Student experiential learning

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Abstract
The Faculty of Built Environment and Engineering at QUT is dedicated to providing learning environments and experiences that are needed for graduate work-readiness and has been working toward redevelopment of laboratory areas to meet this aim. The Faculty has developed new ways of providing experiential learning environments that utilise space more effectively and have a high utilisation by students. The Faculty's Student Experiential Learning Centre (SELC) is a particular application of this approach that integrates and expands a number of initiatives to make practical laboratory and studio work a more exciting and meaningful learning experience. SELC's web based preparatory modules lead students through to individual or group physical tasks in which students conduct their own individual laboratory sessions unsupervised, in their own time and at their own pace. Instead of replacing important laboratory exercises with virtual experiments, SELC exploits the power and versatility of computer and web technology to complement and support students' individualised physical practical work. This rich, student focused environment is interactive on both the virtual and physical realms and is able to recapture student enthusiasm for discovery of knowledge and consolidation into understanding through application. This approach has enabled a redefinition of the role of laboratory programs and an integration of those programs into the curriculum in a way not possible previously. This paper reports on the outcomes of two surveys, one conducted in 2003 on the pilot program comparing the new approach with the more traditional staff-supervised approach and again in mid-2005 to see how students responses varied from the earlier survey.

Learning and Laboratories

How do we really learn to DO something? If we wish to fly a plane there is absolutely no substitute for sitting in the front seat and doing it. No amount of lectures, books or theory will suffice for the white knuckled grip of the controls on your first landing. No passenger would entrust their life to a graduate from a flight school with no aircraft.

On talking with a student about writing a paper on this subject she commented "Why do you need to reference other papers about the value of learning-by-doing? Isn't it just common sense". Even so there is a myriad of sources confirming the proposition that we learn best by doing, while recognising that learning is a combination of many different interactions.

The Cone of Learning shown in Figure 1 was introduced by Edgar Dale in his textbook on audiovisual methods in teaching. The model presents a visual classification of learning experiences from most active and concrete to abstract.

Commentators on work by Dale caution against using his model to push a specific learning style and remind us that Dale[1] stated this. "Abstractions must be combined, if we are to have rich, full, deep, and broad experiences and understanding. In brief, we ought to use all the ways of experiencing that we can."

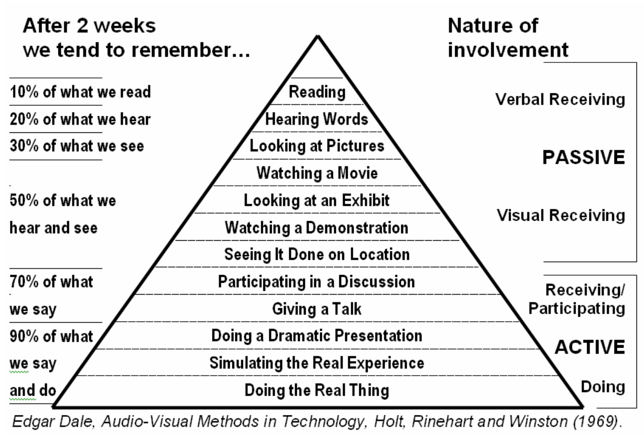

Figure 1 Dale's Cone of Learning

Appropriate methods should be used for the learner and the task. His bias regarding use of media appears to be for a rich combination of concrete and abstract experiences.

Engineering and other applied disciplines have a solid history of applying the principle of learning by doing in laboratories, field trips, projects, design projects and the like. The value of laboratory learning is well recognised and prescribed as requirements for accreditation of engineering courses by bodies such as Engineers Australia (EA) and the Accreditation Board for Engineering and Technology (ABET) in the USA. Accreditation teams are very critical if they perceive inadequacies in practical experiences but not as critical as students whose expectations are not met. Saying that laboratories and practical work are important may be stating the obvious but we need to remind ourselves of their value and look for ways to gain more value if they are to be sustained.

