: Seed questions for reflective portfolio (Brodie, 2002b).

Project	Aspect	Seed questions
Project 1	Teamwork	How well did your team work together? What worked well and what caused problems? How can these problems be rectified and how can you capitalise on the strengths? Reflect on the Code of Conduct and Cooperation your team developed – did it help, did your team stick to it, etc, why/why not?
Project 2	Timelines and project management	Did you personally and your team meet the timelines for the project? What did you learn about time management? What tasks that you took responsibility for did you find difficult? Did the team function as a cohesive unit and achieve more than an individual member could have? In what ways was this achieved and how can things be improved?
Project 3	Problem solving	What have you learned about problem solving and problem solving as part of a team? What have you learnt about project management/timelines/resource management? What have you learned about how to use or apply the technical content of this course?
Project 4	Resources	Discuss briefly how you feel a standard text book approach to a problem helped or hindered the finding of a solution to this problem. Discuss briefly the technical content and complexity of this problem. Discuss briefly the resources used, why where those particular resources used, were they useful, what helped most?

The reflective portfolio was submitted individually at the end of each project. In the course guide (printed resource provided to all students), general guidelines were given regarding the content of the portfolio. Students were required to prepare a short essay in which they considered three aspects of learning – content, context and process – by addressing the basic questions of:

- What have you learned about the topic?
- How does this learning fit into your life's goals, both professionally and personally?
- What have you learned about how to learn, particularly as it relates to open-ended questions?

In addition to these guidelines, students were given "seed" questions to prompt their thinking about certain aspects of the project, as outlined in table 2.

Examples and specific information on reflective writing and the reflective process were provided in a student resource book (printed resource) and students were encouraged to source further information if required.

At the end of the course, students were required to prepare a short essay (1000 words minimum), which reflected on the entire course. In preparing the submission, they were asked to consider the following questions:

- What key ideas or information have you learned?
- What have you learned about how to use or apply the technical content of this course?
- In which areas do you have the most and least confidence? Why do you suppose this is the case?

- What experiences have you been able to integrate, within or external to this course?
- What have you learned about the human dimension of the subject, either regarding yourself and/or your interaction with others?
- What did you learn about yourself as a problem solver?
- What have you learned about how to learn?

It was anticipated that the students, particularly the mature age distance students, would be able to synthesise and evaluate their experiences, building on their prior knowledge and life skills. While a large number of students wrote cohesively and persuasively, analysis of the results showed that relatively few students achieved what could be called true reflective writing. This is discussed further in the following section.

3 INITIAL RESULTS

Grading of the reflective portfolios revealed that facilitators, as well as students, were not comfortable with reflective writing. Facilitators were uncomfortable with the concept of grading personal thoughts and feelings. How can you mark a student wrong or deduct marks? Students, despite being given information on reflective writing, were still unsure of how to go about achieving it and exactly what was required. In the first offer (offer 1) of the course, 165 distance students were enrolled. 68% of the students submitted a portfolio (submission of the reflective portfolio was not compulsory). The average mark for the portfolio was 89.6%. The majority of students could effectively retell events and can add some key reflective phrases of "I learned ...", "I felt…" and "I thought…", but struggled to achieve deep reflection by being able to critically analyse, state opinions and apply new understandings. This average mark was high given the overall level of reflection from the cohort of students. This showed facilitators reluctance to "grade" reflective writing and their lack of understanding on what constitutes "reflection"' at a deep level.

Analysis of the writing showed that approximately 82% of the student wrote mainly in the "retell" mode, ie. summarising information and identifying key concepts. Only approximately 2% of students were able to *reflect*, as identified in the marking criteria, ie. showed an understanding and gained original insights. A qualitative analysis showed that most facilitators believed that students were writing "what they thought we wanted to hear", rather that an accurate reflection of individual learning and team process.

Therefore the examiner (course leader) had no way of determining if students had actually learnt new skills and knowledge, or expanded and built on prior knowledge. Survey results showed that students believe they had met the course objectives, but there was no accurate way of determining if individual learning goals had been set by the student or met. Based on an in-depth evaluation of student learning outcomes and facilitator feedback, several strategies were implemented to scaffold the reflective writing tasks for both facilitators and students.

For the next offer (offer 2) of the course, more guidance and marking scales with keywords were provided. Facilitators were given extra resources and training to help students undertake the portfolio and reflective writing tasks. In this offer, 145 students were enrolled and nearly 88% of students submitted a portfolio. With this assessment guidance, the average portfolio mark was more in line with the average mark for the projects at 73.6%, but there was still a significant difference when the marks were analysed by facilitator, as shown in figure 2. The range of average marks by individual facilitators was

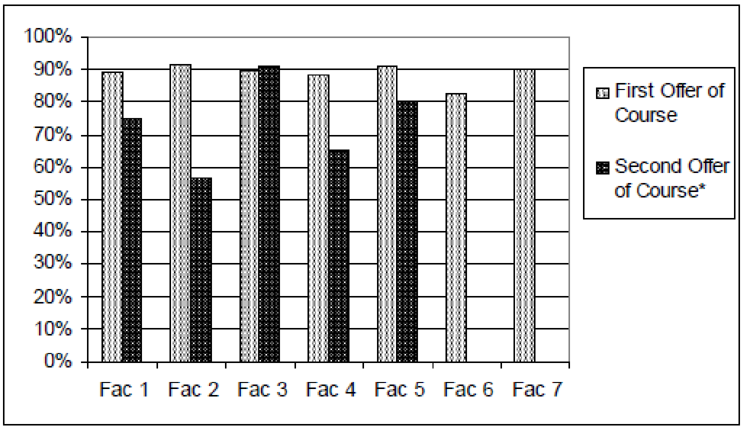

Figure 2: Individual average facilitator marks for portfolio prior to staff training and reflective writing guides (* only 5 facilitators were required due to lower student numbers in this offer).

approximately 56% to 91%, compared with a range of 88% to 91% from the previous course offer. Clearly facilitators still had differing ideas and standards on what constitutes *reflective writing* and differing levels of comfort with grading it.

