

Activity and engagement – keys in connecting engineering with secondary school students *

L Dawes[†] and G Rasmussen
Queensland University of Technology, Brisbane

SUMMARY: *Key factors in developing understanding of engineering among secondary school students are real-world, activity-based experiences. Active learning experience is the foundation of a program developed by the Faculty of Built Environment and Engineering at Queensland University of Technology (QUT), in association with Queensland secondary schools. The “Secondary Schools and QUT Engineering Activity Kits”, or “SQUEAK” program, is an initiative that involves building relationships with secondary schools, motivating and providing role models for engineers of the future, and attracting more students to an engineering career. The program promotes engineering as a profession, increases awareness of the role of engineers in society and benefits students making the decision to study engineering. It assists in attracting quality students to engineering disciplines, addressing long-term shortages in the engineering industry and declining engineering enrolments in some disciplines. It helps secondary school students in connecting real-world engineering with studies of science and mathematics in schools. The connection is enhanced by final-year engineering students visiting high schools with hands-on, practical, problem-solving activity kits, where they engage with the class over one or more lessons. The activity kits are designed to be fully integrated within the subject curriculum. Teachers have part of their curriculum presented by young aspiring engineers in context-rich, group-based activities. All stakeholders benefit from the experience, with many questions being raised about the core material, engineering issues, studies and university. The activity kits developed specifically for this program are well grounded in engineering principles, and can be incorporated into science, engineering and mathematics curriculum, giving students a contextual basis for learning technical subjects. Although best presented by engineering students, they may be used by teachers alone. This paper reports on the success of the program over the past five years, and presents evaluations from both a teacher and student prospective.*

1 INTRODUCTION

The proportion of year 12 students studying appropriate enabling subjects in mathematics and science has continued to decline at the same time that skill shortages in engineering have emerged. Students often comment that study in these areas is based solely on facts and is mostly irrelevant to the real world. Engineering is an exceptional context in which to showcase the relevance of their studies to real examples. It is imperative that secondary school students not only be well informed about career options available within the engineering disciplines, but they also see the links between engineering and

these enabling subjects before making their subject choices in the senior years (Downing, 2006). Activity-based experiences leading to increased student engagement are seen as key factors in attaining these goals. Experiential learning activities run by final-year undergraduate engineering students reinforces the connection between classroom theory and real-world engineering, and demonstrates the importance of studying science and mathematics.

One of the major difficulties inspiring students about careers in engineering is that their main source of information, their teachers, are usually not much better informed than the students themselves (Millican et al, 2005). A review of science, engineering and technology in Australia suggested that new ways of making science and engineering subjects more appealing to students needs to be developed with partners outside the school system, and that these partnerships could also provide students with valuable insight into science and engineering careers

* Reviewed paper originally presented at the AaeE 2006 Conference, Auckland University of Technology, 10-13 December.

† Corresponding author Dr Les Dawes can be contacted at l.dawes@qut.edu.au.

(Batterham, 2000). The SQUEAK program aims to help fill this gap, by offering contextual experiences within the classroom related to theory, along with experiencing engineering in fun and interesting environments. It also supports teachers by using problem solving activities that reduce the separation between abstraction of theory and experimentation. Feedback from teachers, students and engineering students involved in the program are included in the relevant sections of the paper to highlight points and add to the overall performance measure analysis.

The SQUEAK program was initiated as a result of declining tertiary engineering enrolments in the late 1990s and anecdotal evidence suggested that students did not choose engineering simply because they did not know much about the profession. Surveys of secondary schools students over the past four years has shown that this is still the case, with many students identifying engineers main responsibilities as building things and driving trains. To support this, Cunningham et al (2005), in a study in Boston on 504 students, concluded that "though we all are surrounded by the products of engineering in our everyday lives, students and the general public don't understand what engineers do". A study commissioned by the Engineering and Technology Board (UK) of 1011 year nine students found that students lacked understanding about careers in engineering and science. In Australia, a study by Macquarie University (2006) of over 1300 secondary school students identified comparable findings.

