

AC 2007-672: THE PHASED INTRODUCTION OF PBL IN THE ENGINEERING UNDERGRADUATE PROGRAMS AT VICTORIA UNIVERSITY

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The Phased Introduction of PBL in the Engineering Undergraduate Programs at Victoria University

Abstract

In mid-2005 Victoria University (VU), Australia committed itself to convert all of its undergraduate engineering programs to Problem Based Learning (PBL). The Vice Chancellor then mandated that PBL would be used to deliver the first year of these programs commencing in 2006, with an annual phased roll out of PBL into the later years of each program.

This conversion to PBL was part of a strategy by the University to address declining enrolment numbers in engineering programs, and to meet requests from industry that universities should improve the personal and professional skills of their graduates.

The changeover to PBL had been preceded in 2004 by a major revision to the programs to make them compliant with the Australian Federal Government's Higher Education Information Management System (HEIMS). As a consequence the engineering programs have undergone their most significant revision in over 25 years. This revision has enabled the programs to simultaneously address the demands of external stakeholders and to compensate for the problems encountered by the traditional programs ensuing from the standards of prior education of students entering these programs.

This paper looks at some of the background to the introduction of PBL, the models of PBL adopted and their justification, and the process of achieving such a radical overhaul of programs in the compressed time available.

Introduction

Victoria University is situated in Melbourne, Australia, and was formed in 1991 by the amalgamation of Footscray Institute of Technology (FIT), which could trace its ancestry back to 1916, and the Western Institute, which in 1991 was a new institution. The University comprises of eleven campuses and sites around Victoria, it currently has 44,000 enrolled students of which 7,900 are international students from over thirty countries, and it hosts 700 programs in Higher Education (HE) and Technical and Further Education (TAFE). Over 3,900 students are taught in countries across Asia including Singapore, Malaysia, Bangladesh, China, Vietnam, Korea, and Thailand. Victoria University is one of only five, dual sector, universities in Australia which offers both TAFE and HE.

Victoria University's higher education sector is divided into three faculties:-

- Faculty of Arts, Education and Human Development
 - Psychology, international studies, media and communication, multimedia, languages, social sciences, humanities, education and training, exercise psychology, sport, recreation, and performance studies.
- Faculty of Business and Law

- Accounting, economics, finance, marketing, tourism, hospitality, information systems, law, management, international trade, transport and logistics, music industry, and e-commerce.
- Faculty of Health, Engineering and Science
 - Architectural, building, civil, mechanical, and electrical engineering, biomedical sciences, computer science and mathematics, health science, molecular sciences, and nursing and midwifery.

The undergraduate engineering programs of this University are delivered by two schools, the School of Architectural, Civil and Mechanical Engineering (SACME) and the School of Electrical Engineering (SEE). As in most universities, the organisational structure of the Faculty responsible for delivery of engineering programs and the programs themselves have undergone frequent modifications. Despite these changes the programs have evolved and descended from the original programs of one of VU's precursor organisations, Footscray Institute of Technology. FIT had its programs first accredited by the Institution of Engineers, Australia (IEAust) in 1972, and a history of delivering professional engineering programs from 1925.

In Australia accreditation of undergraduate programs under the Washington Accord is the responsibility of the Institution of Engineers Australia, now named Engineers Australia (EA). Satisfying the requirements of accreditation has always been of paramount importance in the development of all of our engineering programs, and has served as a considerable restraint to radical changes to these programs.

During 2004 and early 2005 the engineering schools at VU had re-designed their programs to make them compliant with the Australian Federal Government's Higher Education Information Management System (HEIMS). In mid-2005 Victoria University's Vice Chancellor and President, Professor Harman, employed a consultant, Professor Peter Parr (former Dean of Engineering at the University of Technology, Sydney and also a former Director, Education and Assessment, IEAust), to look into the possibility that the Engineering programs at VU could be delivered in PBL mode. After several months of interviews and consultations, it was determined not only that we could but that we should re-design our HEIMS compliant programs for a progressive roll-out in PBL mode. In mid-2005 the Vice-Chancellor of Victoria University mandated that PBL would be used to deliver all of the undergraduate engineering programs commencing in 2006. Until the time that the 2006 deadline was actually announced Faculty staff had been convinced that 2007 would be the deadline for introduction, and had been working steadily towards that date.