Analysis of the student writing showed marginal improvement, with approximately 76% of the students continually writing in the retell mode. Approximately 10% of students achieved a high level of reflection, and increase from 2%. The remaining students were able to relate incidences and events to prior knowledge or experiences to varying degrees.

While there had been some improvements in both student competences in reflective writing and facilitator understanding and assessment, it was clear that additional guidance was required for the full benefits of this learning practice to be realised. An in-depth review of the literature and the authors own reflection "on and in action" highlighted the need for a reflective writing guide for both course facilitators and students.

4 REFLECTIVE WRITING GUIDE FOR STAFF AND STUDENTS

Dr L Dee Fink (2001) of the University of Oklahoma carefully distinguishes between substantive writing and reflective writing. Substantive writing refers to writing that is focused on a topic and attempts to present information and ideas the writer has about that topic. Reflective writing focuses on the writers experience itself, and attempts to identify the significance and meaning of a given learning experience. Its "value is in its ability to help the candidate become more self-conscious of his or her own learning" (Loyola University Chicago, n. d.).

To guide students through this process, the author developed a reflective writing guide. A similar guide for staff was also written to enable staff to assist students and effectively assess the submissions.

The reflective writing guide articulated aims to guide students, not only through the reflective writing tasks, but also through the reflective process. Students are asked to set:

- individual learning goals for the entire course, considering their prior knowledge and experience and the course objectives. They must also plan how these goals will be met, resources required and an effective evaluation strategy.
- individual goals for each project in line with personal learning goals identified above
- team goals in discussion with team members, focusing on team process, as well as team outcomes.

Once goals have been set, students and teams were required to reflect during, as well as after, the completion of each project to determine areas for improvement, learning achieved and the process undertaken. This concept of reflection before, during and after is based on John Cowan's work where he combined Kolb's "learning cycles" and Schon's ideas about reflection to devise what is known as the Cowan diagram or Kolb coils (as cited in Helbo et al, 2001). This work defined the three reflection stages to enhance the learning process (figure 3):

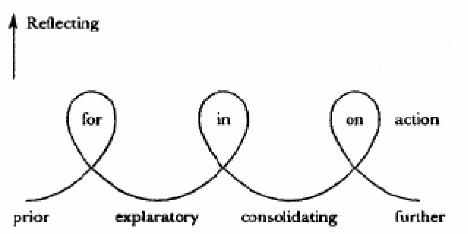

Figure 3: Cowan diagram – Kolb coils (Cowan, 1998).

- **before** (*for*) the project decide what the learning process will be to meet needs (personal and team)
- **during** (*in*) the project to consider how the process and learning goals are being achieved, and what action needs to be taken
- **after** (*on*) the process to decide if goals have been met, what could have been done better, etc.

The different stages of reflection are: retell (set the scene, summarise information, state the main ideas and identify key concepts); relate (make new connections, apply personal experience, compare and contrast, etc) and reflect (draw conclusions, apply judgement, state opinions, new understandings, etc). To help students through these stages, they are asked initially to fill in a table in dot points rather than complete an essay (see table 3). In subsequent tasks in the portfolio, these dot points were expanded until students could complete an "essay" submission.

To guide both staff and students on assessment, marking and feedback rubrics were developed for each topic of submission. The goal was to provide a quick and consistent method of giving feedback to students. Over future offerings of the course, examples at each level of the rubric will be collected to give further assistance to facilitators on marking. A sample rubric is shown in table 4. In addition to the reflective writing guides, a staff training session on reflective writing and its assessment was developed. This training aimed to gain a consensus between facilitators and ensure consistent and regular feedback and information was given to students.

The following results are based on a student cohort of 164 students in offer 3 of the course. The submission rates were increased to 98% and the average mark

Table 3: Personal reflections (Gibbs, 1988).

Description	Describe what happened and set the scene
Feelings	What were your reactions and feelings?
Evaluation	What was good and bad about the experience?
Analysis	What sense can you make of the situation and your experience?
Conclusions (general)	What can be concluded, in a general sense, from these experiences and the analyses you have undertaken?
Conclusions (specific)	What can be concluded about your own specific, unique, personal situation or ways of working?
Personal action plans	What are you going to do differently in this type of situation next time? What steps are you going to take on the basis of what you have learnt?

Table 4: Rubric for individual reflection on projects.

Level 1	Little/no effort; insufficient
Level 2	Presentation of basic facts, but some may not be relevant to reflection. Feelings/thoughts are simple obvious statements and no attempt to elaborate on ideas. Basic plan, but does not address relevant issues or in sufficient detail. May need to take more care with spelling and grammar – these errors detract from comprehension.
Level 3	Presents relevant facts, but does not go deeply into reflection, uses concrete detail and poor generalisations. Simple generic language. Personal action plans are not thoroughly planned. Reflections do not relate to evaluation and analysis of the events listed.
Level 4	Presents relevant facts and records personal observations. Relates experiences and observations. Presents strong connection between the events of the project and experience(s). Analyses the experience by looking at more than one angle. Uses specific details to make reflections clear. Uses precise language. Can analyse own behaviours. Minimal spelling and grammatical errors.
Level 5	Presents relevant events in context. Shows great depth of thought, deep insight and effective conclusions and action plan. Depth of analysis of own and others behaviour. Appropriate language, minimal or no spelling and grammatical errors.