Economic rationalisation within universities has seen a trend for larger classes, higher student/staff ratios and a reduction in high cost program components such as laboratory and design studio work. The historical trend for engineering and science faculties has been to adopt the "easy" approach and reduce the amount of laboratory and studio work contained within degree programs or to replace the classical "hands-on" approach with computer based simulations or "virtual laboratories". Computing solutions and the virtual laboratory approach, while providing excellent learning opportunities for students, do not substitute for the real thing and still requires significant resources to implement and maintain. The result, unfortunately, is a decline in laboratory learning[2].

The question is not "is experiential learning important?"; it is "how can experiential learning be achieved, sustained and improved?".

Response to Needs

Due to a number of impacting factors in the late 1990s and the recognition that action was required to revitalise laboratory based teaching, staff in the Civil Engineering discipline of the Faculty of Built Environment and Engineering at Queensland University of Technology, commenced working on a concept to address the needs.

The laboratory teaching of most units was carried out using equipment and techniques of 70's technology that:

- Provided students with limited accessibility to laboratories during their time at QUT.
- Was resource intensive both in materials and staffing by academics and technicians.
- Lacked the desirable dynamics of small group work that model the real world.
- Did not integrate well or utilise the benefits of computing and web technology.
- Were unsafe for individual students to use without extensive training.
- Did not provide a sense of control or empowerment for students.
- Moved from active to passive learning as classes got larger and resources less.
- Failed to develop life long skills required in a graduate.

A major reconstruction of courses within the Faculty gave Civil Engineering a timely opportunity to develop a course which was far more student-centred than in the past, and is now focussed very much on the progressive development of students' generic as well as technical skills. As part of this development, a grant was obtained from a Faculty initiative fund to create a laboratory system specifically designed for use by students under minimal to zero supervision by staff. Equipment was planned to be installed in a secure, safe space and be constructed such that students could conduct individual or small group, model-scale experiments on the properties of construction materials, at any time the building is open for public use. Consequently, there would be great scope for students not only to investigate relevant principles more widely than has been possible in previous large-group tests of large single specimens, but also for students to design their own experiments to study such principles in a more meaningful way.

This facility for construction materials would be a student centred learning environment with high usage and incorporate other learning elements such as web based preparatory modules. Safety mechanisms and safety training, assessment and control were a vital part of the plan for the concept. Such a flexible learning environment fits in very well with the new course emphasis on developing generic skills. The staff of Civil Engineering had gained good experience previously in developing student-centred resource facilities; for example a Geomechanics resource centre had been set up so students could use the centre freely and at their own pace, with a wide range of hard copy and computer based materials at hand. This approach was fundamental in the design of the proposed construction materials flexible laboratory area and would allow students to interact with physical equipment and materials. So, instead of replacing important laboratory exercises with virtual experiments we are utilising the power of computer, web and physical technology to work with, compliment and support important practical work.

A core team including academic and technical staff worked on the project to bring it to fruition. In addition, a reference group of other educators in the Faculty and from other Faculties and students assisted in the conc ept development. The expertise of IT developers, mechanical design fabricators and administrative staff was also utilised. This collaborative team approach was central to the success of the project.

The SELC Concept

The new facility was given the name Student Experiential Learning Centre (SELC).

- Student: Student focused, requiring each to personally engage with the activity.
- Experiential: A real hands on experience interacting with equipment, materials, systems and people.
- Learning: Learning through a variety of media, primarily constituting "active learning".

- Centre: A physical space providing a centre for activity and integrating physical and virtual resources.

SELC is both a reflection and a driver of QUT's Faculty of Built Environment and Engineering vision to provide rich learning environments and develop new virtual and physical facilities to progress this aim. The SELC concept of on-line preparation for hands-on experimentation is being expanded across the Faculty as further student-centred implementations are developed. The Faculty has recognised that all engineers, construction managers and architects must have an appreciation of the performance of construction materials. Although able to be supplemented by computer simulation and web based resources, this learning can only be truly achieved in a hands-on teaching laboratory[3]. The hands-on experience adds value and aides in the visual orientation of the learner by seeing and doing[4].

