

In 1994 the James Goldston Faculty of Engineering (JGFE) at Central Queensland University (CQU), in Australia, introduced Co-

Project Based Learning and Professional Practice - Enhancing Co-operative Education

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Abstract

The Bachelor of Engineering program at Central Queensland University has been run in the Co-operative Education mode for over ten years. In 1998, in response to a range of stimuli, Project Based Learning (PBL) was introduced to complement and enhance the program. The stimuli consisted of, a need to better prepare students for their work placements, a recognition of the fundamental problems with the old program structure, and a recognition of the need to respond to significant social changes. These social changes are relevant to the engineering profession, especially in the context of sustainability, and graduates need to be aware of, and attuned to, their importance.

The development of the combined PBL/Co-operative engineering program was the result of extensive national and international study. The combined program provided context for holistic student learning and practice, and an integrated learning environment. It was determined after this program had run for several years that professional practice knowledge and skills were acknowledged elements of the program. However they needed to be made explicit. It was recognized that students could be even better prepared for their work placements, and ultimately graduation.

The development of a dual award program introduced in 2004, combined a Diploma of Professional Practice with the PBL Bachelor of Engineering (Co-operative Education). This combination expressly identified, and enabled students to demonstrate, the acquisition of professional practice knowledge, skills and attitudes. This professional practice component of the dual award program, in concert with the PBL and Co-operative Education elements, ensured the students' preparation for, application of, and reflection on these professional practice skills. These skills have been acknowledged world wide as a requirement for a professional engineer in the 21st century.

This paper is the second of two companion papers.

operative Education as the model for an integrated learning strategy for its Bachelor of Engineering program. The introduction was made without any substantial curriculum changes. The only real pedagogical change was the introduction of distance education to deliver two courses whilst students were on their work placements. The work integrated learning components consisted of two nominal six months work placements, one at the beginning of third year and the other in the second half of fourth year.

The introduction of Co-operative Education as discussed in the companion paper (Jorgensen & Howard, 2005) achieved only part of the aim of better preparing students for the engineering work place of the 21st century. It was recognized at the time that a complete review of the program would be required to develop the professional of the future. It was well recognized that employers considered that engineering graduates were not being properly prepared for the workplace. They were considered weak in generic skills, such as problem solving, creativity, communication and teamwork.

The Faculty Review

A number of the issues relating to the old program are identified in the companion paper (Jorgensen & Howard,

2005). Those program issues were specifically:

- Overloaded program with technical content (as technology changed, material was simply added to the program, with very little being removed)
- Students were overloaded with excessive class contact hours (29 hours per week in first year)
- High student attrition rates (up to 50% attrition from first year)
- Repeat teaching (surface learning resulted in material being forgotten as soon as the course was passed, and consequently material had to be re-taught when it was next needed)
- Students were not properly learning or integrating material.

During the review process it became clear that the traditional CQU (and generally Australian) engineering curricula no longer adequately prepared graduates for professional life. The curricula were still heavily analytical, even though technology had automated many analytical tasks. Self-learning and sustained learning was not strongly encouraged, even though it was an obvious strategy for coping with rapid technological advances.

A National Review, conducted by the Institution of Engineers Australia (IEAust, 1996) and local industry surveys, had shown that life long learning and other critical professional capabilities and attitudes, such as communication skills, a commitment to sustainability, problem solving skills and team skills were not adequately developed.

The Institution of Engineers Australia was modifying its program accreditation process to have a strong focus on quality concepts. The demonstrable competencies of graduates would be the key to

accreditation. There would no longer be any constraints on program structure.

The timing of the National Review, the movement to quality principles in accreditation, together with the inherent flexibility of a small institution, presented CQU with the opportunity to redefine engineering education in Australia. The Faculty made the best use of this opportunity by identifying the international best practices in engineering education. This process highlighted fundamental problems with the traditional program structures. These included:

- the promotion of rote or surface learning by excessive course workloads and a reliance on closed book examinations
- the development of a fragmented knowledge base in traditional course units; students find it extremely difficult to integrate knowledge in a design environment, and have poor problem solving skills
- poor understanding of professional attitudes and values amongst students.