Professor Parr was extremely effective in overcoming resistance to the changes from the Faculty staff and in launching the internal University processes to lock in place a 2006 commencement. The proposals were endorsed by the Board of Studies of the new Faculty of Health, Engineering and Science on the 21st July 2005 and approved by the Higher Education Program Advisory Committee (HECAC) on the 5th of August 2005. Professor Parr was also successful in securing tacit approval to the changes from Engineers Australia. His main finding with respect to the reason for change ¹, and why we should introduce PBL was

“Introduction of PBL will require substantial effort and commitment, and offers major benefits in return. These include helping VU graduates attain a demonstrably higher level of capability, halving attrition rates, and raising the University’s profile in engineering education. PBL provides the means to:-

- a) address more explicitly the essential attributes needed by engineering graduates in professional practice;*
- b) enhance pedagogical effectiveness;*
- c) tackle at the outset the learning difficulties faced by many commencing students.”*

In summary there were political, practical, social, industrial/employment related as well as the pedagogically sound reason that PBL would best suit our particularly diverse student cohort. Overall VU could cite 8 (namely 1, 2, 4, 6, 7, 8, 9 and 11) of the 12 reasons for making the change to PBL as identified by Moesby ², and shown in Table 1.

1	To attract better and - if preferred - more students.
2	To improve the learning outcome of students.
3	To improve the conditions for the staff.
4	To establish an interdisciplinary learning environment.
5	To sustain integration of research in the education.
6	To present a teaching and learning institution that matches the demands of modern society.
7	To sustain a learning setting where solutions are correlated with the context of which it will serve.
8	To create a setting where changes in demands from industry and society can be integrated in the curriculum when the demands appear.
9	Increase the cooperation with industries and society.
10	International competition.
11	Economical motives.
12	Demands from staff.

Table 1 List of Possible Incentives for Considering a Change in Educational Model

As a consequence of the introduction of PBL overlayed on the changes to the programs to make them HEIMS compliant, the engineering programs have arguably undergone their most significant revision in over 25 years.

The Challenge Facing the Faculty

The two engineering schools were now presented with a severe challenge. How, in the restricted time available, to design and have ready for delivery at the start of 2006 a suite of PBL based programs of sufficient quality to at least match the superseded, traditionally delivered programs. This task was superimposed upon the normal workload, and hence largely had to be delayed until the end of semester 2 of 2005. The following SEE email typifies the challenge presented to the teaching staff ³:

“ ... By my reckoning we have approximately 18 weeks before our first PBL students are sat in the room waiting for us to deliver our material. From this we need to subtract time taken by holidays, PBL training sessions, and of course completing our current semester’s assessments etc. (say 3+2+2=7 weeks?)

We have a significant problem to have a satisfactory semester 1 program in place, let alone have material prepared for the semester 2 program (there being so little time between semesters). Despite our current workloads, and despite the fact that we have not yet had Egon’s course on PBL design it seems very desirable that we start to do some ‘nuts and bolts’ work on the new program. ...”.

In both of the schools the response to this challenge was pragmatic, in each case a relatively small group of academics formed into a design team in order to produce a PBL based program for the start of the 2006 academic year.

The constraints presented to each team were threefold:-

1. The mode of delivery should be that of PBL,
2. The programs should meet with the approval of Engineers Australia, and
3. The graduates should satisfy the Core Graduate Attributes requirements of all graduates of Victoria University.

Professor Parr advised that Victoria University should create a PBL construct or format appropriate to this University. This allowed each design team some freedom in the development of the PBL programs of each school. Furthermore it was accepted that the PBL program should be introduced over four years (basic EA accredited Bachelor of Engineering programs being of four years duration). This ensured that students enrolled in the traditional programs would be able to complete their studies without the need to adapt to the PBL paradigm. Irrespective of the desirability of a phased roll out of the PBL programs the available time and resources precluded a more rapid conversion of the teaching mode.