The SELC concept ensures that laboratory-based studies will continue for students in the Faculty and, more importantly, in ways much more meaningful to students. A high level of control exists for students using SELC, because responsibility for conducting tests has been devolved to the students themselves. Through integration of computer based learning modules and management systems in a variety of media, the richness described by Dale's model now becomes available to students. SELC now has a central role in developing junior students' generic skills of self-management, life-long learning and teamwork; it also encourages an enjoyment of enquiry and exploration.

Continued Development

Building on this approach the Faculty is exploring other possibilities utilised by institutions such as the University of Colorado, the University of Idaho and Queens University in Canada. The University of Colorado's Integrated Teaching and Learning Laboratory (ITLL) presents a unique model of integration and realised visions[5]; see Figure 2. The ITLL vision was developed by university staff, students and industry representatives and is based on full integration of disciplines in a centralised space with strong teaching and learning focus. It has been operational since 1997. Many education conference papers document the success of the ITLL.

Figure 2 Lab Plaza ITLL

The facility is supported by many donors who believe in its worth with Hewlett Packard describing it as "….one of the finer teaching environments on the planet".

The School of Mechanical Engineering, University of Idaho has implemented a facility called the Idaho Engineering Works (IEWorks) that embodies many of the concepts that enhance learning and utilise space in the process. IEWorks stresses human dynamics, communication, teamwork, personal reflection and professionalism. Much of the learning is related to surroundings and to social processes, according to documentation from the University of Idaho team[6]. The team also proposed the Idaho Mind Works concept that will expand on what has already been achieved and builds on what they call "the enriched learning environment model: a community for learning". Physical space with an experiential learning focus is central to the model. Some of the ideas on student instructors incorporated in the recent Idaho proposal have been based on and credited to work by Dr Martin Murray from QUT.

The Integrated Learning Centre (ILC), Faculty of Applied Science, Queens University, Canada is another example of an advanced learning environment. It incorporates many features that facilitate active learning, teamwork, lifelong learning, elevating theory to practice and student focus [7].

While facilities such as those established at Colorado and Queens have required millions of dollars in investment, the concepts and philosophy behind them can be implemented with modest resources. The SELC system at QUT embodies much that has been done by these other institutions and will set a framework for continued developments in experiential learning in QUT's Faculty of Built Environment and Engineering.

SELC – Materials Facility

The construction materials testing facility in SELC consists of approximately 130 m^2 of floor space for undergraduate laboratory teaching and discovery learning (Figure 3a) and consists of:

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- Three (3) self-contained universal testing stations with load cells and data acquisition systems.
- An adjacent student resource room for evaluation of data from the above equipment with network access. This is a linked space that allows students to study and work on projects that are integrated with practical work in the laboratory.
- Associated on-line and hard copy instruction modules for use in the resource area by students in self-paced learning.
- Provision of manuals, guides, videos, texts, standards and equipment.
- Moulds and rigs for manufacturing and testing various materials.
- Safety controls for all equipment.

The facility has card access and video monitoring and can be accessed at anytime that the building is open (generally 7am to 10pm). The adjacent student resource room (Figure 3b) has interchangeable workstations, framed contextual photographs of engineering projects (donated by industry) and relevant artefacts that students find is conducive to both group work and individual study. Developments of building component displays are being developed similar to the University of Colorado ITLL, living laboratory concept[5].


Figure 3a SELC Materials Facility **Figure3b Adjacent Student Resource Room**

About 450 students have used SELC over the past two years. The testing machines were first used by students in 2003 with the dedicated resource room coming on line in 2004. As part of SELC, students complete web based learning modules that include health and safety training, assessment, ordering test specimens and booking the equipment. The new facilities will shortly provide equitable and open access for all disciplines within the Faculty, leading to education and financial benefits across the Faculty.