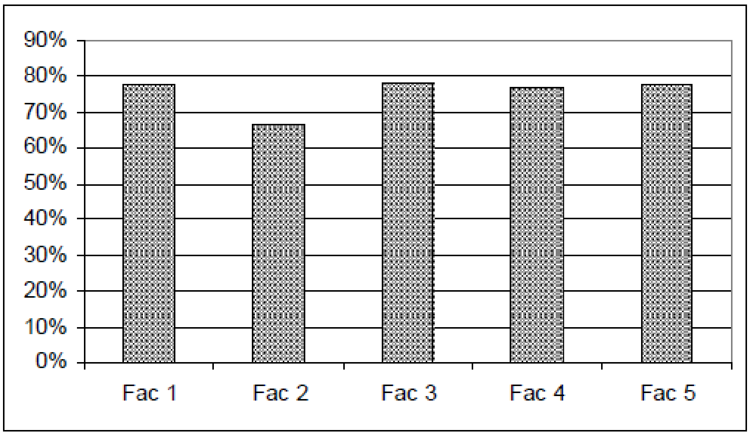

Figure 4: Individual facilitator marks for portfolio after staff training and reflective writing guides.

for the portfolio was 75%. Analysis of the writing tasks showed that students who could demonstrate a high level of reflection, ie. level 5 on the rubric increased, to 32.5%. The result of staff training and development can be seen in figure 4. There was much closer correlation in the assessment marks between facilitators 1, 3, 4 and 5, with a variation of only 1.5%. It is interesting to note that the one exception (Fac 2) did not attend the training session.

Over subsequent semesters, the portfolio tasks, reflective writing guides and staff training have been slowly evolving. More scaffolding tasks have been incorporated into the portfolio and qualitative analysis shows that this is having an impact on student's appreciation of reflective writing and the role it plays in their learning as illustrated by the following comments.

> *"The idea of reflection has been one of the positives in my list of goals. I have never really reflected on my learning ... or about any of the past subjects that I have completed. I believe that this will definitely help me as I proceed with my degree."* – Student comment.

> *"The course also gave us invaluable knowledge about ourselves and how to learn at university ... I personally have gained a lot from the experience."* – Student comment.

> *"This reflection really started me thinking. It is helping me to examine not only what and how the course is teaching, but how I am performing, my shortcomings and what I need to work on."* – Student comment.

> *"Completion of reflective writing task[s] strengthened the meaning of each experience allowing students to truly reflect and learn from the course."* – Team reflection comment.

5 SUMMARY

Table 5 shows a summary of results from three offers of the course. Only the results from distance education students have been included in the analysis. The implementation of scaffolding, including the production of reflective writing guides for both staff and students, and staff training strategies, has significantly and consistently increased submission rates and the number of students who can critically reflect and evaluate their learning through a PBL course.

Students embarked on the reflective writing tasks with varying degrees of enthusiasm. Initially there was some resistance, especially from the mature age students. Comments such as "but I enrolled in an *engineering* degree" and "these tasks are more suited to younger students" were common. However, as the reflective writing tasks developed and became more integrated into student projects and assessment, the link between *reflecting*, learning and professional development became easier for students to see and appreciate.

> *"Another important part of the course that has really stood out to me is the life long learning. Until now I had always thought that uni was going to be the end of my educational years. I have now learnt that I am not going to uni just to learn how to be an engineer, but also to learn how to learn ..."* – Student comment.

Unfortunately facilitators, on the whole, see reflective writing as tedious to mark, even given substantive rubrics. While they can see the overall benefit to student learning, the general feeling is that examinations and assessments with "calculations" are easier to mark. However, the ability to reflect has an association with higher levels of learning and perhaps should be encouraged in more courses. King (2002) states that "reflection is indicative of deep learning, and where teaching and learning activities, such as reflection, are missing only surface learning can result". Perhaps the introduction of more reflective tasks across the curriculum would contribute to more students seeing the benefit of reflection, as well as the development of this key skill.

6 CONCLUSIONS

PBL is well established as an effective teaching and learning method in many professions, especially those where knowledge must be applied, not simply acquired. The emphasis that employers and accreditation bodies are now placing on the core skills of teamwork, communication and problem solving places additional impetus on academics and universities to change their teaching paradigms. Where PBL, in whatever form, has been adopted, reflection must play an important part of the learning process. In addition, the benefits of reflective writing in achieving *deep* learning make it a useful, and perhaps necessary, tool in every course regardless of the teaching method.

However, reflective writing and the reflection process are not easy skills to acquire, as shown by initially poor submission rates and low levels of deep reflection. Evidence from numerous offerings of the PBL course shows that guidance, feedback and continuous monitoring for staff and students is required. To begin the reflective writing sequence, students must, however, "set the scene" by retelling

Table 5: Key statistics of PBL course offerings.

Course offer	Number of DE students enrolled	% students submitted portfolio	Average mark % of the portfolio	Percentage of enrolled students who achieved "deep reflection"
1	165	68.0	85.0	2.0
2	145	88.0	73.6	10.0
3	164	98.0	75.0	32.5

events. The majority of students effectively retell events and can add some key reflective phrases of "I learned ...", "I felt ..." and "I thought ...", but to achieve true reflective writing students must be able to critically analyse, state opinions and apply new understandings. This skill, as much as any technical competencies, must be demonstrated to the students and avenues for constructive feedback found. Deep reflection is not a skill that comes easily to most first year students, particularly those in engineering and surveying disciplines. The results from the introduction of the comprehensive reflective writing guide for staff and students and appropriate staff training provide another step in the process of helping students to be independent and lifelong learners.

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European Journal of Engineering Education
Vol. 33, No. 4, August 2008, 433–443

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Engaging distance and on-campus students in problem-based learning

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(Received 12 October 2007; final version received 14 February 2008)

The University of Southern Queensland in Australia offers multiple entry pathways to a suite of integrated programs delivered to on-campus and distance-education students. The programs cover 2–5 years in nine majors. A specially designed strand of four integrated courses using problem-based learning (PBL) was incorporated into programs and replaced some traditionally taught (lecture) content-based courses. The first offer of the new foundation course took place in 2002. It has since been recognised through a number of national and international awards. For the initial offer, delivering a PBL course to distance engineering students working in virtual teams had never been done before in the world. It is currently delivered to approximately 400 students annually. Student feedback indicates that the course successfully inculcates attributes such as teamwork, communication and the ability to solve technical problems. All these attributes have been identified as being desirable by professional and industry bodies around the world.

Keywords: problem based learning, distance education, graduate attributes

1. Introduction

The University of Southern Queensland (USQ) is a regional University located in the city of Toowoomba approximately 130 km west of Brisbane, the capital of the state of Queensland, Australia. The University incorporates five faculties – Engineering and Surveying, Arts, Education, Business and Science. Total enrolment exceeds 25,000 students (University of Southern Queensland 2007).