Parallel Design and Educational Programs

The staff in each design team were required to concurrently design PBL based programs, whilst developing their understanding of this new paradigm of program delivery. Design team members had a spread of prior understanding of the PBL learning methodology. In 2005 in addition to self motivated learning the following Professional Development activities were provided to the staff.

July 4th & 5th 2005, Associate Professor David Jorgenson and Dr Steven Senini from the Central Queensland University delivered a two day seminar to staff at Victoria University upon the experiences of that university in delivering engineering programs using PBL. This presentation was a comprehensive and intensive description of the CQU model of PBL.

September 8th & 15th 2005, Internal 2-day workshop to serve as a further introduction to PBL.

September 25th 2005, Professor Anette Kolmos from Aalborg University delivered a one day seminar to staff at Victoria University, outlining some basic principles of PBL, describing some alternative models of PBL, including that used at Aalborg.

October 3rd to 14th 2005, Associate Professor Egon Moesby from Aalborg University had several meetings with both the managers of Victoria University and with the design teams.

November 2nd & 4th 2005, Victoria University Staff College delivered a 2-day workshop on a variety of topics required to support the implementation of PBL.

These activities were all extremely valuable to the design teams in selecting their preferred “flavour” of PBL. The educational programs were well attended by the staff in each of the design teams, and were open to all staff interested in PBL across the university. A challenge presented to all those delivering the training sessions was to simultaneously satisfy both those with regular attendance and those with no prior knowledge of PBL.

From July 24th to 28th 2006 Associate Professor Moesby delivered a PBL based workshop “Pre-planning for a change towards Project Oriented Problem Based Learning (POPBL)”. It had originally been intended that this workshop be conducted during December 2005, but its postponement was necessary because of staff workloads and other commitments at that time. Although delayed until after the completion of the first semester of PBL based program delivery, this workshop again proved to be valuable to the design team members attending, not only due to its content, but also as a demonstration of an experienced PBL practitioner in action. Whilst too late for the start of the 2006 program, many of the concepts presented have found application in the planning for 2007 and beyond.

Two Flavours of PBL

The SACME design team elected to modify their existing programs by injecting PBL into these programs. Thus in the first semester of Year One of these programs two technical courses, *Engineering Physics 1A* and *Engineering Mathematics 1A* remained largely unaffected by the introduction of PBL. The remaining two courses, *Experimentation & Computing* and *Engineering Profession* were each converted to be taught using PBL, all four courses having an equal value of 12 credit points. Table 2 shows the structure of the first year of the SACME program and indicates the courses being delivered in PBL mode with an asterisk (*).

SEM 2	REP1003 Engineering Physics 1C	RMA1002 Engineering Mathematics 1B	VAN1022 Solid Mechanics 1 (*)	VAN1032 Introduction to Design (*)
SEM 1	REP1001 Engineering Physics 1A	RMA1001 Engineering Mathematics 1A	VAN1011 Experimentation & Computing (*)	VAN1051 Engineering Profession (*)

Table 2 First Year of the SACME Program

The SEE first semester Year One program was not to be so easily converted. It had consisted of four 12 credit point courses each of a technical nature, *Engineering Mathematics 1A*, *Engineering Physics 1A*, *Circuit Theory & Electronics 1A* and *Computer Engineering 1A*. To accommodate the introduction of PBL these courses were replaced by two traditionally taught 12 credit point courses (*Enabling Sciences 1A* covering mathematics and physics and *Electrical Fundamentals 1A*, covering circuit theory, electronics and computer engineering) and a 24 credit point course *PBL & Engineering Practice 1A*. This more extensive change permitted the SEE programs to address earlier criticisms from Engineers Australia of excessive technical content at the expense of the development of generic skills⁴. The *Electrical Fundamentals 1A* course forms the context for the problems in the PBL course and acts to provide scaffolding or broadening material for the PBL problems where the students gain the depth of learning. The structure of the first year of the SEE program is shown in Table 3, which also indicates the courses being delivered in PBL mode with an asterisk (*).

