5.3 Engineering Problem-Based Learning Spaces at Victoria University

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What is it?

The electrical engineering problem/project based learning (PBL) precinct at Victoria University (VU), Melbourne, Australia, is designed to support the transition from traditional lecture-based teaching to problem-based learning. In designing the learning spaces in the precinct, it was considered critical to support student team meetings, research, design, construction, testing, report writing and reflection, all of which are important aspects of the VU PBL model.

The learning spaces that exist in the PBL precinct have been specifically designed for engineering students who work in teams on PBL projects. The cost to complete the precinct was AUD$7M.

The physical environment is a PBL precinct that is made up of multiple PBL studios for small group work, a multifunction room or PBL common room, a soldering and experimentation workshop, plus secondary support infrastructure such as the technical store, small lecture theatre, printing services and the campus library (Figure 1).

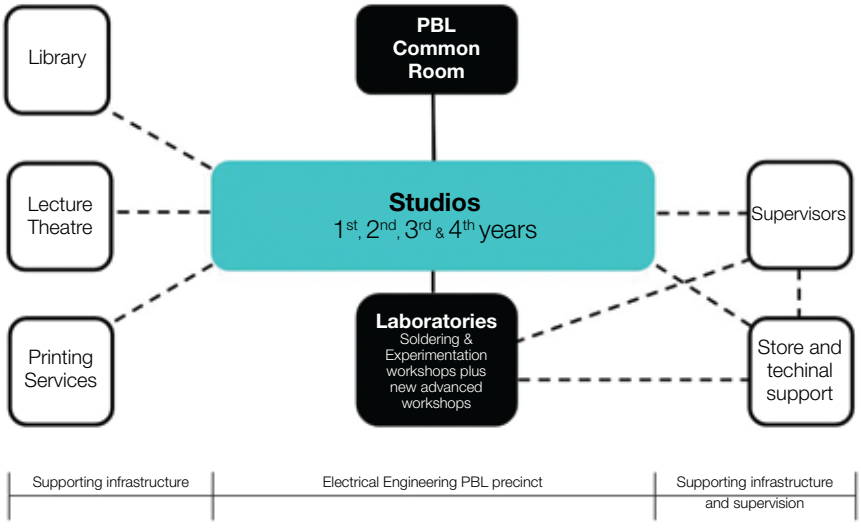

Figure 1: The PBL precinct organisational diagram (Dane, 2008).

Each student team is allocated a studio space (see Figures 2 and 3) that they can use for an entire semester; they effectively "own" the studio for that time. Each studio is approximately 3 x 3 metres in its dimensions and equipped with a table setting and chairs for 6 or 7 people, whiteboard and pin-board, a desktop computer, wireless network and one locker per student. Partitions are 1600 mm high, so it is possible to see over them when standing, but to have a degree of privacy when seated.

> *Academic staff member:*
>
> *We did tell [the architects] what would happen and we did tell them that we'd like the studios set up in this environment with dividers and so on. We did tell them that we were going to have about four to six students in each studio with the supervisor in each studio… It gives students flexible learning because each studio has a computer for the students. Each studio has wireless access. Each student has a locker in the studios.*
>
> *Dane, 2008.*

Each team is assigned at least one academic staff member as its supervisor and is timetabled to meet with the supervisor in the studio for one hour per week. Supervisors also communicate with their allocated groups via Blackboard/WebCT and provide occasional support in the workshops.

The first stage of the PBL infrastructure development involved the construction of PBL studios as shown in Figures 2 and 3. The precinct also includes a workshop and an experimentation laboratory as shown in Figures 4 and 5. Each PBL team has its own workstation in this area.

The PBL laboratories are slightly different to traditional laboratories both in terms of design and student access. A major challenge has been to design laboratories that allow students to construct and test electronic and mechanical projects without continuous supervision. The laboratories are equipped with appropriate technical equipment and general-purpose

Figure 2. A cluster of PBL studios.