The University has an international reputation for providing distance education with approximately 77% of the student body studying via distance education. The University also offers online education and the traditional face-to-face (on-campus) courses and programs.

USQ offers many alternate entry paths to a broad range of people who would not normally have the opportunity for tertiary education. This has led to a very diverse student population. In Australia, student demographics have changed dramatically in the last decade. Nationwide, 41% of university students are the traditional school leavers while 37% of students have attendance patterns other than internal full-time modes (Department of Education Science and Training

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ISSN 0304-3797 print/ISSN 1469-5898 online

DOI: 10.1080/03043790802253574
http://www.informaworld.com

(DEST) 2002, 2004). This contrasts with USQ where less than 30% of students enter university directly from school and only 24% are internal full-time students (USQ 2005).

The Faculty of Engineering and Surveying (FoES) has no departmental subdivisions and offers nine majors (agricultural, civil, computing/software, environmental, electrical/electronic, mechanical, mechatronic, surveying/spatial science, GIS). 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 2500 students with 76% studying via distance education. These students are located across Australia and the world. The diverse background of students in the Faculty includes people with trade backgrounds, 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 a prerequisite entry. At the same time some students with previous qualifications have exceeded 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 pool 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.

Figure 1 shows the long-term average age distribution of commencing students in engineering bachelor degree programs. While about 80% of on-campus students are under age 24 at commencement, the external students are statistically much more widely distributed. A total of 70% of external students are aged between 20 and 34 at commencement. As would be expected, the background of these students reflects the spread in age, with many bringing experiences from a diverse range of jobs to their studies.

The challenge of managing the student diversity is complicated by the different expectations of students in the three levels of Faculty programs. We offer Associate Degree (2-year full time), Bachelor of Technology (3 years), Bachelor of Engineering and Bachelor of Spatial Science (4 years) programs across all majors and a number of 5-year double degree programs (e.g. engineering/business, engineering/science) as shown in Table 1. 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.

In 2000, the Faculty prepared for a re-accreditation by embarking on a major review and restructure of its programs. Engineers Australia, the professional accreditation body, required the inclusion of new graduate attributes, such as teamwork (in multidisciplinary teams), problem

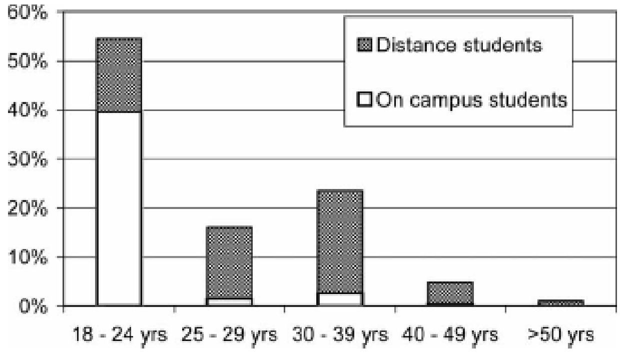

Figure 1. Commencing student age profiles for USQ engineering programs.

Table 1. Undergraduate programs in engineering and surveying.

Field of study	Five-Year Programs	Four-Year Programs	Three-Year Programs	Two-Year Programs
Agricultural Engineering	✓	✓		
Building and Construction Management			✓	
Civil Engineering	✓	✓	✓	✓
Computer Systems Engineering	✓	✓	✓	✓
Electrical and Electronic Engineering	✓	✓	✓	✓
Environmental Engineering	✓	✓	✓	✓
Geographic Information Systems			✓	✓
Instrumentation and Control Engineering		✓		
Mechanical Engineering	✓	✓	✓	✓
Mechatronic Engineering	✓	✓		
Software Engineering	✓	✓		
Surveying/Spatial Science		✓	✓	✓

solving and the development of life-long learning patterns. This resulted in major changes to the programs (Dowling 2001).

2. Program requirements

Engineering educators are becoming increasingly focused on graduate attributes. This focus is driven by the needs of employers for immediately productive professionals and of professional registration bodies for globally comparable graduates. In Australia, the national accreditation body (Engineers Australia) has focused heavily on the development of graduate attributes required in engineering professions, in addition to discipline-specific technical knowledge. 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 (IEAUST 1999, ABET 2007, Engineering Council UK (EC UK) 2003). 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 graduateattributes including teamwork, communication skills and problem solving (MUni 2004, USyd 2006, MelbUni 2007, USQ 2007). 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 29 out of 38 nominated success factors. Thoben and Schwesig (2002) and National Academy of Engineering (2004) 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 major challenge especially 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 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.

Spender and Stewart (2002) 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 (Brodie *et al.* 2006).

3. Implementation strategy

The Faculty concluded in 2000 that the recent 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 which were traditionally taught by lectures and tutorials were removed and replaced by a strand of four new courses to be delivered using PBL. The final-year research project was retained as a capstone course for our 4-year programs. The new courses were designed to cumulatively develop key attributes. They were summarised as:

- an ability to be flexible, to adapt to changing circumstances and to master new techniques;
- an understanding of, and ability to apply, knowledge of engineering fundamentals and basic science including computing and mathematics;
- an ability to gather and utilise information from the range of sources relevant to their field, and an ability to be discriminating in the way it is used;
- an ability to apply problem-solving techniques. This encompasses:
  - problem identification, formulation and solution;
  - a capacity for analysis, evaluation and synthesis;
  - innovation and creativity;
  - an ability to utilise a systems approach to design and operational performance.

The first course 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 'Project and Design' strand shown in Table 2.

Table 2. 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	3–4 students
Engineering Problem Solving 3	Bachelor of Engineering	3–5 students
Engineering Problem Solving 2	Bachelor of Engineering, Bachelor of Spatial Sciences, Bachelor of Technology, Associate Degree	5–7 students
Engineering Problem Solving 1	Bachelor of Engineering, Bachelor of Spatial Sciences, Bachelor of Technology, Associate Degree	6–8 students

The curriculum and specific course objectives for these four courses were completed and formal specifications written so that the strand functioned as an integrated unit (Brodie and Porter 2001, Porter and Brodie 2001). These individual course specifications can be found online at the universities web page under the course numbers ENG1101, EGN2102, ENG3103 and ENG4104 (http://www.usq.edu.au/course/specification/).