SEM 2	VEF1002 Enabling Sciences 1B	VEF1004 Electrical Fundamentals 1B	VEB1002 PBL & Engineering Practice 1B (*)
SEM 1	VEF1001 Enabling Sciences 1A	VEF1003 Electrical Fundamentals 1A	VEB1001 PBL & Engineering Practice 1A (*)

Table 3 First Year of the SEE Program

As an example of the detail of these models, in the SACME model shown in Table 2, VAN 1051 students are presented with a sequence of problems with supporting lectures and tutorials. In VAN 1011 there are two streams, one in Computing and one in Experimentation. In each stream students undertake several problems, again supported by lectures and tutorials.

In the SEE model shown in Table 3, in semester 1, VEB 1001 students undertake several problems which are supported (or scaffolded) by the lectures and tutorials in the non-PBL courses, VEF 1003 and (to a lesser extent) VEF 1001.

It can be seen from these brief descriptions that the SACME PBL model follows the “Individual Level” shown in Figure 1 and the SEE model follows the “System/Group Level” shown in the same Figure.

The models adopted by both schools achieved an approximately equal balance between course work and problem/project work. These are similar in proportion, though not in structure, to the models described for Aalborg and for the Central Queensland University (CQU) by Mills and Treagust⁵.

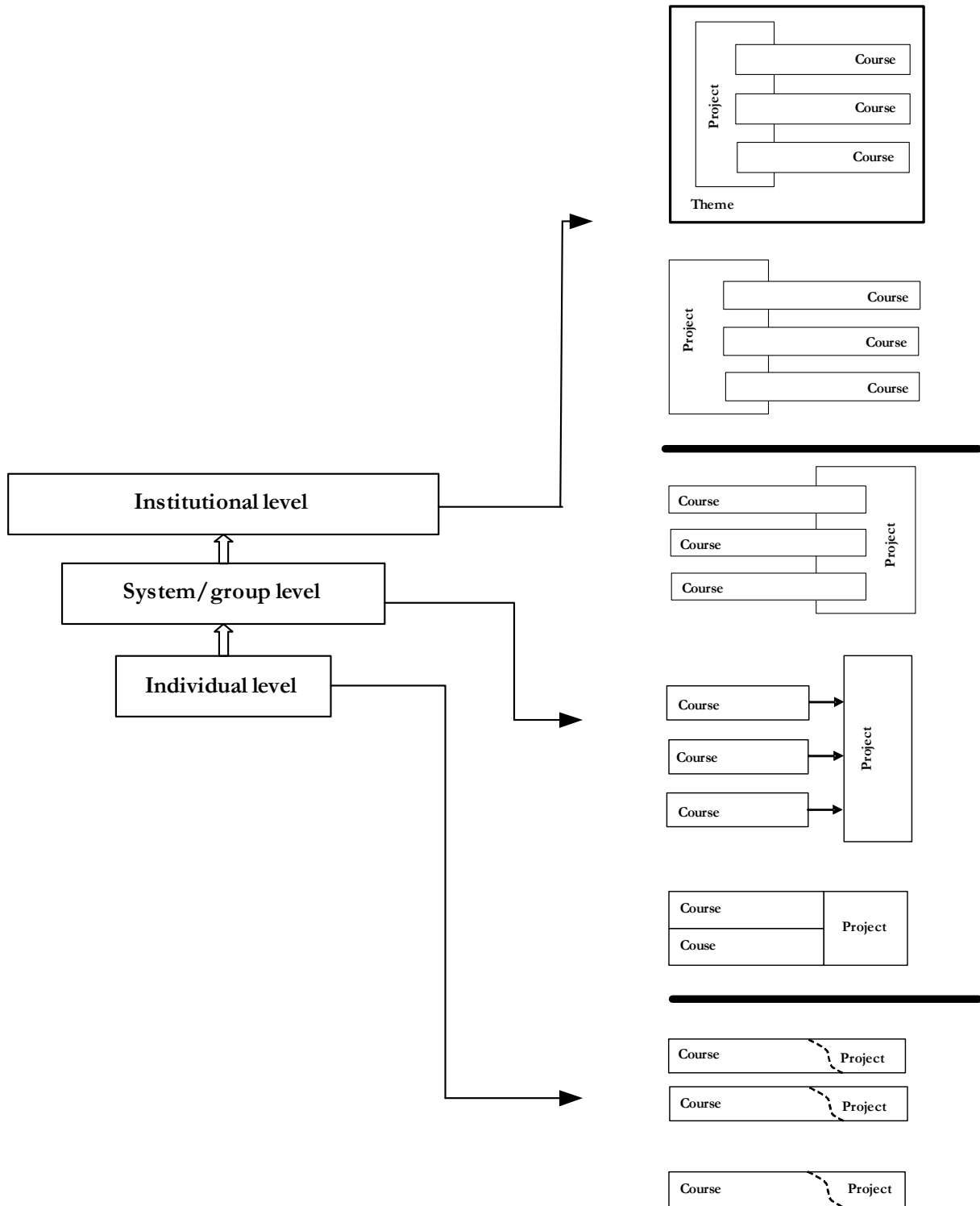


Figure 1 Different Levels of PBL Models⁶

We would like to thank Associate Professor Moesby for his permission to reproduce this Figure.

The differences in program structure between the two schools has resulted in some consternation by those wishing to see a “VU flavour of PBL”. The choice of structure was a decision that had to be made early by each school, and as noted above within a very restricted time. At school level this lack of commonality has enabled the design teams to better tailor PBL to their programs. This freedom has been an important component in maintaining the enthusiasm of the staff involved in these changes. Further the program designers should be able to review the performance of each model, and to adapt either program as required. There is every expectation that the two structures will converge as each school discovers and adopts to the better practice.

Within SEE a consideration throughout has been how to use PBL to enhance the delivery of ‘soft’ generic skills whilst maintaining the technical content at a similar level to that of the superseded program. This required considerable care in the design, so as to not negatively impact upon student progression rates. Technical lectures were transferred into the traditionally taught courses (VEF coded courses of Table 3). These courses use traditional end of semester examinations and mid-semester tests for assessment. The School has had to provide additional tutorial support to students as part of a strategy to maintain progression rates in an arguably more challenging program.