Figure 3. A single PBL studio.

hand tools and assembling apparatus. They were designed to meet the University's strict occupational health and safety guidelines and meet the State Government's legislative requirements (Victorian Occupational Health and Safety Act 2004). Such requirements include rules about safe working numbers, the installation of fume extraction units and the general control of access to the laboratory facilities to ensure the facilities are used by authorized persons only. To control access to the PBL precinct, all students are given an electronic key (fob) that allows them entry to the PBL studios, the multifunction room and the laboratories between 8 am and 10 pm.

Why is it?

Victoria University has a strong record of producing engineering graduates who are technically competent. However, today's engineers also need well-developed generic attributes, including the skills associated with oral and written communication, working in teams, locating and evaluating information, and project management. This emphasis on generic attributes is reflected in the accreditation requirements of the professional body in engineering, Engineers Australia:

Graduates from an accredited program should have the following attributes:

- ability to apply knowledge of basic science and engineering fundamentals;
- ability to communicate effectively, not only with engineers but also with the community at large;
- in-depth technical competence in at least one engineering discipline;
- ability to undertake problem identification, formulation and solution;
- ability to utilise a systems approach to design and operational performance;
- 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;
- understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;
- understanding of the principles of sustainable design and development;
- understanding of professional and ethical responsibilities and commitment to them; and
- expectation of the need to undertake lifelong learning, and capacity to do so.

Engineers Australia, 2006

In order to address this need, the Vice-Chancellor of VU created a working party comprising academic staff and a large contingent of industry partners. It worked throughout late 2004 and into 2005 to identify those competencies of an engineer that industry really seeks. The industry partners expressed a view that an engineer should possess strong oral and written communication skills, project management skills and technical knowledge. This view was one of the major drivers for change in the undergraduate engineering programs in the Faculty of Health, Engineering and Science at VU, and led to the shift from the traditional lecture-based curriculum to a PBL curriculum. The other major driver for change was the desire to improve retention rates in engineering programs. These drivers are consistent with the notion that curriculum change is highly influenced by external social factors.

Following the decision to introduce an engineering PBL curriculum and associated infrastructure at VU, a consultant was appointed to advise on the curriculum change process and to assist with the first step in implementing the change to PBL (Parr, 2005). The PBL so far at VU has been critically dependent on both the academic structure of the programs and on the development of appropriate infrastructure, especially the learning spaces to support the programs.

The PBL pedagogical principles, which drive the Engineering curriculum, were the main driver for the design. The following learning principles have been extensively used and employed in most, if not all, PBL models:

- Project-based learning
- Participant-directed or "self-directed" learning
- Activity-based learning
- Interdisciplinary learning
- Analytical thinking
- Team-based learning

Figure 6 illustrates the main learning principles in three categories: cognitive learning, collaborative learning, and contents used in the Engineering curriculum.

The cognitive learning category involves learning that is scheduled around some types of problems

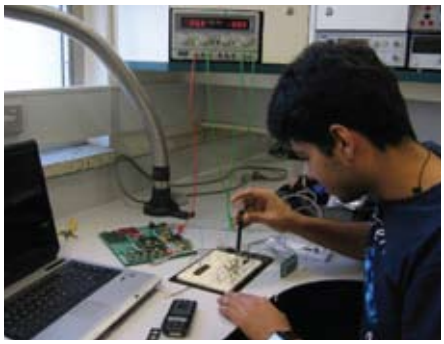

Figure 4. A PBL experimentation laboratory.

Figure 5. Team workstation in PBL experimentation laboratory.

and that is achieved through project work. Here the problem is the initialisation of students' learning and in this way, learning is placed in context. The idea behind learning being achieved through project work means that a unique task involving complex problem analysis is usually required.

The collaborative learning category encompasses learning that takes place in teams and is self-directed. Here learning takes place through communication that will usually involve a team of students with similar objectives. An integral part of this process is that students learn from each other, and take ownership in what they do, especially in the formulation of the teams.