The strand design intends students to take different team roles from project to project and from course to course. In the first course students are encouraged to rotate team roles and meet personal learning goals through peer assistance and mentoring. This encourages students to take roles and responsibilities which are outside their areas of expertise and knowledge, e.g. a student with experience in formal report writing is encouraged to mentor a less-experienced team member. Similarly for other roles and task allocations within the team, e.g. leadership and technical tasks.

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 reassuring that they have significant knowledge and skills from their life experience to contribute to help the overall task of the team. This is particularly true of the mature-age distance students. The appreciation of their own and their peer's skills and the friendships formed through working together are common outcomes of these courses. As student confidence in their ability to learn and research grows, the team support is reduced until each 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. This approach sets a platform that allows them to progressively develop their engineering skills throughout the rest of the strand.

Students are allocated to a team of appropriate size, as indicated by Table 2 and assigned an academic staff member who acts as a team facilitator. The facilitator is responsible for monitoring student participation and team communication, *guiding* problem solution, assessment of team and individual submissions, helping the team in conflict resolution, helping students meet individual learning goals and directing students (and teams) to appropriate resources (Brodie *et al.* 2006). Resources provided for the teams in these courses include a course web page and a course resource book.

The course web page documents the team's technical problems to be solved. Specific resources are provided to help address the technical problem or improve the team operation. The web page includes a Frequently Asked Question (FAQ) section, tips and hints from the examiner and extra resources particular to each problem.

The course resource book 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.

Communication is facilitated through a commercial Learning Management System (LMS). This system 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 (Brodie 2006, Gibbings and Brodie in press). In a typical semester with an enrolment of 300 students, approximately 17,000 postings in total are made to discussion boards in addition to email and chat communications. It is interesting to note that in some semesters the use of discussion boards as the main communication facility is greater for on-campus students than distance teams (Brodie 2006).

For distance students, the LMS is the only means of communication with the facilitator. Facilitators monitor student discussion boards at least three times per week and in the early part of the semester they check communications every day. Facilitator interaction is somewhat driven by team communication methods. If the team meets synchronously they are asked to supply an overview of the meeting, e.g. minutes. If a team undertakes most of its communication via email, regular reports to the facilitator on progress, problems and participation are required. Future implementation of the course will utilise a team 'wiki' which will help the facilitator to monitor more efficiently individual contributions to the final report.

In line with a problem-solving strategy students are also encouraged to seek resources from outside the course, e.g. work colleagues, team members, etc. and apply this information to the problems. They are also encouraged to determine a communication and meeting strategy which meets the needs and commitments of all team members. For example, some distance teams meet regularly using synchronous methods (chat) while other teams make use of asynchronous methods (email and discussion boards) to accommodate varying time zones and commitments of team members (shift work). On-campus teams have approximately 10 hours per week timetabled for the PBL course. They can utilise this time as required for team meetings, research and completing team tasks or for individual assessment items (portfolios).

Assessment of the courses varies according to the learning objectives. 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 team 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 3. The team's project report must cover aspects of project planning, management skills 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

Table 3. 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.

to enhance the communication skills of the students by identifying the audience and writing appropriately (Gibbings and Brodie 2008).

4. Achievements

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

References in the literature on team work organised for distance-education students are limited and all depend on some face-to face meetings at specified times during the course (Bygholm *et al.* 1998, Whittington and Sclater 1998, Brandon and Hollingshead 1999, Helbo *et al.* 2001, Jensen *et al.* 2003, Karlsson 2004). The external cohort of students at USQ studies entirely 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, but allows students who for work, family or personal reasons cannot be present on campus during normal hours. Team-based work was implemented with these students in mind. Course delivery for the on-campus cohort was then a comparatively simple exercise as a variation on the external offering.

The work of the staff in the PBL 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 the first two successive courses and the Australasian Association of Engineering Education award for excellence for Curriculum Team Project. The delivery team for the foundation course were finalists in the prestigious Australian Awards for University Teaching in 2005, won a Carrick Citation for Innovation in Teaching in 2006 and the Carrick Australian Award for University Teaching (Innovation in Currilula, Learning and Teaching) in 2007. 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 PBL 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 (Brodie *et al.* 2006). 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 PBL course have given University-wide seminars and workshops on the techniques and strategies employed in the courses.

A smaller but still significant achievement is that 'reflective practice' is 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 is available on the course web page. Where students undertake the reflective exercise properly during the semester, the results have been very positive as demonstrated by the following student comment (Brodie and Wood 2004, Brodie 2007).

"This reflection really started me thinking. It is helping me to examine not only what and how the course is teaching but how I am performing, my shortcomings and what I need to work on." – (Student comment)

5. Challenges

While we have developed significant resources to support student reflections, a lower level of support has been available for staff. Thus facilitators have not seen the importance of 'becoming reflective'. The introduction of such tools as journals and portfolios for staff, is expected to meet with resistance as it is seen as an extra duty on already overworked academics but developing this skill and philosophy of teaching is critical for the continued improvement in student learning (Walkington *et al.* 2001)

The rotation of staff through the PBL courses has, in some cases, been successful in changing the didactic delivery of other courses, but staff attitudes still remain one of the greatest challenges for the program and the Faculty. An honest analysis of facilitator performance would indicate that some staff do not take on the philosophy of the course and do not support either individual student learning or the working of the team to a satisfactory standard. This is particularly true of the distance teams, where facilitation and communication are electronic. The monitoring of participation, individual contributions and team direction can easily be a task that an individual will not do regularly or in sufficient detail either due to lack of motivation or knowledge on how to 'facilitate'. Work on overcoming this attitude is continuing.