A second difference in approach to PBL as adopted by the two schools is in the designs of the workspaces.

The SACME followed the model developed by CQU. The primary workspace being an open-plan, flexible tutorial space capable of accommodating 30-40 students in reconfigurable clusters. This room is equipped with wireless internet access, and incorporates a central presentation facility providing full projector facilities. The room can be quickly transformed into an 80 seat lecture room. In addition there are several “break out” rooms that may be booked by students. Attached to these is a student lounge with kitchen facilities.

The SEE model is derived from that developed by Aalborg. Each team, consisting of 4-5 students, has its own office. Each office has cabled and wireless internet access, individual storage lockers, whiteboard, pinboard, and is designed for 24 hours, 7 days access. Associated with these facilities is a student lounge area and kitchen, together with a central reconfigurable tutorial space, capable of accommodating 25 students. The students are encouraged to consider their offices as a home away from home, and a place to work when they are not in scheduled class spaces.

Some Problems Encountered

The short time frame for the establishment of the PBL programs caused a number of problems. The construction of the rooms required by PBL was not achieved within the required time. For the first semester of 2006 the programs had to be conducted in temporary, makeshift accommodation. As with many universities, the Victoria University administration system is not designed to accommodate rapid change.

Many staff with a genuine commitment to teaching were disaffected by the speed of introduction and the impression of a lack of consultation in the decision to convert the programs to PBL.

Fortunately their genuine interest in teaching has led them to work constructively with the staff who more willingly embraced PBL and consequentially formed the original design teams. There remains considerable debate over the relative merits of the traditional versus PBL delivery modes. This debate is viewed as healthy and challenging.

The conversion to PBL has resulted in a significant administrative burden on the staff involved. This has detracted from their performance in delivery of the programs. Indeed the staff could spend more time undergoing training, responding to reviews, and preparing the necessary documentation for the subsequent phases of the PBL roll out than on teaching. Research, other than in pedagogy, has been seriously curtailed. Lack of opportunity to take leave and the increasing administrative workloads are having a significant negative impact on the staff involved.