The contents category involves multidisciplinary learning and analytical thinking. Here the work that students perform can be spread across traditional field-related boundaries, as well as outside these boundaries. Analytical thinking is another critical learning principle where theory and practice come together. It is indicated in Figure 6 that practice is across all of the learning principles of the VU Engineering PBL model. This is very important, as it not only indicates that practice is the integral part of the model but that it is performed while achieving all of the abovementioned learning principles.

What happens here?

A PBL program requires students to work in teams, ideally teams of about five to six students in early years and individually or teams of two to three in final year. In each semester, the students take one PBL unit of study that constitutes half their study load and two non-PBL units of study that are taught conventionally. They therefore work on PBL projects for approximately half of their study time in each semester.

The PBL cycle requires each team to meet to identify learning issues (what they need to learn in order to address the technical problem) and allocate specific issues to members of the team to research. The next stage is for the members of the team to research these issues, either individually or in small sub-groups, and then report back to the team what they have found. What happens next depends on the required output of the problem or project. Typically, individual team members or sub-groups design, build and test components of a final product before working as a team on assembling that product and the technical report that accompanies it. Reflection on the learning experience is an essential part of the PBL approach, so students prepare both individual and team reflective reports during the PBL cycle.

The PBL cycle therefore involves a range of team and individual activities. Each team meets formally once a week with its supervisor and, in first year, each team will typically have two supervisors – an engineering academic and a language and communication academic. Between these formal meetings, there are unsupervised team meetings.

Figure 6. PBL Learning Principles

There is also a range of other group activities in which all teams participate. For example, in first year, students attend workshops that introduce them to the PBL process, working in teams and project management. A series of language and communication workshops focusing on writing both technical and reflective reports is also provided. Individual activities include locating resources, writing software, building and testing equipment, and writing sections of reports and presentations.

Thus, although work in small teams lies at the heart of PBL, the PBL precinct must also support learning in larger groups in a workshop format and students working independently or in groups of two or three. It must support students working around a whiteboard or a computer screen as well as working in a workshop to build and test prototypes.

How is the space used?

A formal study of the level of use of the studios, laboratories and multifunction room has not been conducted as yet. However, informal observation confirms that students use the PBL precinct extensively throughout the day, with some students also using it in the evenings. The various spaces are used for the many team and individual activities for which they were designed but also for some that were not considered in the design phase. For example, it was not envisaged that the studios would be used as the set for several short videos of the student view of PBL that some teams produced and uploaded to YouTube!

The pattern of use of the PBL precinct in the first year of operation was somewhat different from what was planned, in that there were fewer unsupervised meetings of full PBL teams than expected and more work by individuals and groups of two or three. Working in teams was a challenge, as reflected in responses to student surveys and focus groups:

> *Students acknowledged that working in teams would be a feature of their working lives and many saw the benefits of learning how to work effectively in teams. They identified benefits of team projects such as developing friendships and socialising, sharing the workload, gaining different perspectives on a given problem, support and motivation. Relatively few students reported being members of effective teams, characterised by respect, collaboration, rotating leadership, task focus, productivity, and meeting deadlines. Most students, unsurprisingly, found that teamwork was challenging. In particular, many reported being in teams with students who did not contribute to the work of the team or even attend team meetings. .*
>
> *Gabb & Keating, 2007: vi.*

Students told us that they sometimes found it difficult to arrange team meetings because most of them had part-time employment off campus and some had family commitments as well. Some students chose to meet off campus because they lived in the same neighbourhood.

While there were fewer meetings of full teams than expected, it was observed that the PBL precinct rapidly became the students' "home" on campus. The PBL common room has developed as a space where students meet informally, use computer facilities, use kitchen facilities, conduct presentations, attend occasional lectures and workshops, and where staff also meet for PBL planning and coordination. It is generally a non-timetabled space with open access, apart from occasional dedicated meetings, workshops and presentations.

Researcher:

The common studio, do you use that for other events apart from presentations?

Academic staff member:

We do use them for other meetings… the meetings [for] all the academics…we usually meet in there to discuss PBL. Usually we meet two or three times a semester… The language and communications workshops are being conducted in the PBL common studio.