Learning Modules

The self-paced web based learning modules are designed to accommodate multiple locations, experiments and equipment for multidisciplinary uses. The modules are flexible enough to empower students to construct their own experiments, fabricating and testing their own specimens at their own pace and in their own time. Students will therefore become progressively more skilled and confident in using the facility and will see it as an integral part of their learning at QUT. They will be able to evaluate structural assemblies and study all aspects of the characteristic performance of construction materials such as concrete, timber, steel and composites in flexure, compression and tension.

Before students commence the SELC modules they must undertake an online Health and Safety Induction which involves becoming familiar with H&S principles and jargon and must complete an assessment task. On successful completion of the assessment, SELC enables staff to print a H&S contract which is signed by the student and is kept in QUT files. The contract is binding for the duration of their course and promotes a better understanding of the importance and relevance of health and safety to students. The student can then progress to the specified learning modules for any practicals in that unit. Most modules developed to date have centred on guiding students through specified tests on particular materials, but plans for modules are underway utilising "what if" scenarios in the construction area. The learning and instructional modules in SELC are versatile enough to allow academics to design new modules from existing templates without reinventing the wheel, as it were.

Many of the instructional modules in SELC are within the context of an engineering failure in which students must test for material properties of failed components and report on their findings. A reference and learning section has web-based modules on material properties, their behaviour and testing, and includes videos (high speed for on campus and 28k for off campus), animations, and references to prescribed texts in a logical sequence. Students must work through these modules and successfully complete on-line assessments (quizzes and mazes) based on their expanded knowledge about material behaviour, testing procedure and safe operation of the equipment before progressing to the online Booking and Ordering Module and Testing Modules. Progression can only occur if the student has successfully completed all previous stages.

When students reach the Booking Module they must book the required equipment and order the material specimen. Lead time is 48 hours prior to testing. On the test day, the student sets up the test specimen and applies the load through a hand operated hydraulic ram. Load and displacement data are displayed in a graphical format on the computer monitor and saved in digital format. Students produce graphs of the data with Excel and include the graphs and deduced material properties in downloadable report templates which are submitted for assessment.

Students have already capitalised on the new facility by utilising it on their own initiative for evaluating and selecting appropriate materials for subsequent projects in which they experiment with materials (paddle pop sticks, balsa wood and spaghetti) for use in designing bridges, beams and columns in other units. SELC makes practical laboratory work a more exciting and meaningful learning experience. The major advantages of the redesigned facilities come about from a reduced scale of experimentation, utilisation by other disciplines and shifting the emphasis from staff labour intensive towards student accountability. SELC also provides students with a more enjoyable experience, flexibility, more relevance to the real world.

Outcomes of SELC Implementation

As mentioned earlier, 450 students have used the SELC system to conduct formal practical classes in the past two years, 350 within a first year unit MMB131 Engineering Materials, the other 100 within a second year unit CEB215 Structural Engineering 1; informal uses by students also have occurred in some other units. The unit MMB131 covers basic chemistry and study of the material properties of steel, ceramics, plastics, etc; CEB215 focuses on design of reinforced concrete elements.

2003 Survey of Users

The first implementation of SELC was in 2003, in which 100 first year students in MMB131 were required to undertake five practical classes on various materials. One of those practicals was a tension test on a coupon of steel, the others were various bending and compression tests on other materials. In order to pilot the SELC system, the tension test was converted to the student-centred SELC approach; the other four practicals were run in traditional fashion in which the practicals were closely overseen or actually run by technical staff, with a mostly passive role by students.

A survey of the students was conducted towards the end of that first semester to identify how students responded to the SELC concept. With regards to whether they found the SELC approach or the passive approach more interesting, the respondents were evenly balanced. They were also evenly balanced in their feelings about which type of approach helped them learn more.