Concurrent with the introduction of PBL in Engineering, VU has also been undertaking many radical administrative changes. Some of these have been internally driven and some by external requirements (eg. the need to comply with the expected requirements of the Australian Universities Quality Audit (AUQA)). As a result the implementation of PBL has been taking place in an environment of changing administrative foundations. This has resulted in the production of a large number of policy documents and procedures, and has created further difficulties in the implementation process. One example is the introduction of a new template for program submissions, accompanied by a refusal to accept existing program documentation, which had already produced on the original template.

The Phased Roll Out

The proposal for the introduction of the second year of each program had to go through the VU program approvals processes in February 2006, ie. before the first year material had even been taught. Because of the short timescales involved each school found it prudent to use the same model for the program structure that had been developed for their first years. The third and fourth year material was required late in 2006 for submission to the University for approvals purposes and for submission to Engineers Australia for accreditation. This meant that there was insufficient time to evaluate the first year of each program before the third and fourth year material had to be defined. These administrative deadlines meant that the potential for convergence of the two models has had to be delayed.

Following the classification of PBL models given by Moesby^{6 and 7}, the SACME model exhibits characteristics of both the individual and the system/group models, and the SEE model exhibits characteristics of the system/group and institutional models. What this means as far as a new student is concerned in the SACME model, is that they must adapt to the requirements of each individual unit of study. Conversely for a student entering the SEE model, there is a need to understand and embrace the expectations of that year of study (and indeed the program as a whole). More problems for new students are presented by the SEE model than by the SACME model.

Phased Roll-Out Implementation and Problems

The transition from the old program to the new will take 4 years as shown in Table 4.

Year 4	Old	Old	Old	New
Year 3	Old	Old	New	New
Year2	Old	New	New	New
Year1	New	New	New	New
	2006	2007	2008	2009

Table 4: The Four-Year Phased Implementation Plan for the New PBL Programs

Following from the concept shown in Table 4, by 2009 the program structure of the Bachelor of Engineering in Electrical and Electronic Engineering in the School of Electrical Engineering should be as shown in Table 5.

The phased roll-out (stepped transition) shown in Table 4 is designed for students in the old program who pass all components on a year by year basis. They will be able to progress towards graduation from the old program. This is rather like surfing the crest of the wave of change of the introduction of the new program. A problem (but not quite a Wipe-Out) occurs, however if they should falter and be overtaken by the roll out of the new program. In this event, or if new students are admitted from another higher education institution with advanced standing, some form of bridging program had to be designed to help them to quickly develop the pedagogical skills necessary to survive in the new learning methodology which is PBL. In the event a suite of bridging tools was developed. The needs of each individual student are considered, and appropriate bridging components equivalent to 6, 12, 18 or 24 credit points are integrated into their enrolment in their transition semester.

The program shown in Table 5 includes a common program for all students in years 1 & 2. Starting in the third year (semester 5), students are allowed to select specialist streams. This delays their need to choose their specialisation until they have had exposure to the breadth of Electrical Engineering, and until they are within two years of graduation.

A significant consideration in introducing PBL into the undergraduate programs has been to improve the preparedness of students for professional practice. The final two years of the program have been designed to allow and assist Learning In the Workplace (LIW).

Bachelor of Engineering in Electrical and Electronic Engineering					
SEM 8	VEI4002 Individual Project 2 (12cp) or 2x6cp Electives		Elective 11 6cp	Elective 12 6cp	VEB4002 PBL Design Problems 4 24 cp
SEM 7	VEI4001 Individual Project 1 (12cp) or 2x6cp Electives		Elective 9 6cp	Elective 10 6cp	VEB4001 PBL Design Problems 3 24 cp
SEM 6	Elective 5 6cp	Elective 6 6cp	Elective 7 6cp	Elective 8 6cp	VEB3002 PBL Design Problems 2 24 cp
SEM 5	Elective 1 6cp	Elective 2 6cp	Elective 3 6cp	Elective 4 6cp	VEB3001 PBL Design Problems 1 24 cp
SEM 4	VEF2002 Systems & Mathematics 2B 12cp		VEF2004 Systems & Applications 2D 12cp		VEB2002 PBL & Engineering Practice 2B 24 cp
SEM 3	VEF2001 Linear Systems & Mathematics 2A 12cp		VEF2003 Systems & Applications 2C 12cp		VEB2001 PBL & Engineering Practice 2A 24 cp
SEM 2	VEF1002 Enabling Sciences 1B 12cp		VEF1004 Electrical Fundamentals 1B 12cp		VEB1002 PBL & Engineering Practice 1B 24 cp
SEM 1	VEF1001 Enabling Sciences 1A 12cp		VEF1003 Electrical Fundamentals 1A 12cp		VEB1001 PBL & Engineering Practice 1A 24 cp