Similarly students have struggled with the change in the program. Distance students develop a 'study book' mentality to a course that is summarised as 'Learn what is in the study book and you will pass'. In the PBL courses, there is no study book and what an individual student learns is determined by their individual learning goals based on past knowledge and experience. The change in paradigm is sometimes a difficult adjustment. In addition, particularly in the first course, students focus solely on teamwork aspects. Mature-age students comment 'I already work in a team, I know how to do it'. The course examiners have put significant effort in overcoming these challenges through development of resources, appropriate assessment which recognises prior knowledge and experience, encouraging and rewarding mentoring and peer assistance and building individual student knowledge through each course.

6. Results

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 student's 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 2005 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 7% 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.

It is beyond the scope of this paper to identify the learning outcomes and results for each of the four courses. However our research indicates success in most areas. One example is a study on the students' understanding of 10 fundamental physics concepts using computer administered quizzes at the beginning and end of the semester. This study indicates statistically significant improvements in performance were noted for all topic areas except for two minor areas where most knew the answer at the beginning of semester, leaving little room for improvement (Sabburg *et al.* 2006).

7. Conclusions

The move to PBL was a huge undertaking by the Faculty of Engineering and Surveying at the USQ. 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 challenges were overcome, many of the inherent benefits of PBL became more apparent. The cost of PBL however is a significant barrier to its implementation. *Facilitating* student learning, either on an individual or team basis as opposed to lecturing and supplying comprehensive study notes for distance students does have a large impact on staff workloads. Facilitating virtual teams takes time, effort and significant staff training. However, if significant resources and effort are applied in the early years of the program it is expected that students will become accustomed to the learning style and become more proficient in self-learning. Thus by the final years of a program, facilitator effort could largely be directed to the technical aspects of the problem and not the team or team work.

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. 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 PBL 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.

The overall grades for distance students show they perform significantly better than the on-campus students despite the problems of working in a virtual team. There are many reasons why this could be the case including the older average age of the student cohort and hence increased motivation and application to study; increased awareness of the importance of teamwork and problem solving due to their work experience and their ability to find and use their own resources in problem solving. The interaction of these factors is difficult to unravel but the fact remains that PBL for distance students working in virtual teams is successful and does deliver significant benefits to the students and Faculty.

It would seem that the natural progression of this success is to incorporate PBL into more courses. However, it is unlikely that this will happen in the near future. Staff resistance and resource requirements limit adoption of PBL. It would also be true to say that PBL does not suit all course material and some 'traditional' course delivery is sometimes a more efficient way of achieving outcomes. However, recent literature on engineering education reports that an increasing amount of traditional course material is out of date before (or soon after) students graduate. There will also be an increasing emphasis on 'creative thinking', working globally and locating and using appropriate resources. In this world, PBL will be able to play a significant part in engineering education.

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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

This article has been peer-reviewed and accepted for publication in *SLEID*, an international journal of scholarship and research that supports emerging scholars and the development of evidence-based practice in education.

ISSN 1832-2050

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

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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).

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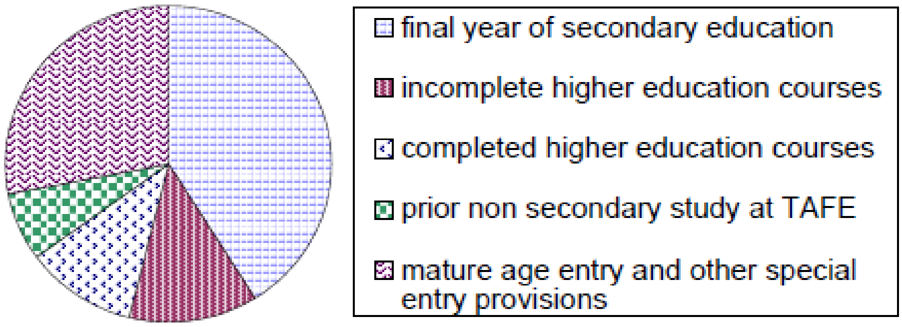

***Figure 1* Mechanisms for entry to undergraduate programs**

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.

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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;

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- 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

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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).

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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.

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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.

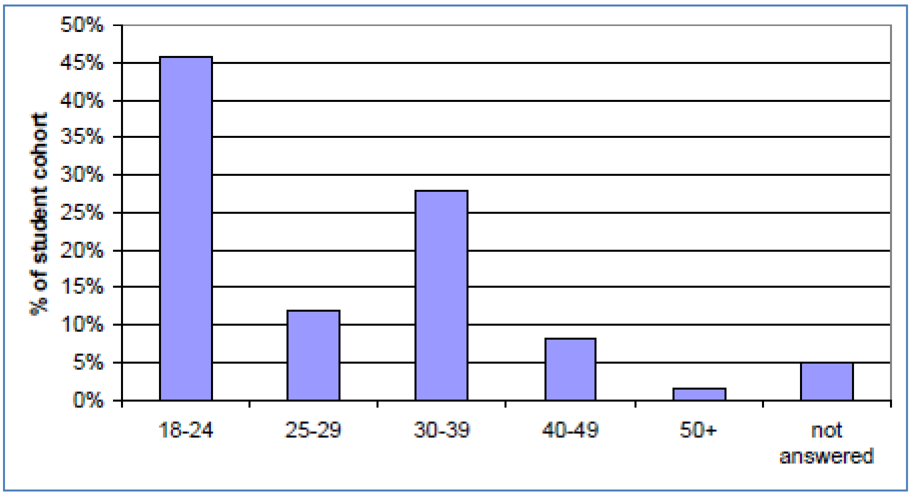

Figure 2 Profile of Student Age

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.

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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.