Problem-centred or project-based curricula were identified as providing the best solution. They provide an environment which reflects the professional workplace and a meaningful context in which the fundamentals of technology and design can be studied. Significant examples of international education literature (Woods, 1994; Kjersdam & Enemark, 1994; Ostergaard, 1989) had for at least twenty years, agreed that project-based learning had the following advantages:

- it takes account of the way in which students learn, the learning style is active, deep and contextual
- enormous improvements in student motivation have occurred elsewhere; first year attrition rates can be as low as a few percent
- it develops a high level of generic and self learning skills
- it supports the integrated view that most engineers have of their profession
- project-based learning produces highly valued engineers in the industrial setting.

The outcome of the review proposed significant curriculum and pedagogical changes. While the review was driven by a desire to produce the best program, it was also a necessary response to significant social changes. These included a shift away from mathematics and sciences in high school education, the move to mass education and the automation of many analytical tasks in the engineering workplace. On a national level it had become clear that engineering curricula must evolve to remain relevant (JGFE, 1997).

The grassroots recognition of these phenomena within the engineering community prompted a national review. This national review was undertaken by The Institution of Engineers Australia, (IEAust), the Australian Council of Engineering Deans and Australian Academy of Technological Sciences and Engineering. Several CQU engineering staff were actively involved in the national review.

The outcome of the faculty review conducted in 1995/6 was the development in 1997 of a Project Based Learning philosophy to complement and enhance the co-operative education model already in place. The recommendations of the review report, *Changing the Culture: Engineering into the Future*, (IEAust, 1996) aligned well with the objectives of this restructured program.

The PBL/Co-operative education Bachelor of Engineering program commenced operation in 1998. This program was then granted full accreditation by Engineers Australia (the Australian professional body previously known as IEAust) for the maximum possible five years in January 2003.

Project Based Learning

What is Project Based Learning (PBL)?

Project Based Learning is any learning environment in which the project drives the learning. While there are a number of interpretations of PBL, they all have the following points in common:

- The problem or project is posed so that the students discover that they need to learn new knowledge before they can solve the problem/project.
- Students learn by engaging in investigation.
- The problem/project is the context for the learning.

PBL is a curriculum design and teaching/learning strategy that simultaneously develops generic skills and a disciplinary knowledge base. It is ideally suited to professional practice oriented programs as it places students in a problem solving role as they would be in the workplace. PBL also purposefully confronts students with a situation that is ill structured, just as in “real world” problems.

The characteristics of PBL are:

- Student centred
- Small teams
- Lecturers become facilitators
- New information is acquired through self directed learning
- Collaborative learning.

PBL uses a cyclic approach to developing knowledge and skills. An important aspect is that the student must be confronted with the problem to be solved, and start on self directed learning, by identifying what they need to know, before any

formal or structured learning event is enacted. This is different to the traditional Taylorist (passive didactic) approach of presenting material to be later used in a project, whether the project is “real world” or not. From an educational point of view, the PBL approach to learning is ideally suited to preparing students to hit the ground running in their work placements, in a co-operative education program. See Figure 1 for the PBL learning cycle.

Why use PBL?

Traditional programs have been suitable for producing graduates whose requirements had not changed for many decades. However as the interface between technology and society has evolved, the need for a different type of graduate has also evolved. Educators must be producing graduates for tomorrow, not today.

Today's World		Tomorrow's Graduate
Rapid explosion of knowledge	⇒	Self directed and lifelong learning
	⇒	Problem solving/analytical and critical thinking skills
Increased technology and social complexity	⇒	Integration of interdisciplinary knowledge/skills
	⇒	Teamwork and interpersonal skills

Many institutions claim to develop all the graduate attributes required without the use of PBL, so why use it? Both the faculty and the 1996 IEAust review (IEAust, 1996) determined that students needed to be motivated, and a context given to their studies. It was expected that the context for the learning would bring enthusiasm. The following outcomes are what was expected would be achieved by engaging students in project based learning:

- Integration of knowledge and skills
- Motivation and enthusiasm
- Problem solving in context
- Teamwork
- Interpersonal skills
- Lifelong Learning Skills
- Proactive, critical, systems thinking
- Self directed learning skills
- Communication Skills
- Professional practice (make reasoned decisions in unfamiliar situations)

Problem and Project Based Learning in Engineering – Internationally

At the time of the faculty review, final year projects had been common in professional engineering programs at most universities in Australia. However, the concept of PBL was only occasionally utilised in the earlier years. As part of the review process, a search was conducted to determine world wide best practice in PBL in engineering education. The following summary describes the results of that search.