Dane, 2008.

The multifunctional design of this space has enabled its more informal use by students. Students sometimes use this space for watching movies, making movies, playing computer games and other social activities. This appears to contribute to the sense of community that is evident throughout the precinct and is therefore not discouraged.

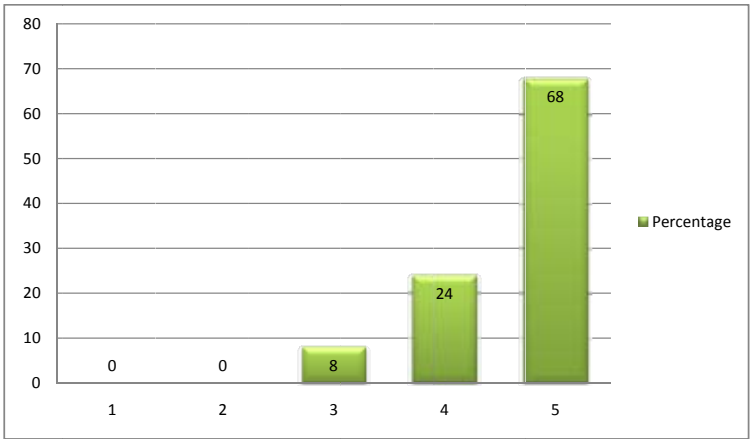

Figure 7. Student responses to the question: "How would you rate the PBL studios in terms of a teaching facility?" expressed as a percentage of the 37 responses in total.

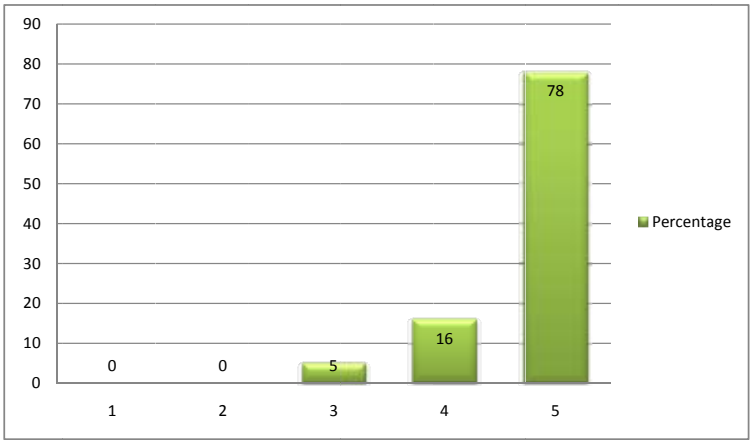

Figure 8. Student responses to the question: "How would you rate the facilities within the PBL studios?" expressed as a percentage of the 37 responses in total.

Technical staff member:

One of the most important things is the fact that the students have the sense of community, and therefore we set up a facility where they had that, where they could come and go, they had the community, they had space where they could sit down, do their work, do their team-based work, and where their supervisors could go in and meet them. The studios have multiple functions, one of which is where they can just go in and work, but then also where they can have their supervisor meetings, their group team meetings, but overall I think the fact that they're all located within the one space gives the students a sense of community.

Dane, 2008.

Moreover, students do not use the spaces exclusively for their PBL activities and for social activities. As noted above, PBL units of study only constitute half of the study load and students also undertake two units that are conventionally taught. While these units tend to utilise individual assessment tasks, the students often work together on these tasks in the PBL precinct. They therefore make considerable use of the PBL precinct for individual and small group study related to non-PBL units.

Academic staff member:

In their studio they don't just all work on their PBL problems, but I have witnessed them working on their tutorial questions, for other subject-based units.

Researcher:

So when they're not required to work collaboratively they're still working

collaboratively?

Academic staff member:

Yes, that's right, for other subjects as well.

Dane, 2008.

How is technology used?

When the PBL precinct was designed, computers were deliberately not installed, on the assumption that most students would bring their own laptops to the studios. Student feedback in the first year of operation indicated that students chose to work instead in the Library or open-access computer laboratories where they could access the internet and do their research more easily. Desktop computers were then placed in the studios and almost immediately student use of the studios increased.