2 ENGAGEMENT

There are many programs aimed at developing an awareness of what engineers do and addressing the declining engineering numbers both in Australia and in the US. These programs generally fit into the following categories: competitions, summer schools, speaker programs, site visits, career advisers and teacher resources. Some examples of these include Project Lead the Way (PLTW), which is a hands-on, contextual curriculum that uses an interdisciplinary approach based on national state and local science, technology, engineering and maths standards at Purdue University. Authentic Teaching Alliance (ATA) is a National Science Foundation (NSF) sponsored program in which University of Oklahoma fellows (undergraduates) from engineering and education disciplines team with school teachers to design, implement and assess authentic, inquiry-based activities to teach secondary science and mathematics. At the University of Boulder in Colorado, through the support of NSF, an elective for ninth grade students called Creative Engineering enhances student learning through experiencing hands-on inquiry-based engineering to instil knowledge of engineering as a career and to provide an appreciation of engineering as the creation of things for the benefit of society.

In Australia, The Engineering Link Project focuses on helping motivated high school students make informed choices about engineering as a career, and encouraging more high school students to study mathematics and science at secondary level. The Science and Engineering Challenge run by the University of Newcastle introduces applications of science and engineering to year 10 students in the form of simple activities to solve problems, develop teamwork, and encourage the students to take up study in science and mathematics subjects in senior years.

Many of these programs are on the right track and seek to engage the student, albeit in some cases for a short duration. Follow up and reinforcement are required to increase their impact and overall effectiveness. What differentiates SQUEAK from other Australian programs is that this program, developed with secondary school teachers, runs in parallel with the school curriculum and enables students to relate their experiential learning with theory in the classroom. The timing of the school visits are coordinated with the teacher and students learning sequence over years 11 and 12. This is supplemented by facilitated visits to university engineering laboratories, where school students experience first-year engineering classes. One aspect this program has in common with a number of the US programs is using final-year engineering students to run the program. Feedback from school students over the past four years confirm that the connection between the younger university students is valued far greater than using lecturing staff.

The program pursues similar guidelines to Douglas et al (2004) for improving engineering education and outreach. These include:

1. hands-on learning – less theory based and more context-based
2. interdisciplinary approach – add technological component
3. standards – use engineering in lessons that map to standards in mathematics and science
4. improve teachers – engage more teachers in outreach efforts and curriculum writing
5. make engineers "cool" – create more mentors and role models
6. partnerships – create better incentives for groups to engage in outreach.

This should not be seen as a magical list, but these guidelines offer a broader base for improving the quality, methodology and engagement of engineering education in schools.

The goals of the SQUEAK activity kits are to enable students to directly experience the relevancy of their education to "real-world" problems, as well as experience a direct link between their education, their

community and themselves. Rather than didactically focusing on memorisation of factual information, the activity kits are designed to engage students in personal construction of new knowledge, promote disciplined inquiry and help students see the value of the learned material beyond the classroom. Rhoads et al (2005) supports this approach and reports on the effectiveness of authentic teaching to 1500 secondary school students, where students taught authentically consistently outperformed those taught by traditional methods.

Authentic or experiential learning is a pedagogical approach that defines learning as “the process where by knowledge is created through the transformation of experience” (Kolb, 1984). Kolb states the process of experiential learning can be thought of as a four stage process:

1. concrete experience
2. reflective observation
3. abstract conceptualisation
4. active experimentation.

The cycle is a continuous process with the current “concrete experience” being the basis for observations and reflections, which allow the development of a “theory”. This theory is then tested in a new situation to lead to a more concrete experience. Similarly Dale’s (1969) Cone of Learning presents a visual classification of learning experiences from most active to abstract. 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 (Dawes et al, 2005).