Aalborg University in Denmark had been delivering PBL programs in engineering for more than 30 years, producing approximately 500 graduates annually. Their programs had been independently evaluated, with positive outcomes. (Ostergaard, 1989; Kjersdam & Enemark, 1994).

McMaster University in Canada offered several PBL courses in Chemical Engineering. Don Woods developed a small group, self assessed and self directed approach to PBL. (Woods, 1994)

Colorado School of Mines in the USA introduced in the late 1970's, “Engineering Practices Introductory Course Sequence” (EPICS) to teach in a PBL environment (Pavelich & Olds & Miller, 1995).

Kotka Polytechnic in Finland, introduced a PBL system in the early 1990's to address socio-technical issues (Letho, 1995).

Drexel University in the USA, as part of a University Coalition developed the E⁴ curriculum (Quinn, 1993).

Project Based Learning at CQU

The CQU interpretation of PBL is “Project” Based Learning, which provides a longer term, and multi-faceted “problem” to allow an exploration of the breadth and depth of the stimulus material. When a project is defined by students there is an expectation that they will holistically consider all variables, parameters, and constraints including technical, social, environmental and cultural. The term project based learning was also used to focus the staff and students on a systems approach to potential outcomes, rather than a series of discrete problems to be solved in isolation.

The Engineering Faculty at CQU developed, and introduced in 1998, a new Project Based Learning (PBL) Bachelor of Engineering (BE), re-incorporating Co-operative Education Learning from the previous program. The educational and theoretical issues surrounding this program have been discussed (Wolfs & Howard & Vann & Edwards, 1997). The introduction of this program, as previously mentioned, was in response to the recognised shortcomings in the old program. The

new PBL/Co-op Bachelor of Engineering program was established with 50% of each term of study designated as a single course incorporating Project Based Learning.

The Revised 1998 Program

The CQU BE program was established on an overall 50% PBL basis, where half of each term's student load is a single project based course. This structure can be seen in Table 1 below. Each project based subject is worth 12 units of credit, while the lecture based subjects are each worth 6 credit points, making the project based subject 50% of the term's offering (24 units of credit – in each of two terms a year).

The curriculum was vertically integrated and partially inverted to allow the generic skills to be developed throughout the entire program. It also allowed content to be delivered as it was needed, rather than as parcels of information presented in the first year or two, to be utilized in the last two years.

It was recognized that the students would need to learn how to learn in both a team environment and the project based mode. To this end, an induction program was developed, and the first term project based subject, centred on learning how to learn, and developing a propensity for life long learning (See Table 1).

All of the PBL characteristics as described earlier were to be included in all projects within the project based courses

The Common First Year

The program was established with a common first year, encompassing a mathematics and a physics course in each term, plus the project based courses, which concentrate on professional engineering skills, common to all disciplines. These two courses, Engineering Skills I and II, are designed to introduce students to the profession of engineering, and to represent a normal engineering environment. All projects are team based, where students are assigned to teams using various methods.

The Later Years

At the start of the second year of the program, students must select a specialist discipline. From that point, each discipline develops a technical skill and knowledge base, based on the concepts developed in the first year, as well as further developing the generic skills imparted in the study of Engineering Skills I and II.

An important aspect in the development and delivery of many of the technically based project subjects has been the involvement of practicing

engineers. This allows current practice to be displayed, and real projects to be used.

Industry placements

The program places students in a co-operative industry placement for a period of six months at the end of their second year, and middle of their fourth year. These placements, which are an academic component of the program, allow students to apply their already learned skills and knowledge. At the start of 2000, the first cohort of students from the PBL program began their first placement. The faculty considered that the feedback from the employers would be a valuable interim assessment of the effectiveness of the new PBL program.