The University's online learning system is Blackboard/WebCT and it was used to support the work of PBL groups, but in the first year of PBL operation its use by both students and staff was somewhat variable:

Participants reported that they found it difficult to find time for face-to-face team meetings. WebCT was offered as a communication tool to complement face-to-face meetings but it was evident that it was not used a great deal... When it was used, students generally just used the basic features. [Some] supervisors encouraged students to use WebCT and reportedly checked the amount of traffic from time to time. Participants from both groups claimed that they were not shown how to use WebCT effectively. In any case, some participants found WebCT clunky and preferred to use other online tools, such as Hotmail and Messenger, for team communication.

Gabb & Keating, 2007: 61.

In broad terms, technology plays a central role in any undergraduate engineering course and the PBL units of study at VU are no exception. As noted above, the PBL laboratories were the site of considerable activity which presented new challenges for the technical staff:

Technical staff member:

There's a very important change in the role of the technical support staff, from problem-based learning, in that it shrinks the gap between academics and support personnel. Because we rely on the students to find out information and learning for themselves to a large extent with the problem-based learning, they will come and ask for help from technical staff… we try and direct them to the source where they can find the information where they will be able to do it for themselves.

When you have the [technical] staff from the beginning, you can work with, because the technical staff has familiarity in terms of facilities, equipment, everything that we have in the school, we are also familiar with how to obtain certain bits of equipment. It helps in saying 'okay, we can plan ahead, we can obtain those things, they're quite cheap', instead of 'oh, that's going to cost us a lot of money if you want to go in that direction'. So it sort of gives you a bit of perspective in what sort of projects we can do.

It's almost like the PBL cycle we go through, we sit down, we brainstorm, then we go, everybody goes off working with particular parts of the [problem], then we come back and we produce a problem for the students to work on. So it's sort of like the PBL process in what we're doing in terms of planning the PBL problems themselves.

Dane, 2008.

When all the PBL facilities are eventually completed, they will include a range of laboratories for students at different year levels:

> *Technical staff member:*
>
> *This room has been decked out with computers where they can run simulations and things like that, as well as a section on where they can just do soldering, but also for testing and for checking their circuits with the test and measuring equipment… we have generators, power supplies, frequency counters, which they will be able to use and which they do use, as well as computers with computer aided design software, simulation software.*
>
> *Academic staff member:*
>
> *Every team has a dedicated time and a bench in the soldering area…to avoid a lot of groups going into the laboratory and hogging the laboratory I suppose, this is integrated into the timetable.*
>
> *Technical staff member:*
>
> *We have two new laboratories being built there, where the students will be able to manufacture circuit boards, so that will allow our students to go from the design stage of electronics through to the manufacture of completed products.*
>
> *Dane, 2008.*

How was the facility evaluated?

The student experience of PBL is evaluated each year. After the first year of operation in 2006, a comprehensive report based on a series of student questionnaires and focus groups was prepared. It found that the students were generally positive about their PBL experience:

> *...Students on the whole reported enjoying PBL. In particular, the hands-on style of learning and working in teams were aspects that many students enjoyed. They were also mostly supportive of what PBL was designed to achieve and they generally understood the principles of PBL, such as self-directed learning, collaborative learning and a focus on engineering practice. There was general agreement that this style of learning would help prepare them for working life. They appreciated the importance of developing the capabilities of working in teams, communicating effectively and managing their own time and their own learning.*
>
> *In their questionnaire responses and in the focus groups, most students reported learning a great deal from their PBL experience. Most reported improvements in generic skills such as working without direct supervision, writing both technical reports and reflective reports, working on problems, working effectively as a member of a team, reflecting on their learning, working without direct supervision, speaking in front of a group and managing their time effectively. Most also agreed that they had learnt technical skills and knowledge in PBL, although in second semester they were less sure that they had learnt much in the way of technical skills and knowledge. In both semesters, the students were less sure that they had learnt about using the library or about diversity. Most students were also doubtful that they used what they learnt in PBL in their non-PBL subjects...*
>
> *Students consistently identified the role that working in teams played in helping them to develop friendships within the class, especially in first semester. The value of this cannot be understated, as social integration in first year university is considered an important factor in student retention. Given the University's current focus on improving the retention of its students, this is an encouraging finding.*
>
> *Gabb & Keating, 2007: v.*