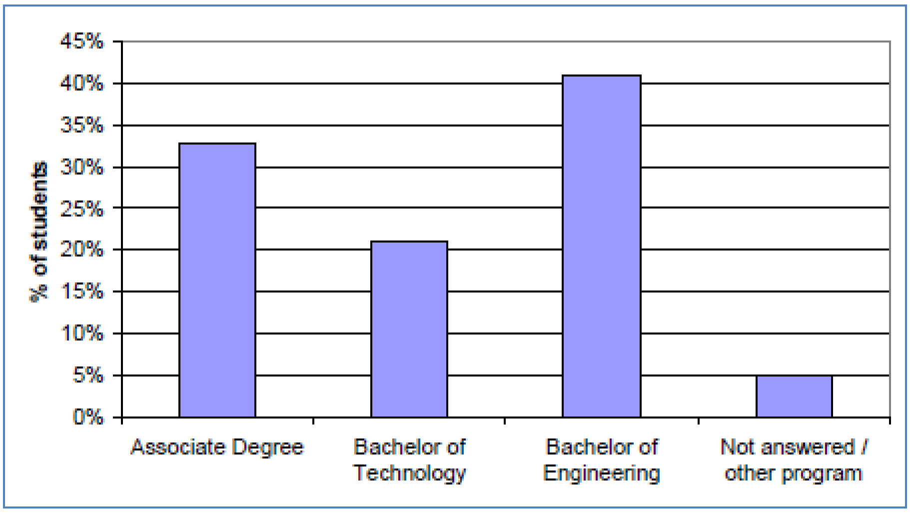

Figure 3 Profile of Students in engineering programs at USQ

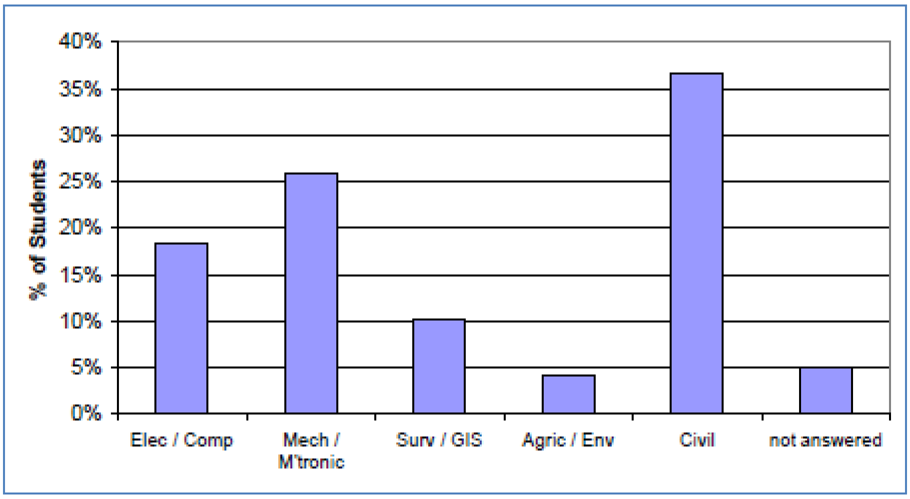

Figure 4 Profile of Students in engineering majors at USQ

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:

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> *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.

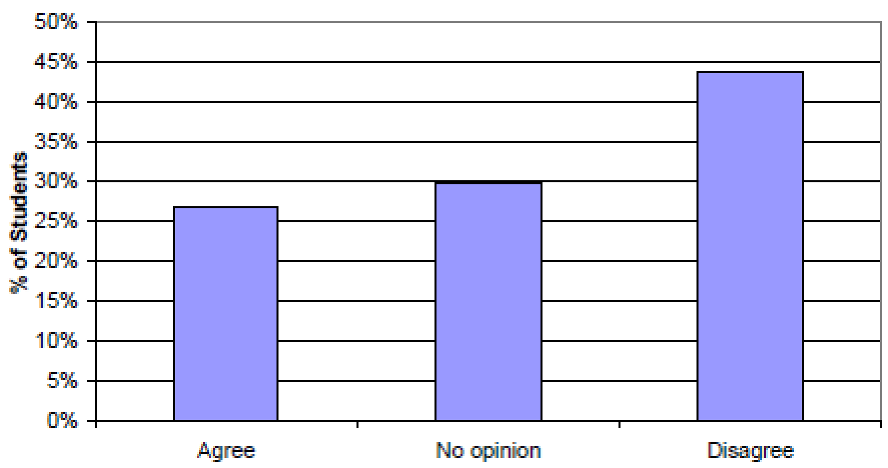

Figure 1 **Student response on preference of lecturing for course delivery**

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.

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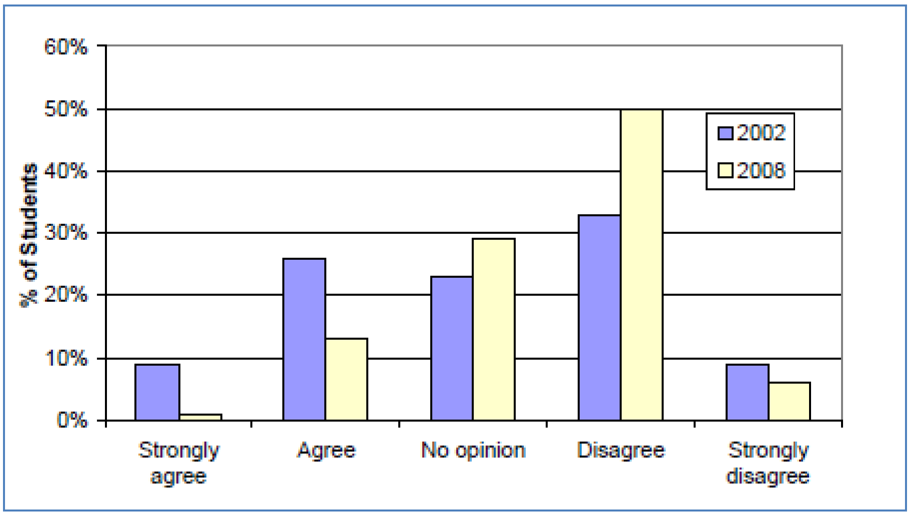

Figure 2 **Student response to retention of knowledge being less than in Traditional subjects**

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.