Reactions

The feedback from employers of co-op students in their work placements has been overwhelmingly positive. In formal interviews with the employers, towards the end of each placement, employers have commented on the quality and value of the students. Employers are particularly enthusiastic about the ability of, what are in actual fact second and third year students to:

- Function independently
- Work in a team
- Communicate articulately
- Problem solve
- Have confidence in their ability
- Know their limitations, and are prepared to ask for help

The co-operative program has been in operation for several years, and a number of employers remarked that the students in the PBL/Co-operative education cohorts are the best they have encountered.

The feedback for the introduction of PBL into the Co-operative Education engineering program has been positive. The student evaluation is positive, and their reflective journals show mostly an acceptance of the philosophy of PBL. They have become independent active learners, and motivated enthusiastic students. This is reflected in the attrition rate, which has dropped significantly to approximately 15%.

In 2002 the IEAust assessed the CQU submission for the Accreditation of all Bachelor of Engineering programs which constituted review of a complete set of documentation and a two day visit to the faculty in August by a panel of national experts in engineering education under the observance of international Washington Accord delegates. Full Accreditation for five years of the Bachelor of Engineering (Co-operative education) programs was granted – the highest level of achievement possible.

The engineering faculty of at CQU established a new paradigm with the PBL Bachelor of Engineering degree. It was apparent that it would (and did) supply graduates who are better prepared for professional engineering practice than graduates from the traditional program offered at CQU. Feedback from students and employers of co-operative industry placement and graduating students indicated that many of the goals of the program are being explicitly realized (Jorgensen & Howard, 2000).

Professional Practice - Philosophy and implementation

Educators need to develop graduates with attributes and abilities previously not considered core to their professional practice. According to a review of Australian engineering education steered by the Institution of Engineers, Australia (IEAust, 1996) future accreditation of engineering courses will depend upon demonstrated development of attributes including effective communication, the ability to work in multi-disciplinary teams, utilization of a systems approach to design, and an understanding of the social, cultural and ethical responsibilities of the professional engineer (Howard & Jorgensen & Toft, 2000)

Partially as a result of this, moves have been made to redefine professional engineering practice (Thom, 1998). Global conferences have called for the development of generic attributes in engineers, which encompass the multi-faceted concepts of engineering practice (Boeing, 1997). As the concept of sustainability stands on the three legs of economic, environmental and social sustainability, engineering as a profession, in order to embrace the concept of holistic practice, must first develop an understanding of individual and societal needs (Crofton, 1998). Students need to not only be aware of, but have the opportunity to prepare, practice, and reflect upon these issues.

Since the inception of the BEng(Co-op) program by the faculty graduates had demonstrated good professional practice skills. These had resulted from professional practice skills training, delivered by the faculty, and the opportunity to work in industry where they can use and develop these skills. Upon their return to the academic environment, they were encouraged through reporting requirements for their work placement, to reflect upon how those issues had impacted their placement. These learning opportunities however were not formally recognised by the university (except in the assessment of the work placement report) and was not credited towards their degree. This lack of recognition and credit was the motivation for the development of a Professional Practice program. This program replaces and extends

material currently provided in the Work Placement courses of the Engineering Co-op Program.

The Diploma of Professional Practice, integrated with the PBL Bachelor of Engineering (Co-operative Education), aims to explicitly equip graduates with the knowledge, skills and attributes needed in professional practice and for professional leadership. The combined program is designed around the triple themes of intellectual, social and professional development. (JGFEPS, 2004a)

A feature of the professional practice program is its incorporation with the periods of work placement in a professional environment that provides the opportunity to learn and put into practice, professional practice skills. The existing work placements are highly regarded by employers, and this program provides students with the training and education to maximize the learning occurring in the professional environment. The program is structured with internal courses delivered before and after work placement periods to provide necessary preparation and review of skills, which will be put into practice in the work place. They also require reflection on the learning.

The new program separates the professional development components previously combined with the BEng(Co-op) work placement courses and presents them in an explicit program. This explicit program provides students with due recognition of their professional practice skills. This program is now integrated with the BEng(Co-op) program to form a dual award program known as Bachelor of Engineering (Co-op)/Diploma of Professional Practice (BEng(Co-op)/DipProfPrac(Eng)). With the introduction of this dual award, the BEng(Co-op) is no longer offered as a stand alone program.