Felder & Silverman (1988) evaluated the impact of engineering students’ approaches to the effectiveness of learning and developed the Index of Learning Styles that assesses preferences for learning in four dimensions:

1. Visual (verbal learners)
2. Sensing (intuitive learners)



Figure 1: A student group is assisted by an engineering student (back).

3. Active (reflective learners)
4. Sequential (global learners).

Students do not have one fixed learning style; they have particular modes of learning that are more dominant than others. The SQUEAK activity kits are designed to accommodate different learning styles. Studies showing that students exhibit a stronger preference for the active sensing, visual and sequential learning styles indicate that integrated active teaching can have an enormous impact on engineering education (Haque et al, 2005; Ohland et al, 2005; Avery et al, 2003).

3 SQUEAK PROGRAM

SQUEAK is the result of successful collaboration between staff members from the Faculty of Built Environment and Engineering at QUT and various secondary schools throughout southeast Queensland. Commencing in 2002, the program originally targeted the senior subject Engineering Technology (ET), as it is an ideal subject for students wishing to undertake an engineering career. The ET curriculum gives a good grounding in engineering across all disciplines, including studies in materials, mechanics, control systems, industry and society. The subject draws upon the fundamental principles of science and technology, encouraging a positive interest in the translation of theory into practice. Since 2005, Maths C and Physics subjects have been included in the program with exercises developed by enthusiastic secondary school teachers and tertiary academics that use the existing activity kits. Over 1500 students have participated in the SQUEAK program.

The SQUEAK program is all about high school students engaging in activity related to their studies and the engineering context. The name “SQUEAK” was coined by Tracie, the program’s first project officer and a full-time, final-year undergraduate student. The “Secondary Schools and QUT Engineering Activity Kits” program should probably be called SSQUTEAK, but who would have been able to say that? Tracie thought SQUEAK would make itself heard and be an appropriate onomatopoeia.

Final-year engineering students visit high schools with hands-on activity kits where they engage with the class for the subject period. Each kit activity is designed to be fully integrated with the subject curriculum so teachers have part of their curriculum presented by young aspiring engineers in a context-rich, group-based activity. One activity type is used per class session with all students working in groups to complete the activity. Three or four school students normally work together, as shown in figure 1, where they are constructing the suspension bridge with a little guidance from the engineering student at the back of shot.



Figure 2: Engineering students training with the concrete kit in a QUT laboratory.

Final-year engineering students are trained in using the kits and in the skills required for leading high school students through the learning experience. A high level professional approach to the task and communication ability is required of the engineering students, and not all students are selected for the program. One or two final-year students are appointed to coordinate the program each year. The appointment is made in the last quarter of the year prior to their final year. This time is used to transition between coordinators and is an important aspect of sustaining the program operation. Coordinators are paid appointments, while all other engineering students undertake the task in association with a unit being studied or purely for the experience, skills learned and community service. Coordinators help develop at least one new activity kit in their year, recruit and train the engineering students, liaise with high school teachers to initiate school participation, and keep the kits prepared and stocked for use. The

selected engineering students undertake training, as seen in figure 2, arrange a time to visit their school and work in pairs to visit the school to conduct the activity.

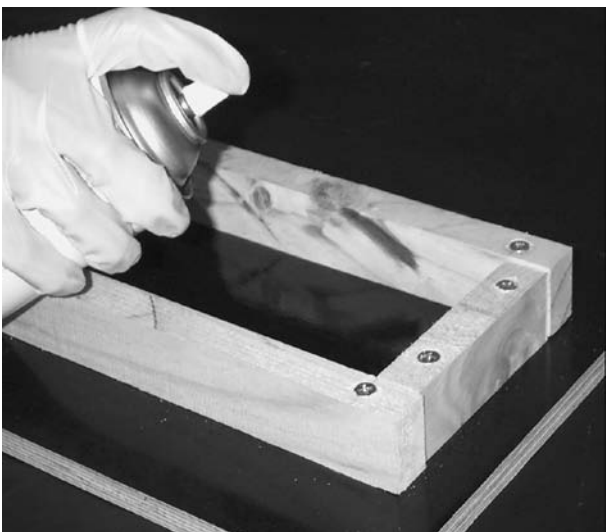
3.1 Activity kits

A pilot program commenced in 2002 using two activity kits, Moments and Concrete, with 20 fourth-year engineering students visiting nine high schools. Kits have since been developed for Bridges and Water Treatment Plant, with an Ergonomics kit in the development stage. Some schools have joined and left the program, with between 10 and 14 in the program each year. Significant expansion of the Engineering Technology subject is expected over the next few years (QSA, 2006).