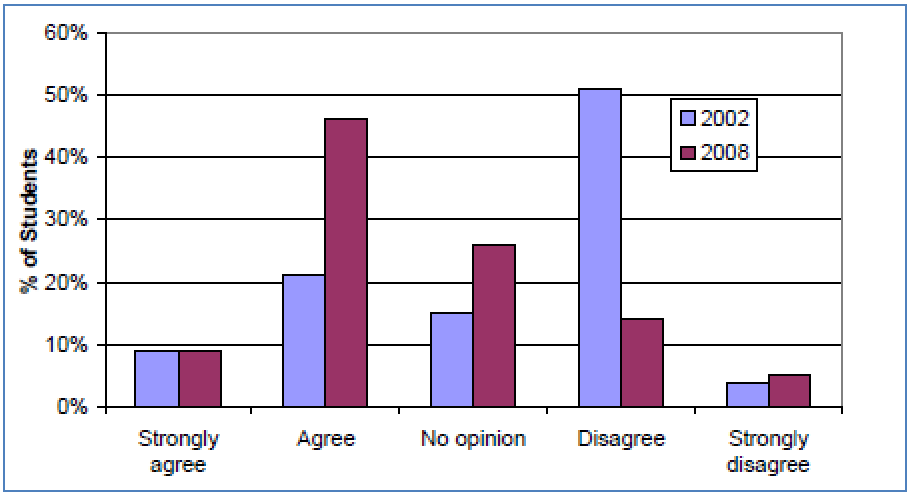

Figure 7 **Student response to the course increasing learning ability**

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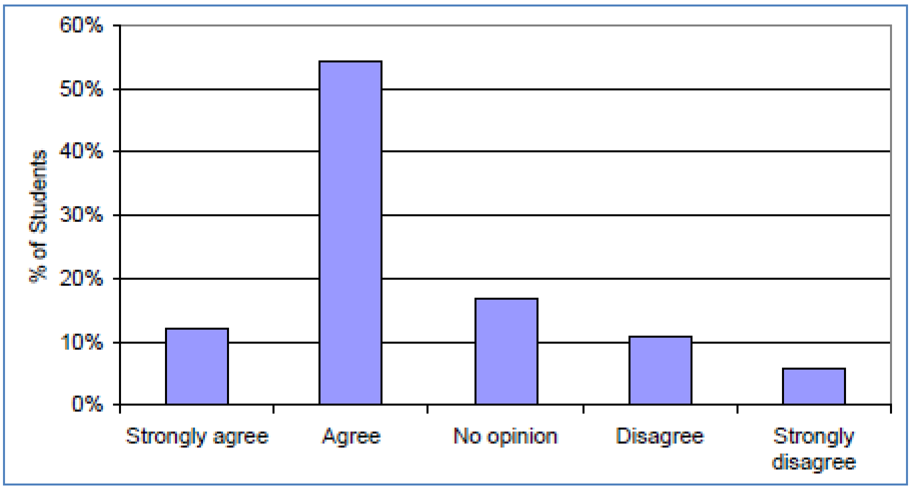

Figure 8 **Student response to the course increasing their ability to undertake independent learning**

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.

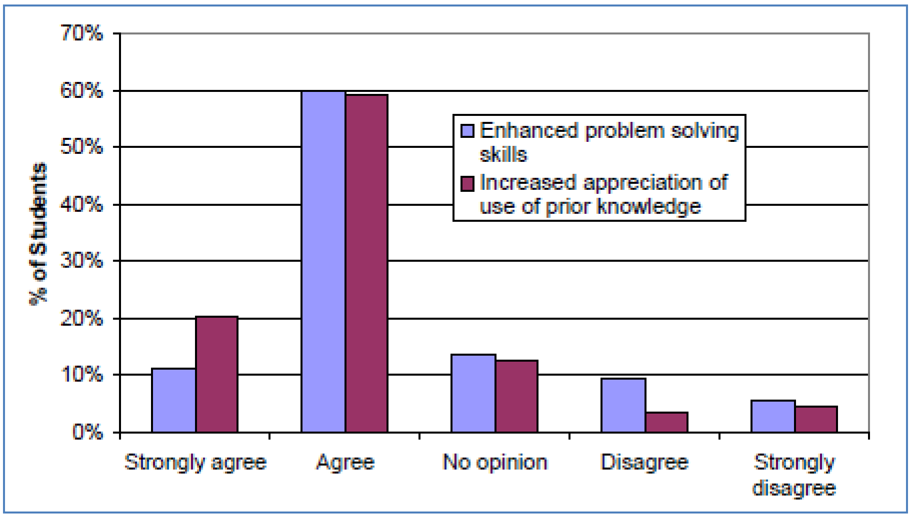

Figure 9 **Student response to the PBL course enhancing their problem solving skills and increasing their appreciation of prior knowledge in solving problems**

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.

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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.

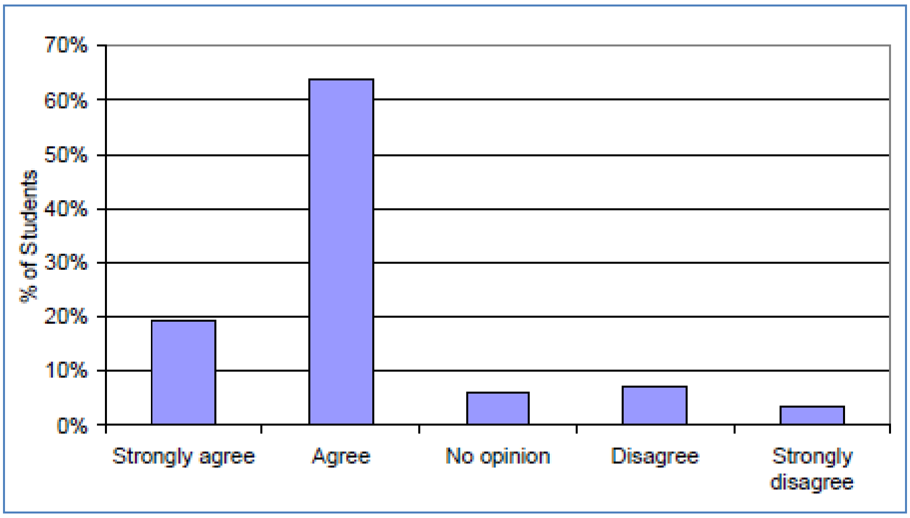

Figure 10 **Student response to the PBL course helped them to meet other students**

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.

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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 form the course.* (Comment from Student Portfolio)

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