However, when asked which type of approach they preferred overall, 70% of them said they preferred the passive approach. Now, the SELC practical activities required the students to do all the steps described in Learning Module section above; that is, they had to do the online health and safety quiz, do all the learning and quizzes online, book and order specimens, conduct the test themselves, and so on. But with the four passive practicals, they simply turned up at the session where they were given practical sheets to fill in, told everything, simply watched the technician conduct the test, and then regurgitated it all onto the practical sheets. So, when we explored their preference for the passive practicals, what they were actually saying was they preferred that approach which caused them least work. An understandable reaction!

In 2004 another large group of 1st year students used the system for their practicals in MMB131. Also, students who used SELC in 2003 used the system again in 2004 in the 2nd year concrete design unit CEB215. These 2nd year students constructed their own small reinforced concrete beams and cylindrical compression test specimens and then tested those beams and cylinders using the SELC equipment. None of the 2004 users of the system were surveyed, but the 2nd year students appeared comfortably familiar with the individualised SELC approach and were at ease using the SELC testing equipment. From observations and anecdotal evidence, these 2nd year students appeared to appreciate the way the SELC approach enabled them to observe and learn about how reinforced concrete behaves at a time and pace that suits them.

2005 Survey of Users

To date in 2005, 99 first year students in MMB131 have been required to undertake four practical classes, three of which were SELC type tests of tension, bending, and compression properties, and one was a technician-run Charpy impact test. A second survey was conducted to see how students' responses may have changed since the pilot implementation of SELC two years previously.

Twelve questions in the survey asked students to respond on a 5 point Likert scale of 1=strongly agree, 2=agree, 3=neutral, 4=disagree, 5=strongly disagree. The questions covered topics such as: whether the instructions on finding their way through the online part of SELC were easy to follow; if watching the video clips was essential in preparing themselves to test one of the material specimens; was being able to repeat any specimen test if anything went wrong was important to their learning; how interesting was it being able to do the practicals by themselves rather than standing with other students simply watching a technician run a practical; and so on.

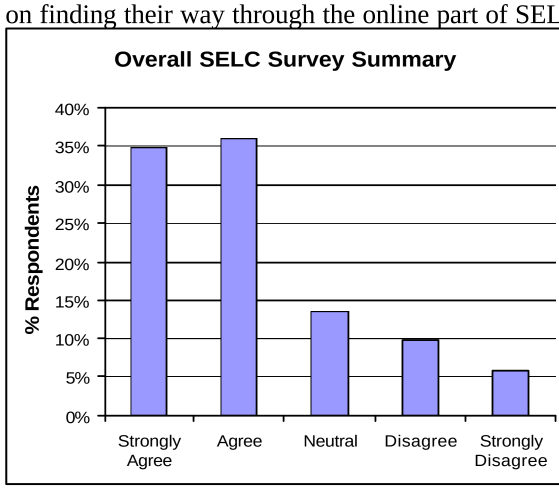

Figure 4. 2005 Survey Results

Three more questions sought their written comments on what they would do to improve SELC, what parts of SELC appealed to them and why, and what annoyed them about SELC and why.

An average of 72% of respondents agreed or strongly agreed with the survey questions overall, while 13% were neutral and 15% overall were unhappy to some degree with the system – see Figure 4. For those few unhappy users, the responses mainly reflected a desire to be a passive learner; that is they preferred to be told what was happening in the tests and to learn from the master, as it were. Other negative responses tended to mention frustration with the inevitable server crashes, computer glitches and the like.

Of all the survey questions, the ones receiving the strongest agreement were related to: the online system being easy to access; being able to repeat the practical; and being able to do the practical themselves. The questions receiving the strongest disagreement were related to: everything not going well with testing of the specimens; and preferring SELC practicals to other types of practicals. However, it must be pointed out that the difference between the overall mean response to the most agreed question (mean response equivalent to "Agree") and most disagreed question (mean response between "Agree" and "Neutral") was not large.