Each kit is contained in a modular format, and includes all equipment and material to complete the activity. Instruction books set out all the users need to know, including learning objectives, words to know, key concepts, timing, instructions, work sheets and contextual information. Clear instructions and photos, as seen in figure 3, set out the steps.

"The kits were outstanding. Everything was provided and well prepared. Relevant to our curriculum 100%." – teacher, St Peters Lutheran College, Brisbane.

Engineering students attend the school at the scheduled time for the class period, agreed with the teacher to fit in with the class curriculum. Material from the kit is set up and the class split into groups to undertake the activity. The teacher takes a back seat as the class is briefed on learning objectives and activity by the engineering students who are now running the class. An instruction book is available



3. Use the can of oil spray provided to oil the inside of the **formwork**. This will allow easy removal of the concrete once it has set.



5. Add $\frac{1}{4}$ of the water to the dry materials and mix through using a folding action.

Figure 3: Steps with photos from the concrete kit.

for each group along with work sheets. Questions to guide discussion and context information provide opportunity for interaction on the activity principles. Binding the activity and theory to real world context is a key part of the exercise. The connection between high school student and final year engineering student is developed through discussion and coaching with that connection centred on the engineering profession.

“Although a daunting task presenting in front of a class of 25, my colleagues and I found the program to be a rewarding experience.” – 4th year civil engineering student.

The opportunity is used by high school students to engage their role models in discussion about university life, studies of engineering and career prospects. The whole activity exercise and connected discussion is timed to allow completion during the allocated class period. Engineering students must be well prepared, follow the instruction book guidelines and manage the time well. Material left with the teacher includes advanced concepts and extension work that the teacher can engage the class in at a later date. Because the material presented is part of the subject curriculum, no time is lost to the teacher for covering the required material.

“The SQUEAK program not only extended the curriculum, but also gave the class an insight into university life, engineering courses at QUT, the engineering profession and women in engineering.”
– teacher, St Hilda’s School, Gold Coast.

4 OUTCOMES AND PERFORMANCE MEASURES

Benefits of the program include: allowing secondary students and teachers to engage in meaningful dialogue with university students; enabling secondary students to gain insight into the life and study of an engineering student at university; providing income to university students; and improving their interpersonal and communications skills for the workforce.

Program outcomes are many and varied. The ongoing success of the program and positive feedback indicate benefits for all stakeholders. At the heart of it are the high school students, who connect with real-world engineering through their studies of science, mathematics and engineering technology. They have opportunity to interact with young aspiring engineers in a context-rich, group-based activity. Many questions are raised about the core material, engineering issues, studies and university. Increased awareness of the role of engineers in society assists students in making the decision whether or not to study engineering.

“Feedback from students was very positive – they enjoyed the hands-on approach to teaching. Very

successful. QUT is to be congratulated on this initiative.” – head of technology department, Palm Beach Currumbin State High School.

“Overall a very good activity, which is relevant to our school curriculum and encourages students participation and involvement. Thank you.”
– Palm Beach Currumbin State High School.

The participating engineering students gained experience in coordinating and leading an activity that involved communicating and coaching. With few exceptions, their professional approach, knowledge and teaching ability was evident. Some students conducted a number of sessions and organised a trip north of Brisbane to visit schools not originally in the program. This is now an annual event.