Professional Practice Program Structure

The structure of the Diploma of Professional Practice program element of the dual award program is as shown in Table 2.

This program is similar to one currently offered at the University of Technology, Sydney (UTS), called a Diploma of Engineering Practice. (University of Technology, Sydney, 2005). This means there are now two engineering faculties in Australia offering a dual award incorporating co-operative education and professional practice. This is evidence that there is an increasing perception amongst industry and educators that the professional practice skills require explicit development and recognition.

Dual Award Structure

The dual award program BEng(Co-op)/DipProfPrac(Eng) structure is as shown in Table 3.

Graduates of this dual award program will have demonstrated the knowledge, skills and attitudes needed for professional engineering practice and leadership. This encompasses academic knowledge and skills with engineering discipline theory, technical expertise, personal development and professional formation. In particular this program enables specific and measurable development of professional engineering practice skills, employment readiness, social awareness and lifelong learning attributes (JGFEPS 2004b)

Conclusion

It is well recognised that co-operative education, even if only simply exposure in a work environment, is capable of informing, or even to some extent, enhancing the development of a graduate's generic skills. However, incorporating and integrating project based learning and explicit professional practice skills development, enables a significant integration, broadening, deepening, retention and internalisation of professional generic and technical knowledge, skills and attitudes. This is through identifiable preparation for, application in, and considered reflection of, learning experiences.

CQU has developed an integrated Bachelor of Engineering program, incorporating project based learning, co-operative education and specific development and recognition of professional practice skills. This program is believed to be unique in the world with its interpretation and combination of these learning paradigms. It has taken ten years of development within the university to reach this stage with parallel developments nationally and internationally informing and shaping its structure. Whilst a significant achievement in its own right, the program as it now stands, should be considered but a staged step in the engineering program's development continuum.

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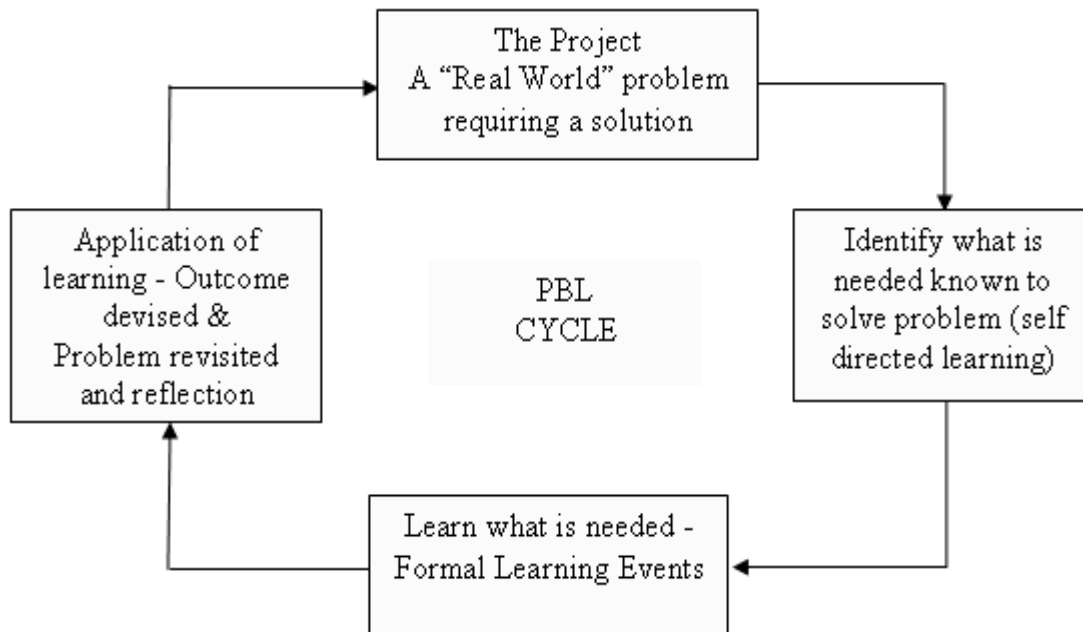
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APPENDIX A