Table 5 Intended Structure for the SEE Program in 2009

In semester 4, the PBL unit (VEB2002) students will receive projects from community based organisations supporting the disabled. An aspect of this project is to prepare students for industry sourced problems in their remaining years.

The third and fourth years of the SEE program are designed to conform to the “Institutional Level” model shown in Figure 1. The final year Individual Project units (VEI4001/4002) are further designed to enable students to take advantage of suitable externally sourced projects. Where an industry project satisfies predetermined criteria a student may, by use of the 12 credit point project and the 24 credit point PBL unit, enrol in 12, 24 or 36 credit points on that project. The criteria to be used are still to be defined. Australia is currently undergoing a mining boom, with the mining industry actively seeking engineering graduates. The design of the final year may enable a student to complete their qualification interstate, using an approved industry based

internship, and the remaining 12 credit points by distance education or by enrolment in approved units studied at an interstate university.

Continuing Independent Evaluation

We were aware that we were on a steep learning curve, and decided to ensure that we could learn as much as possible from the development and teaching of each unit of study. We implemented a wide-ranging evaluation and monitoring mechanism to encompass both student and staff feedback. In order to make this as objective as possible, we “contracted out” the evaluation to colleagues in the Post Compulsory Education (PCE) unit which is part of the Student Learning Unit (SLU) at VU. The evaluation team consists of educationalists and education researchers who are not directly involved in the teaching of any students in either school. A series of focus groups and written questionnaires was devised to obtain feedback several times during the year.

Timely feedback from the students has enabled continuous fine tuning of course delivery to be possible. The compressed documentation and development timescales have meant, however, that it has not been practical to incorporate more significant changes at this time.

Overall, the feedback both formal (through this evaluation mechanism), informal and anecdotal (through student and supervisor interactions) has been positive. A summary of the findings is given in the conclusions section of this paper.

Conclusions

The phased roll out of PBL was made more difficult by the significantly compressed timescale and major concurrent changes in the administrative procedures of the University. Whilst the academic staff were able to adapt and respond in the time available, the University administrative procedures were unable to adapt at the required rate. The introduction of PBL has generated considerable debate over pedagogy amongst the teaching staff. The University has supported the alternative teaching space requirements required by PBL by providing a significant injection of resources in the form of the re-development of teaching spaces, and has committed itself to support future re-development requirements during the roll out period.

The students have adapted to the PBL learning paradigm exceptionally well and the majority, across both schools, appear to appreciate what is required of them and how each unit fits into the entire program. Despite the fact that the new teaching facilities were not completed until well after they should have been, the students worked with the staff and made the best of the temporary facilities which had to be used. One student actually said “We knew that we were guinea pigs, but we also knew that you were learning as well and doing the best you could, so we wanted to make the whole thing work”. Students have, in the main, accepted greater responsibility for their own education. They have worked more in partnership with the staff to overcome “teething problems”. They have increased their overall engagement, to the point that they have made suggestions of how to make changes to improve things for the next generation of students. This greater engagement has been demonstrated by the increase in the retention rate of students. Previously only about 70% of students starting first year programs would still be active

at the time of the exams at the end of first semester. In 2006, 85% of students attended the exams.

There have been a few difficulties as well. Whilst in the PBL courses the pass rate was about 85%, in the non-PBL courses the pass rate remained unchanged at about 50%. Many students identified a major reason for this as being that they were completely engaged with the PBL courses but they found that the non-PBL courses were not as compelling. A secondary reason for this, and one that the students would not have been aware of, is that these scaffolding courses were effectively made more difficult because the practical components were moved into the PBL course which meant the scaffolding courses were only assessed by tests and examinations.

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