“Given the age, experience and training of the 4th year engineering students, they did very well in running the bridge activity. They did it better than many trainee teachers of the same level that I have seen.” – teacher, Iona College, Brisbane.

“QUT students generated a atmosphere of fun and interest, good energy, well spoken, choice of language level.” – teacher, Kelvin Grove State College.

The program promotes engineering as a profession. It assists in attracting quality students to engineering disciplines, addressing long-term shortages in the engineering industry and declining engineering enrolments in some disciplines. The tertiary sector benefits from students being better informed and making choices that can result in lower attrition and higher performance of those students. Secondary schools and university linkage result in better learning outcomes and career guidance. Teachers in subjects such as Science, Maths C and ET appreciate the opportunity to show their students the relevance of studies in the curriculum through connection with the profession of engineering.

“This is a great initiative; the students enjoyed it and thought it worthwhile. It is important to show school students that what they learn is relevant to their future.” – teacher, Palm Beach Currumbin State High School.

Decreasing numbers in engineering enrolments at university level is not unique to Australia. Domestic undergraduate engineering student numbers have remained static or declined over the past 10 years (Sheridan, 2006). Figure 4 shows that student numbers in the areas targeted by the SQUEAK program (civil and mechanical engineering) have increased over the past five years.

Following the introduction of SQUEAK activity kits in 2002, covering both civil and mechanical engineering disciplines, student numbers have increased strongly in the civil profession and held strongly in mechanical engineering, while dropping in electrical engineering. The decrease in electrical

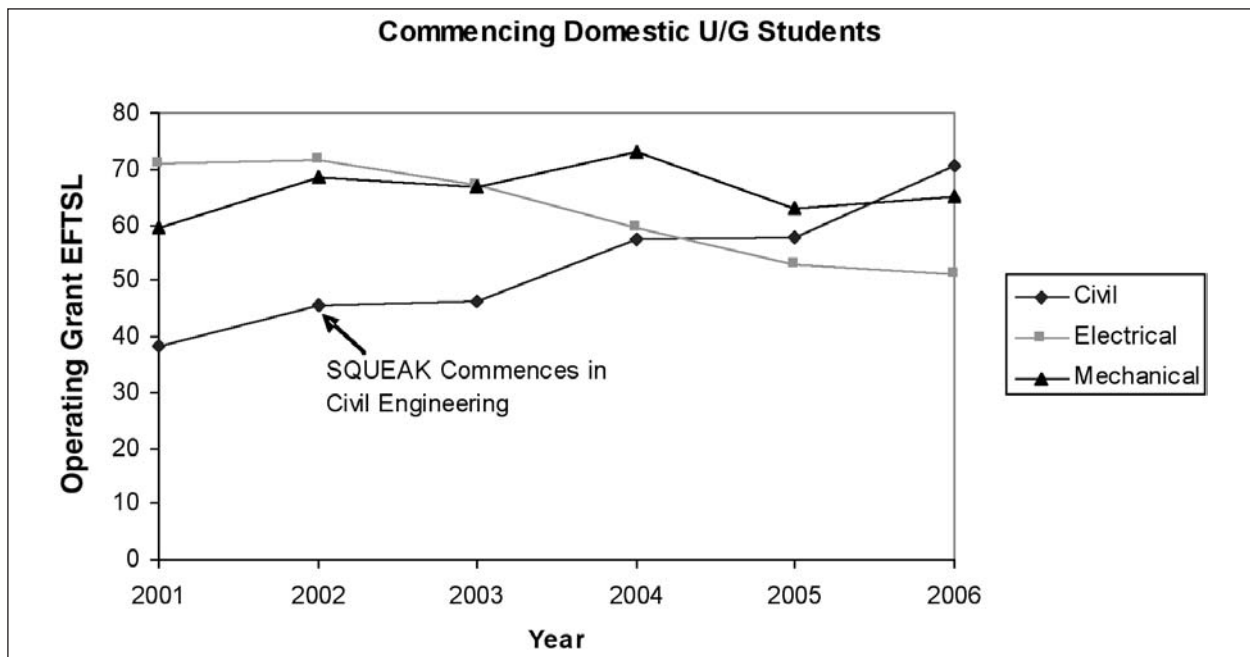


Figure 4: Increase in domestic undergraduate engineering students 2001 to present.

engineering numbers is being addressed in 2007 with the introduction and roll-out of electronics activity kits to secondary schools.