Figure 1 – Project Based Learning Cycle (adapted from Woods,1994)



APPENDIX B
Table 1. 1998 PBL/Co-op Program Structure

YEAR	TERM 1	TERM 2
1	Lecture Based Course	Lecture Based Course
	Lecture Based Course	Lecture Based Course
	Project Based Course	Project Based Course
2	Lecture Based Course	Lecture Based Course
	Lecture Based Course	Lecture Based Course
	Project Based Course	Project Based Course
3	Industry Placement	Lecture Based Course
		Lecture Based Course
		Project Based Course
4	Lecture Based Course	Industry Placement
	Lecture Based Course	
	Project Based Course	
5	Lecture Based Course	
	Lecture Based Course	
	Project Based Course	

APPENDIX C

**Table 2. Professional Practice Element of an integrated
Co-operative Education Engineering Program**

Course	Units of Credit	Comments
Professional Practice Preparation 1 (PPP1)	6	Covers resume writing, interview skills, ethics, health and safety, industrial relations– prior to 1 st work experience
Professional Practice Review 1 (PPR1)	6	Covers documentation of actual work experience using competency framework, formal presentation of work experiences, shared reflection workshops.– following 1 st work experience
Professional Practice Preparation 2 (PPP2)	6	Covers additional engineering workplace skills similar to first line supervisors course.– prior to 2 nd work experience
Professional Practice Review 2 (PPR2)	6	Covers documentation of actual work experience using competency framework, formal presentation of work experiences, shared reflection workshops.– following 2 nd work experience
Work Experience 1 (WE1)	6	Formal course structure to match work experience period. Each course of nominal 12 weeks duration. Assessment limited to weekly activity and reflection journals and self-established job objectives.
Work Experience 2 (WE2)	6	
Work Experience 3 (WE3)	6	
Work Experience 4 (WE4)	6	

APPENDIX D

Table 3. PBL/Professional Practice/Co-operative Integrated Engineering Program

Year	Term	BEng (Co-op) Courses	BEng (Co-op) Units of Credit	Dip Prof Prac Courses	DPP Units of Credit	Total Combined Units of Credit
1	1 - Summer					
	2 - Autumn	1 x 12uc (PBL) 2 x 6uc	24			24
	3 - Winter	1 x 12uc (PBL) 2 x 6uc	24			24
	4 - Spring					
2	1 - Summer					
	2 - Autumn	1 x 12uc (PBL) 2 x 6uc	24			24
	3 - Winter	1 x 12uc (PBL) 2 x 6uc	24	PPP 1	6	30
	4 - Spring	WE 1 ¹	6	WE 1	6	6
3	1 - Summer					
	2 - Autumn	WE 2 ¹ 1 x 6uc	12	WE 2	6	12
	3 - Winter	1 x 12uc (PBL) 2 x 6uc	24	PPR 1	6	30
	4 - Spring					
4	1 - Summer					
	2 - Autumn	1 x 12uc (PBL) 2 x 6uc	24	PPP 2	6	30
	3 - Winter	WE 3 ² 1 x 6uc (Project Preparation) 1 x 6uc	18	WE 3	6	18
	4 - Spring	WE 4 ²	12	WE 4	6	12
5	1 - Summer	1 x 6uc (Project Planning)				
	2 - Autumn	1 x 12uc (Project Implementation) 2 x 6uc	24	PPR 2	6	30
			216		48	240

Table Glossary:

- Dip Prof Prac (& DPP)– Diploma of Professional Practice
- PPP 1 - Professional Practice Preparation 1
- ECF - Engineering Competency Framework
- PPR 1- Professional Practice Review 1
- PPP 2 - Professional Practice Preparation 2
- PPR 2 - Professional Practice Review 2
- WE 1 - Work Experience 1
- WE 2 - Work Experience 2
- WE 3 - Work Experience 3
- WE 4 - Work Experience 4
- PBL – Project Based Learning
- Proj. Prep. – Project Preparation
- Proj. Planning – Project Planning
- Proj. Imp. – Project Implementation