The overwhelming majority of the users liked the concept, but especially liked the aspect of personal control over the whole process and the ability to keep trying until they got it right, both online and with the physical tests. This aspect of personalised control over the practicals particularly featured in the written comments of the students. Very few indicated a preference for practical classes in which they had only a passive role.

So why was there a very great difference between the outcomes of the surveys conducted just two years apart?

In 2003 the students did just one SELC practical, with their four other practicals conducted under technician supervision or conducted wholly by a technician. The SELC practical therefore was viewed by the students as a minor assessment task and an exception to the normal routine of practicals, but one that required considerably more effort than the practicals in which they were passive. It was also the first implementation and because some hardware and software glitches inevitably arose, some students were a little offside about the system.

In 2005 students were required to 4 practicals, 3 of which were done via SELC, so SELC was now the major experience of how practicals operate in that unit. Once they had done one SELC practical, the amount of effort to prepare for and conduct the next two SELC practicals was relatively small. Finally and importantly, virtually all the bugs had been removed by the time of the 2005 survey and so any problems the students had were almost always caused by the students themselves, primarily through not conducting a practical as instructed.

As with any innovation, where the changed approach is the exception, there can be resistance and discomfort; but where it is perceived as routine and the norm, there is much greater acceptance and appreciation of its benefits.

Conclusions

This new approach to undergraduate laboratory testing (SELC) has not only empowered students to take responsibility for their learning, but also redefined the role of laboratory programs by integration more strongly into the curriculum. Students who have utilised SELC have demonstrated improved skills and feel that the new learning experience offers benefits to their learning not possible in traditional laboratory sessions. Provision of experiential learning environments has allowed a shifting of emphasis from staff labour intensive to student centred discovery and accountability. Other benefits include:

(a) the opening up of exciting possibilities for efficient and student-focussed safety management and laboratory testing for undergraduates across the whole faculty;
(b) students doing their own laboratory tests as many times as they wish, at their own pace and at a time convenient to them, instead of simply observing one specimen being tested by a technician at a place and time and in a manner all under the control of others;
(c) the overwhelming majority of students preferring the fully-integrated student-centred approach over the passive role they often experience in staff-driven practicals;
(d) being able to apply, with modest funding, concepts similar to other institutions that have invested millions of dollars in integrated student centred learning facilities, but still leading to significant positive outcomes for students and the faculties engaged in experiential learning;
(e) utilising a collaborative team approach to the development of learning environments such as SELC, including academic and technical staff and students in the team.

References

1. Dale, E. (1969) Audiovisual methods in teaching, third edition. New York: The Dryden Press; Holt, Rinehart and Winston.
2. Rasmussen, G & Topoonyanont, N (2004). Learning Environments – Laboratories at the Cross Roads, In proceedings of 7th UICEE Annual Conference on Engineering Education. pp. 119 - 122, Mumbai, India.
3. Dawes, L.A., and Bullen, F., (1999). "Enhancing the development of generic skills using project based techniques". 2nd Annual UNESCO Conference on Engineering Education, Auckland Institute of Technology, 210-214.
4. Bullen, F., Dawes, L.A., Rasmussen, G., (2000). "Lab-otomy The virtual Engineer". 3rd Annual UNESCO Conference on Engineering Education, University of Tasmania, *Keynote Address*, 51-56.
5. Carlson, L.E. and Sullivan, J.F. (1999), "Hands-on Engineering: Learning by Doing in the Integrated Teaching and Learning Program," International Journal of Engineering Education, Volume 15, Number 1, pp. 20-31.
6. The Enriched Learning Environment Model: A Community for Learning, An NSF proposal by the School of Mechanical Engineering at the University of Idaho USA
7. ILC web site Queens University, Ontario, Canada. http://appsci.queensu.ca/ilc/vision/

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