Surveys of incoming first-year undergraduate students indicate that between six and 12 students per year (over five years) have chosen and enrolled in engineering at QUT based on their experience with SQUEAK and the ET subject. Many also emphasised that they were not aware of what engineers were involved in prior to undertaking the subject and that the teachers in this subject motivated them in making their final decision.

"It was only after studying Engineering Technology that I understood the importance and relevance of mathematics and science to everyday life. I'm never going to ask my teacher again where I'll use maths."
– student, Kelvin Grove High School.

This year a focus group of incoming first year undergraduate engineering students who have participated in or had heard of the SQUEAK program is being surveyed to gain a better understanding of their choice of engineering as a profession and also to track their progression through the course.

5 LINKS AND FUTURE DIRECTION

As a result of the SQUEAK program success, the authors were approached by an enthusiastic secondary mathematics teacher from a non-Engineering Technology school who wanted to introduce engineering concepts into his mathematics classroom by providing a learning environment that connects classroom learning to real-world application. In 2006, this partnership was selected as a participant in the Australian School Innovation

in Science, Technology and Mathematics (ASISTM) project, which is funded by the Commonwealth Government through the Department of Education, Science and Technology. In this project, activity kits will be developed according to SQUEAK program concepts. They will comprise hands-on activities that simulate the work of a real-world professional, and will require students to make connections between the activities and what they have learnt in the classroom to actively construct new and improved knowledge. In addition, each kit will come with extension exercises, assignment and examination questions, created in-line with current senior syllabi and common curriculum elements, to extend student learning opportunities. The activity kits will emphasise authentic experiences, encourage creative problem solving skills and prepare students for advanced education.

6 CONCLUSION

The SQUEAK program is an innovative attempt to change the perceptions of secondary school students in regard to vocations in engineering, and engage them in contextual-based experiential learning that emphasises the relevance of mathematics and science subjects. The activity kits are designed to engage students in personal construction of new knowledge, promote disciplined inquiry and help students see the value of the learned material beyond the classroom.

The program engages students, and their teachers, in activities that are part of or linked to the work of the engineering team. It demonstrates, in interesting and exciting ways, the value and importance of the work of engineers to people's every day lives and to the

environment. Other benefits to stakeholders include: allowing secondary students and teachers to engage in meaningful dialogue with university students; enabling secondary students to gain insight into the life and study of an engineering student at university; providing income to university students; and improving their interpersonal and communications skills for the workforce.

The promotion of engineering in secondary schools needs to make the connection between what students are learning in theory, and what happens in real life in the provision of engineered products, services and infrastructure. It is hoped this program will also assist in increasing community awareness of the importance of engineering to society, the environment and an appreciation of the excellent career prospects that engineering offers.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Faculty of Built Environment and Engineering at QUT for their generous support of the project, along with all schools involved. Special thanks to all teachers who have and continue to participate in the program.

REFERENCES

Authentic Teaching Alliance, www.coe.ou.edu/ata, viewed 29 August 2006.

Avery, J. P., Chang, J. L., Picket-May, M. J., Sullivan, J. F., Carlson, L. E. & Davis, S. C. 1997, *The Integrated Teaching and Learning Lab*, University of Colorado-Boulder.

Batterham, R. 2000, *The Chance to Change*, Commonwealth Government of Australia, Canberra.

Cunningham, C. M., Lachapelle, C. & Lindgren-Streicher, A. 2005, "Assessing elementary school students conceptions of engineering and technology", In Radcliffe, D. & Humphries, J. (editors), *Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium on Engineering Education*, Sydney, Australia, ASEE/AaeE.