This substantially positive evaluation did not focus on the PBL precinct as such, although it was the stage on which both students and staff performed. When explicit questions were asked in student focus groups about the facility, the response was positive:

> *...students liked the new studio spaces and liked having the individual team suites. However, they noted that [they] would like access to computers in their PBL suites rather than having to go out to the PBL multipurpose room:*
>
> *"I think it would help if each room has, like, has a computer or … so then if we need to, like, access our email when we're discussing stuff or we need to show something on a computer screen, it's right there. We do not need to go out of here."*
>
> *They also commented on other minor issues including that markings on the white boards weren't easy to rub off and that they would like a fridge in the multi-purpose room.*
>
> *Gabb & Keating, 2007: 60.*

Stojcevski administered a short questionnaire on the PBL studios to the 2007 cohort in which students were asked to respond to the following:

- How would you rate the PBL studios in terms of a teaching facility?
- How would you rate the facilities within the PBL studios?
- Please also provide your comments in terms of the benefits and difficulties, in terms of the PBL studios used as a teaching facility?

The response scale used for the first two items was 1 (Very poor), 2 (Poor), 3 (Good), 4 (Very good) and 5 (Excellent). The results for these two items are summarised in Figures 7 and 8 below.

In addition, 32 of the 37 students responded to the third open-ended item; "Please also provide your comments in terms of the benefits and difficulties, in terms of the PBL studios used as a teaching facility?" These responses were subjected to content analysis and the following common themes identified:

Benefits

- Dedicated space for each team for the entire semester.
- Supervisors know where to find students.
- High-quality technology.

Difficulties

- Initial access problems (electronic key allocation).
- No microwave and refrigerator supplied.

These results suggest that the students strongly valued the PBL studios and appreciated both the space itself and the equipment provided. Their responses to the open-ended question indicate again that they identify the space as "theirs" and their only real request is to make the space more "home-like".

After interviewing staff members, Dane (2008) reported there is consensus that the PBL precinct has been a tremendous success, supporting the range of PBL activities in which students, technical support staff and academics engage. A number of interviewees spoke of the sense of community that has been achieved by creating a physical environment that enables collaboration, with access to appropriate and relevant resources. The contention is that students become independent learners in a supportive environment that brings them into contact with practice-related problems.

What are the main lessons learned?

The design of the PBL spaces influenced both student and staff behaviour. The studios encouraged students to work collaboratively within their teams on a range of tasks, PBL and non-PBL related, whereas the common space encouraged cross-team activities within the larger group. Because the PBL precinct was "colonised" by the students, teaching staff used the space with less authority than they demonstrated in traditional teaching spaces such as lecture theatres and laboratories. Thus, the design of the space reinforced the shift in staff role from instructor (i.e. "sage on the stage") to facilitator (i.e. "guide on the side"). In another VU PBL program not reported here, individual studios were not constructed and the main space in that precinct closely resembles a classroom. Not surprisingly, staff members that teach in this space were more likely to slip into instructor mode and the students demonstrated less signs of ownership of the space.

Students greatly value having their own place, especially on a campus with limited spaces for social interaction. The campus has few spaces where students can gather, other than two fairly spartan cafeterias. Thanks to recent landscaping work, there are now several external spaces where students can meet in good weather but there are very few internal spaces in inclement weather. It is therefore not surprising that the students used the meeting spaces provided in the PBL precinct, especially when a computer was provided in each PBL studio.