Dale, E. 1969, *Audiovisual methods in teaching, third edition*, The Dryden Press, Holt, Rinehart and Winston, New York.

Dawes, L., Murray, M. & Rasmussen, G. 2005, "Student experiential learning", In Radcliffe, D. & Humphries, J. (editors), *Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium on Engineering Education*, Sydney, Australia, ASEE/AaeE.

Douglas, E., Iversen, C. & Kalyandurg, S. 2004, "Engineering in the K-12 Classroom – An analysis

of current practices and guidelines for the future", ASEE Engineering K12 Center.

Downing, A. 2006, "Developing the next generation of engineers", *Engineering Australia Conference*, Adelaide, Engineers Australia.

Felder, R. M. & Silverman, L. K. 1988, "Learning and teaching styles in engineering education", *Engineering Education*, Vol. 78, No. 7, pp. 674-681.

Haque, M. E., Aluminiumwalla, M. & Saherwala, S. 2005, "A virtual walkthrough on reinforced concrete construction details", *Proceedings of the 2005 American Society for Engineering Education Annual Conference*, Portland, Oregon, ASEE.

Kolb, D. A. 1984, *Experiential learning: Experience as a Source of Learning and Development*, Prentice Hall, Englewood Cliffs, NJ.

Macquarie University, 2006, *Macquarie University Science, Engineering and Technology Study*.

Millican, G., Richards, P. & Mann, L. 2005, "The engineering link project: Learning about engineering by becoming an engineer", In Radcliffe, D. & Humphries, J. (editors), *Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium on Engineering Education*, Sydney, Australia, ASEE/AaeE.

National Foundation for Educational Research, 2004, *Factors influencing Year 9 Career Choices*, The Engineering and Technology Board, UK.

Ohland, M. W., Stephan, E. A. & Sill, B. L. 2005, "Adapting engineering laboratories to enhance learning using real time sensors", *Proceedings of the 2005 American Society for Engineering Education Annual Conference*, Portland, Oregon, ASEE.

Project Lead the Way, www.pltw.org, viewed 30 August 2006.

QSA, 2004, *Engineering Technology Senior Syllabus*, Queensland Studies Authority.

Rhoads, T. R., Nanny, M. A., O'Hair, M. J., Murphy, T. J. & Walden, S. E. 2005, "After the funding sustaining an NSF outreach initiative", In Radcliffe, D. & Humphries, J. (editors), *Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium on Engineering Education*, Sydney, Australia, ASEE/AaeE.

Sheridan, J. 2006, "Why aren't we training more engineers", *Focus #141*, Australian Academy of Technological Sciences and Engineering.

The Engineering Link Project, www.telg.com.au, viewed 30 August 2006.

The University of Newcastle, 2006, Science and Engineering Challenge, www.newcastle.edu.au/group/challenge, viewed 27 August 2006.



LES DAWES

Dr Les Dawes is a lecturer in the School of Civil and Environmental Engineering at Queensland University of Technology (QUT), where he teaches subjects in geotechnical and water engineering at both undergraduate and postgraduate level. He has been involved in developing learning environments incorporating hands-on activities and experiential learning and community outreach for over 10 years. Les is a firm believer in project-based learning using real world problems and providing students with a wider spectrum of learning processes.

Les has a PhD from QUT and a BSc(Geology). He has published the outcomes of teaching practices at numerous engineering education conferences. His scientific research has focused on decentralised wastewater treatment systems, water reuse and groundwater contamination, with main areas of interest being land treatment of wastewater, water recycling and water quality.



GARY RASMUSSEN

Gary Rasmussen is the technology services manager in the Faculty of Built Environment and Engineering at Queensland University of Technology. As well as management of the technical resources in the faculty, he has a keen interest in developing learning environments that use laboratories and experiential methods. He has worked in Thailand on laboratory development, and has publications related to laboratory operation and teaching.