It is important to involve both academic staff and technical staff in planning and development of PBL problems/projects. At least half of the work of a PBL student revolves around the PBL project and most projects involve designing, building and testing equipment. Providing facilities for this "hands-on" work is therefore an important design consideration. Members of the technical staff were initially involved in this process mainly because of their expertise in occupational health and safety but, as some of the interview data reported above attests, their contribution extended well beyond this. Indeed, technical staff members have a key role to play not only in designing the physical facilities but also in designing the projects that drive the activity in the facilities.

It is also important to provide some desktop computers rather than relying on student laptops. The initial assumption was that the students would use their own laptops in the PBL precinct, so no desktop computers were installed. Frequent student requests for computers in the PBL studios showed that this assumption was incorrect. Installing a desktop computer in each PBL studio then led to increased student usage of the studios. It is not known whether a preference for using University machines represents a low level of laptop ownership by this group of students, an unwillingness to lug heavy laptops around all day or a preference for working collaboratively around a larger screen. This is a topic requiring further research. Both the high level of usage of library computers and a recent survey of VU students confirm that, despite the fact that most students have broadband access at home, there continues to be a strong demand for open access computers on campus (Gabb *et al*., 2007). For these students, at least, the age of the omnipresent laptop has not yet arrived.

The PBL precinct enables students to develop a sense of community and ownership of studios, leading them to use the precinct for activities other than their formal PBL units. When appropriate resources are conveniently located and students are provided with facilities they feel comfortable to use, the facilities appear more likely to be well utilised. In the initial implementation of the PBL studios, there was some concern that the facilities were not being well used. Informal feedback from students confirmed they were going elsewhere primarily to access computers, which instigated the installation of fixed computers into the studios. From this point on, utilisation of the studios improved noticeably.

The proximity of studios to each other also contributes to the sense of community in the precinct. Student teams can interact with each other, develop friendships, discuss assignments, and generally provide each other with collegiate support. The PBL common room is essentially a social space, allowing students to interact informally through eating, playing computer games, and watching DVDs, etc. That these activities are not discouraged contributes to the sense of belonging students have in that environment, making it more desirable for them to be there with their colleagues, rather than "somewhere else". In this kind of physical environment social activities tend to blend more seamlessly with educational activities, leading to an increase in collaborative learning and ultimately to increased retention and engagement of students. The research literature on retention tells us that both academic integration and social integration are central to retaining students, especially in their first year (Gabb *et al*., 2006). It also tells us that collaborative learning activities and informal interaction between students and staff improve integration. PBL emphasises both of these activities and the PBL precinct provides spaces that support and encourage these important functions.

References

Dane, J. 2008. Data collected for doctoral thesis entitled: "New Generation Learning Environments in Higher Education", Monash University, (thesis in progress).

Engineers Australia. 2006. Engineers Australia Policy on Accreditation of Professional Engineering Programs, Document No. P02, Engineers Australia, Barton ACT, viewed on 29 July 2008, <http://www.engineersaustralia.org.au/shadomx/apps/fms/fmsdownload.cfm?file_uuid=0B1B282A-EB70-EC35-6B21-BB84E8F0C8E7&siteName=ieaust>

Gabb, R., Milne, L. & Cao, Z. 2006, Understanding attrition and improving transition: a review of recent literature. Postcompulsory Education Centre, Victoria University, Melbourne.

Gabb, R. & Keating, S. 2007. PBL in Engineering: student perspectives 2006. Postcompulsory Education Centre, Victoria University, Melbourne.

Gabb, R., Keating, S., Inglis, A., Dixon, J. & Perri, F. 2007. Making e-learning inclusive: a survey of VU higher education students. Postcompulsory Education Centre, Victoria University, Melbourne.

Kolmos, A., 2006. Why PBL?, PBL models, lecture: in Session 1, Topic 1, Masters in Problem Based Learning: Aalborg University, Denmark, 2006.

Parr, P., Submission to Higher Education Course Approvals Committee, Victoria University, "Proposal to Introduce a Problem Based Learning Curriculum to the Bachelor of Engineering Degree Courses Commencing with First Year in 2006, Overview and Background Briefing", July, 2005.